Electricity Demand on a University Campus in the framework of the ECOCAMPUS collaboration: Case-Study from the University of Bordeaux 1

Patrick FAUCHER+,
Jean-François BONNET+,
Christophe DEVEL +, Jacques ROTURIER +
and NN ++
University of Bordeaux

1 - SYNOPSIS

The University of Bordeaux 1 chairs the European ECOCAMPUS i collaboration and in the last few years has carried out different studies aiming both to increase knowledge concerning the environmental impact of teaching and research activities in their "Scientific Process" and to disseminate a number of basic ideas to promote a voluntary "in-situ" Sustainable Development policy among all university staff and students. Different aspects were studied, including electricity-related issues, optimisation of water supply and demand, improved waste management. The present paper deals with a very brief survey of electricity-related issues, with special attention paid to the "stand-by consumption" both on a broad survey of the whole campus and from case-studies restricted to examples. In these examples, two contrasting situations are shown : a promising move towards the use of more energy-efficient equipment and on the other hand an energy analysis of opportunities not implemented during the recent recommissionning of a Chemistry Research building. From these examples and other data, it may be concluded that it is now time to focus on technical means, working in partnership with manufacturers and developing permanent collaboration with scientists and facilities staff to save a significant amount of power and to reduce the energy bill. This analysis may be regarded as a new step in the "Practice-What-You-Preach" programme, the main guideline of the whole ECOCAMPUS collaboration.

2 - ABSTRACT

The ECOCAMPUS collaboration, partly funded by the European Commission under the THERMIE Programme had an important goal : to create a European network of University campuses and Research laboratories whose managers, academic staff and scientists are deeply concerned by the In-House issues of Sustainable Development. Over the past two years, an analysis of data concerning the electricity demand, heating energy and water consumption has been carried out, with special attention being given to the specific use of electricity in buildings and facilities. Members of the ECOCAMPUS collaboration were obviously committed to implement a feasibility study in at least one University of their own country. The Bordeaux group, while completing a survey of the overall electricity consumption, decided to focus on the stand-by electricity consumption. The latter is far from being negligible, particularly in buildings devoted to research activities where scientific equipment is plugged in even though it is not necessarily permanently used. This is one of the electricity issues that is commonly ignored. In the present paper an overview of the main data is given and the electricity demand is analysed at each level of decision identified as in the following :

- first, the whole area that includes most of the higher education teaching facilities, research laboratories and related facilities (students residences and restaurants, sports halls, public lighting, …) was investigated. Gross data (annual consumption, real cost of kWh, indicators, annual growth, …) have been calculated mainly through an analysis of the electricity bills;

[+] ECOCAMPUS Laboratory – CENBG University of Bordeaux 1 BP 120 33 175 Gradignan-Cedex (France)
[+ +] EDF

[+]

- in a second step, the activities of the Science and Technology sector (University of Bordeaux 1) were considered in a more thorough manner, not only from an analysis of the electricity bills but also from metering campaigns and interviews with users and building managers. Two categories of equipment are identified, namely those shared between all users or those assigned to a single experiment : their relative contribution, both in terms of power load and annual consumption in relation to the whole installed power load is now being accurately assessed;
- then, the resulting third level is analysed though two case-studies. The first one was carried out on a laser physics experimental set-up where not only the electricity consumption but also the water demand was metered (the water demand results are not shown here). The second case study was observed after the recommissionning of a Research building where a facility was recently installed in order to improve the Air Quality in Chemistry laboratories which now have to comply with more stringent requirements. In a brief survey, a preliminary analysis of its impact on the building power load is shown.

3 - INTRODUCTION

Possibly as a result of the UN Conference of Rio de Janeiro (1992), several initiatives have been taken over the past five years within the scientific community in an attempt to increase concern for Sustainable Development issues : (i) under the UNESCO International Association of Universities sponsorship, a Declaration was published in 1993 (IAU93) (ii) another Chart (COP 97) was submitted by the European COPERNICUS [ii] network. Independently, participants in the Energy-University-Environment (EUE) Seminar, hosted by the University of Bordeaux 1 (France) in March 1995, have recognised that in most of their University Campuses or Research Laboratories, the management of natural resources, including energy and/or water use, is usually based on a "Laissez-faire" Policy. Such a situation was regarded by them as unwise, unfair and moreover unaffordable, for at least two reasons :

- The financial cost associated with the daily operation of teaching and research activities continues to grow as more electronics are added to our laboratories and as more computers are added to our offices, not to mention the resulting environmental degradation associated with the power production for the operation of heating, cooling (including cooling water for science equipment such as lasers, etc.), lighting, …..
- Students are not receiving the best training because of limited, out-of-date texts, poor examples in campus buildings and also isolation from others around the world who are interested in efficient building design and protection of the environment.

Of the four main goals assigned to the ECOCAMPUS European collaboration, partly funded by the EU DGXVII Thermie Programme [iii], the Feasibility Studies are of special interest, in particular to provide an unambiguous demonstration of the main benefits of such an initiative on both a local and a national level. The present paper, is devoted to a brief survey of the main findings and conclusions obtained as part of the University of Bordeaux 1 Case Study.

4 - SUMMARY OF MAIN RESULTS

As shown in the ECOCAMPUS final document (ROT 99), similar studies also aiming to participate in Sustainable Development issues are being carried out in universities in different parts of the world (HAB 96), (BEN 98), (DEL 98). However most of them only analyse the impact of waste production and management or, when energy or water issues are quoted, the data usually refer to bills only. On the contrary, the present ECOCAMPUS analysis (i) makes a permanent and explicit reference to the energy (heat, electricity) and water supply and demand, in physical units, (ii) includes the efficient-use policies, (iii) takes into consideration, of course, waste production and management programmes (FAU 98). In its present status, the ECOCAMPUS study underlines a number of conclusions that will hopefully be submitted to further investigations, due to the large differences in size, climatic conditions or status of the economy in different countries. Nonetheless, it seems appropriate to consider all data, and particularly the few indicators shown below, as a significant order of magnitude, possibly in a macroeconomics approach :

- The sum of heat demand and electricity consumption data is in a 250-350 kWh/m² range, shared into about 60 % (heat) and 40 % (electricity). A more accurate analysis would probably show some differences possibly correlated to the teaching activity : i.e. Science and Technology are probably more energy-intensive than Law or Humanities.
- Concerning electricity, the data vary from 30-170 kWh/m² for teaching and 60-110 kWh/m² for students residences. Indeed, the ratios of annual consumption/m^2 ***or*** students ***or*** employees also increase significantly e.g. + 4,5 %. In most cases, this phenomena may result from a significant increase, in the last decade, in

equipment in Universities and also the absence of an energy-efficiency policy. Electricity consumption has increased over the past 8 years on all the Universities sites under study : the annual growth rate is in a 3 - 5 % range.

- A high standby power load, about 90 kW or 40 % of the maximum demand, is called for at nights and week-ends in buildings where several large R-D laboratories are housed. Such findings result in a more detailed analysis of the energy efficiency of specific pieces of equipment used in the scientific process of research that are more completely investigated in two directions : (i) a possible energy/environment labelling policy for scientific equipment similar to that used for domestic appliances or office equipment ROT 98) ; (ii) the creation of a data bank aiming to provide users with updated electrical and cooling specifications of each apparatus or appliance used in the experimental set-up.
- Water consumption, including students residences and restaurants, varies from 0.5-0.9 m^3 per year. The growth rate seems to be under control.
- Solid waste quantities are growing (about 1 kg/student annually). This growth is possibly related to a more efficient collecting programme. Chemical waste represents about 10 % of the total weight.
- No accurate correlation can be yet established between the increase in consumption and the variations of surface areas, number of students or net number of employees.

Regarding the costs :

- the utility (energy/water/waste) bills represent about 3-5.5 % of the annual turnover ;
- heat and water bills do not show any significant growth while the electricity bills continue to increase;
- payback time may be as low as 2.5 years.

5 - AN ECOCAMPUS FEASIBILITY STUDY : UNIVERSITY OF BORDEAUX 1 CASE STUDY

Almost all higher education activities of the Bordeaux region are located about 6 km south of the town centre in the suburbs of Bordeaux on the territories of 3 municipal authorities : GRADIGNAN, PESSAC, TALENCE (acronym GPT). With a total area of about 2.5 km², the whole campus is one of the largest in France. Each year about 50,000 students are enrolled in one of the Higher Education organisations available on the campus that offers almost all disciplinary fields except medicine. Moreover, there are also many services available such as students restaurants and residences, a water supply facility, a post office, culture and sports rooms and facilities etc.. As far as electricity consumption and water demand are concerned, the GPT area is equivalent to a town of 10,000 inhabitants. In 1998, the total power was about 9,5 MW, the cumulated maximum power load reaching 10,3 MW. The annual electricity consumption was 25 GWh resulting in a bill of 12,7 MF (tax not included) or about 2.2 million Euros (it is to be noted that overhead costs such pass extra power demand, "reactive" power, delay in payments, … are 4.6 % on average). In Figures 1 and 2 respectively, the Consumption and Annual growth 1996-97 and the Consumption (kWh/m²) analysed on a Per Activity basis are presented. The annual growth may significantly vary for several, not yet completely known, reasons : + 2% in 1997 and + 8 % in 1998 when compared to the previous year.

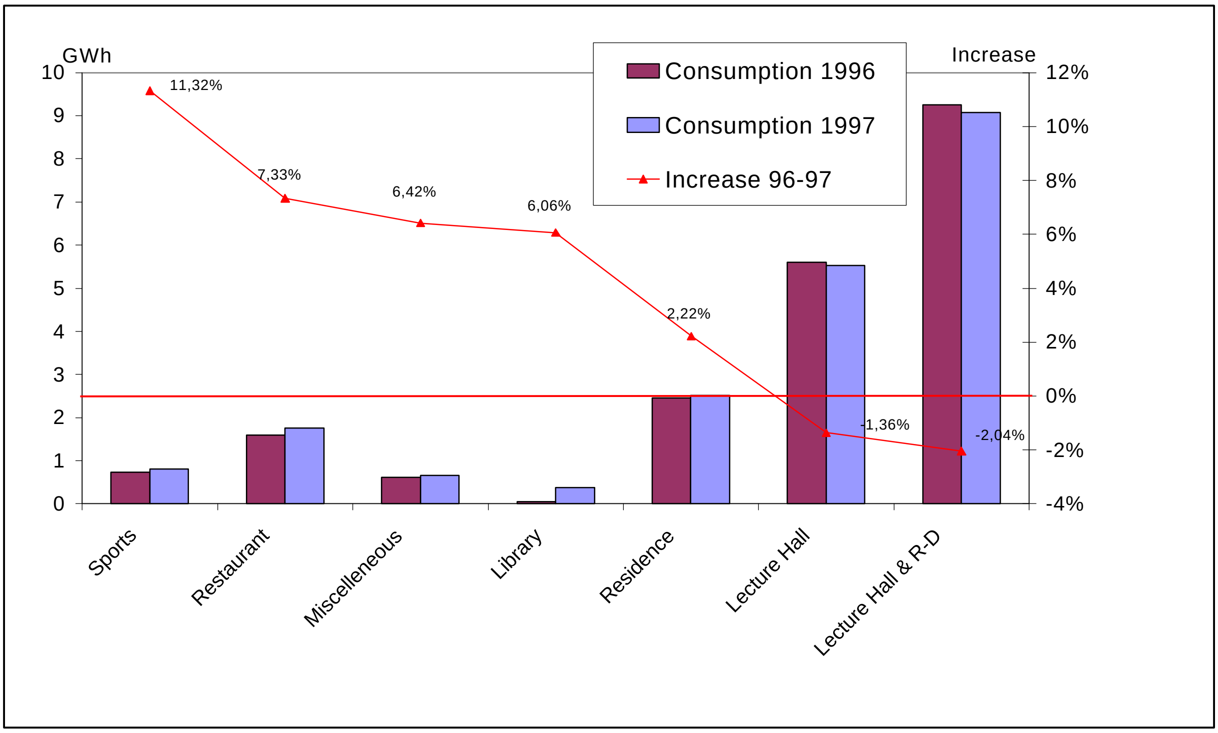

Figure 1 Consumption and Annual growth 1996-97

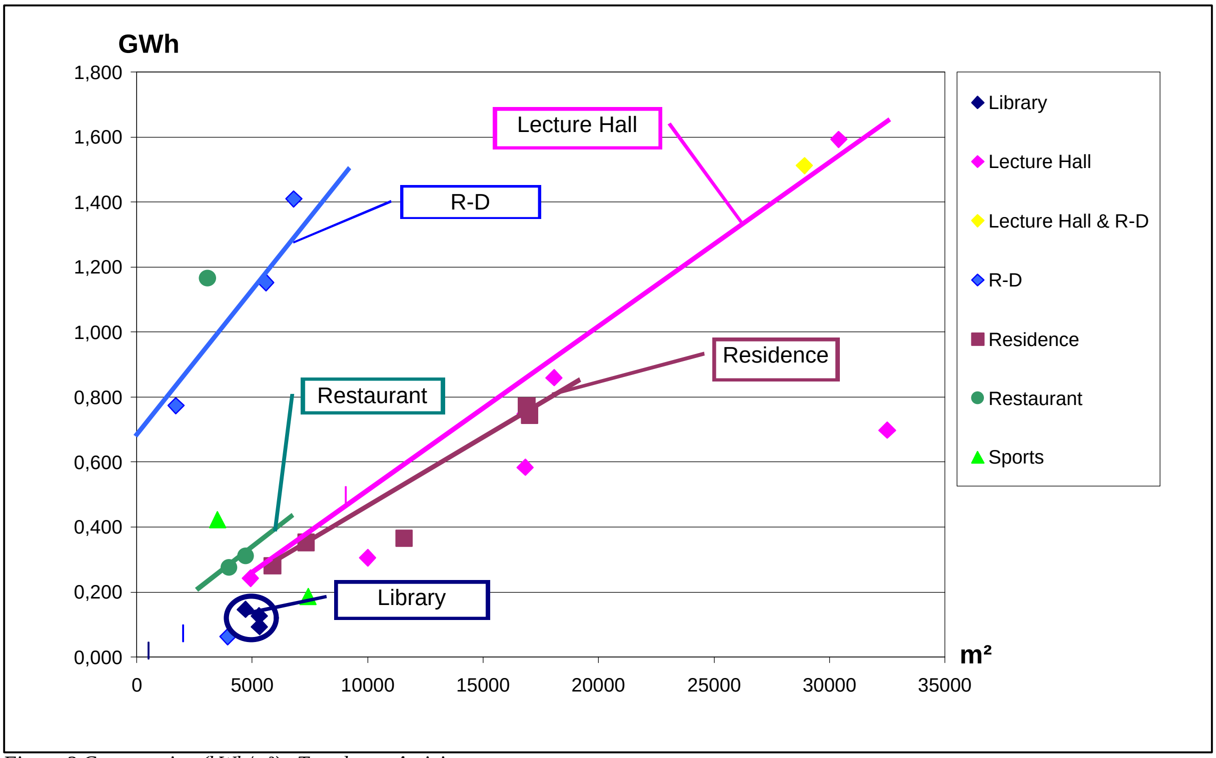

Figure 2 Consumption (kWh/m²) –Trends per Activity

PANEL 2

The percentage share of 1998 consumption, on a per administrative management (the main operator in charge of each building), and on a per activity basis is shown in Figures 3 and 4 respectively. Unsurprisingly the largest consumers are : research (42 %), teaching (28 %), and student restaurants and residences (16 %). On average the total growth over the last 2 years is about 10 %. All activities but the two largest (teaching and research) show a significant increase. Also, in the long range, strong fluctuations appear that are probably associated to structural changes in some teaching and research activities i.e. a move in new buildings. A very preliminary benchmark is also being investigated, with studies relying on indicators such as Euro/kWh, kWh/m², etc… Related data, shown in Table 1, may permit a comparison with equivalent figures from the other feasibility studies i.e. of buildings with similar activities, such as libraries, lecture halls, students residences or restaurants, while obviously greater attention should be given to the analysis of research buildings. Although such gross data, shown in Figures 3 and 4 are easily obtained, a few obstacles remain when a more comprehensive study has to be done (lack of a centralised source of information, large autonomy of management for almost all institutes, departments and laboratories, electricity and water uses or waste collection available provided at no charge, complex electricity and water networks, technical managers working independently, …). Such constraints need to be more deeply investigated and clearly identified as one of the main obstacles to future actions. For such reasons, the first step of the feasibility study has been started on the territory of the campus of University of Bordeaux 1, one of the Higher Education organisations located in the GPT area. It is important to underline here that the present work, part of a voluntary energy and environment policy defined by the President of the University, was successfully implemented in close partnership with the Facility Department Staff. In addition to the analysis of the electricity demand on a period covering the past 10 years, other issues related to the University of Bordeaux case-study are introduced in the ECOCAMPUS final report: (i) energy and water end-uses concerning in particular the scientific equipment - an electricity end-use usually ignored, despite being certainly responsible for most of the night and week-end consumption, thus having a significant impact on the electricity bill, (ii) a survey of the waste management policies. Another research study concerning the water supply and demand issues is part of a recently started study (Fall 1998) that is partly funded by the Regional Water Authority.

The present first step, however is now seen by all members of the university staff as a reliable and complete demonstration of the benefits resulting from the optimisation of both electricity and water demand, and waste management. A significant decrease in the related costs, that have increased each year up to now, can be expected. A policy to implement the Environmental Management and Audit System as a key part of the operation of a university campus appears to be affordable and a quite obvious necessity, in terms of financial resources, of up-dated environmental training of students and new opportunities in research.

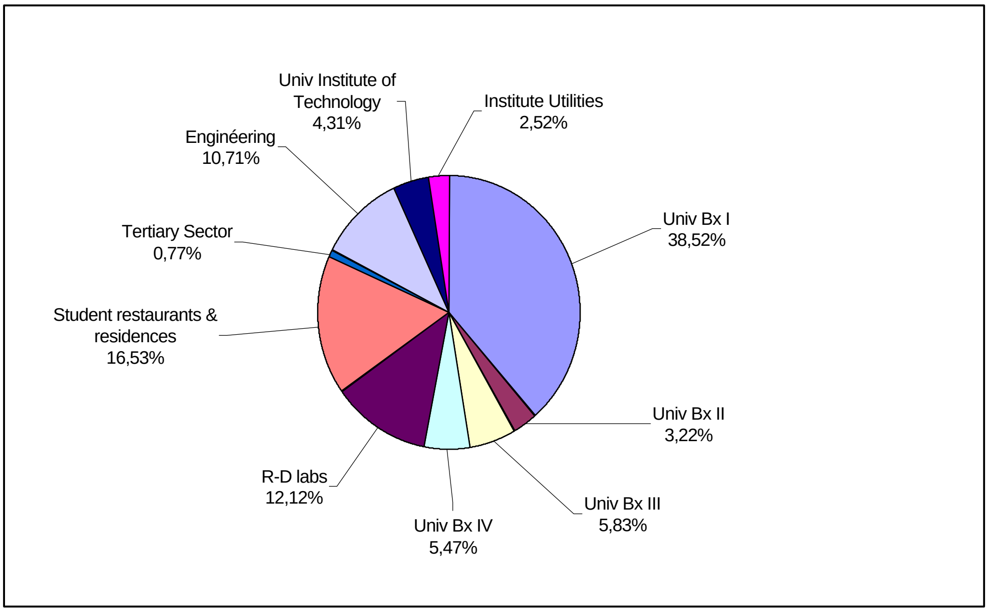

Figure 3 – Répartition administrative des consommations 1998

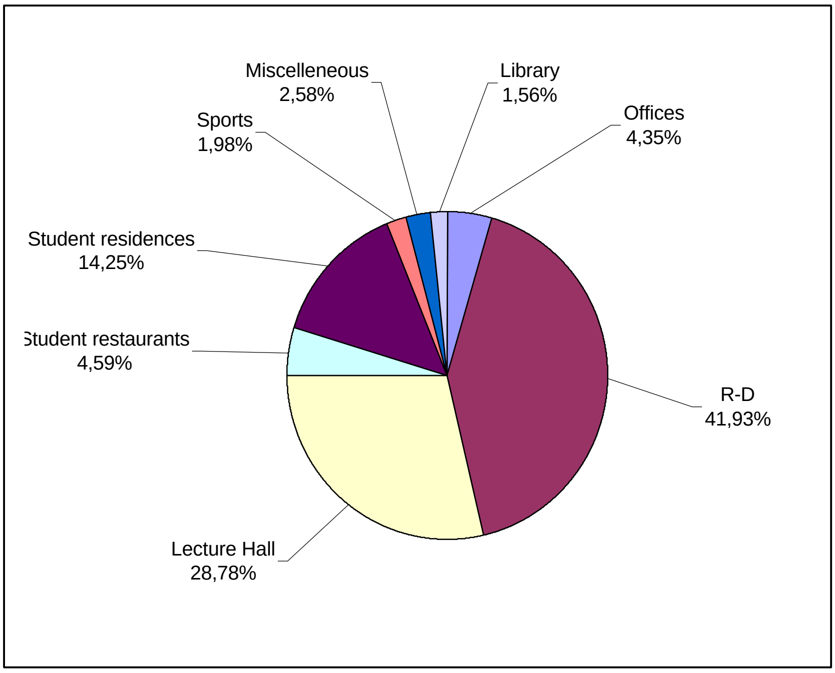

Figure 4 Share of Consumption : Activity basis 1998

Table 1 - Survey of comparison of a few indicators

	Teaching	Administration	Stud. Resid.	Stud. Restaur.	Libraries	Research
Water demand m^3/m^2	0.4	0.2	2.28	0.98	0.2	2.5
Electricity kWh/m²	37	33	44	78	25	129
Elec. / Water kWh/m^3	92.5	165	19.3	79	125	51

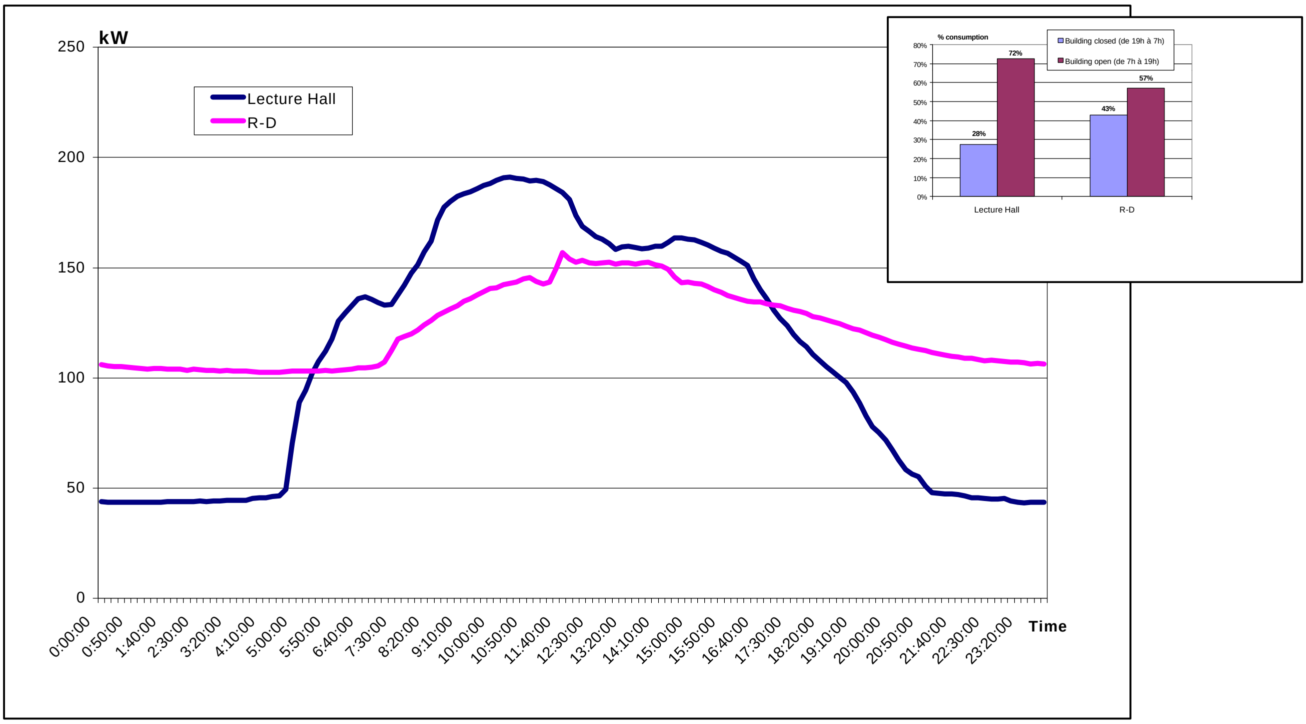

Figure 5 *Comparison of buildings mainly devoted to teaching and research activities, showing a different area but a similar power load : the standby loads show large discrepancies*

When the maximum and standby power loads in teaching and R-D buildings are compared, a factor of 4 and 1.5 respectively is found. As a result of this situation, the related standby (« off-business hours ») consumption is 25 ***% 42 %*** in teaching and R-D buildings. It seems clear from the present preliminary results that a significant amount of the standby consumption in research could probably be avoided if a convenient automatic turn-off equipment were supplied to users (see section 6 and 8).

6 - FIRST EXAMPLE : CHARACTERISATION OF SCIENTIFIC EQUIPMENT

6.1. General objectives

As shown above from a global point of view, electricity and water consumption of scientific universities and research laboratories is quite high and is mostly due to the specific needs of research equipment. It appears that the savings potential from research equipment use is significant, not only for the universities themselves but also for the private sector where scientific appliances are needed. Different ways of achieving the savings potential have been identified from our past studies :

- **improvement** of existing equipment and its use, relying on :
    - the appliance itself (use of timers, improved control panels, etc.),
    - the mode of utilisation of the appliance,
    - the possibility of regulation or remote control of appliances.
- **substitution** of existing equipment by more environmentally effective ones,
- promotion of research in and development of **highly efficient innovating technologies**.

Improvement and substitution are short term or mean term approaches, with appliance improvement seeming to be generally easier than substitution, which often requires preliminary evaluation of the energy consumption of several appliances and energy and economic balance of the replacement. Promotion of R&D is obviously a long term approach, for which a comprehensive strategy of characterisation is being implemented. This constitutes one of the main aspects of the research strategy of the Ecocampus Laboratory.

6.2. Case study of substitution and improvement : Argon Laser versus Laser Diode

In the framework of a co-operation project between the Ecocampus Laboratory and the Centre de Physique Moléculaire, Optique et Hertzienne (CPMOH **-** University of Bordeaux 1), the feasibility of replacing part of the existing, high energy consuming Argon Lasers by new diode-based laser technology has been studied by laser physicists, taking into consideration the high level of electricity and water consumption and related costs. The study consisted of a 2-week *in situ* measurement campaigns for both laser systems, and took into account the whole equipment used for different types of experimentation. A total of 35 appliances were monitored, revealing the highly dominant part of electricity use of laser systems and their cooling among the total.

7 - SUBSTITUTION

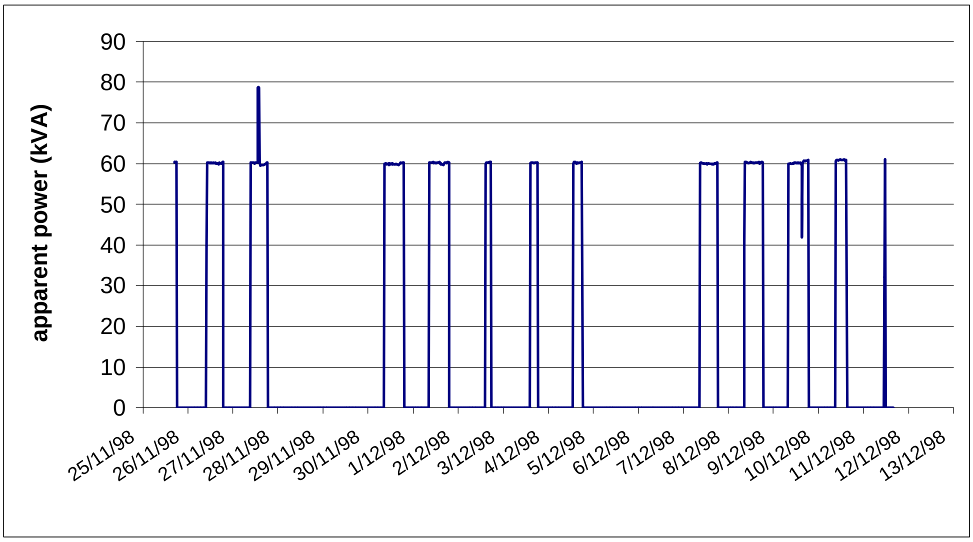

Figure 6 *- Measured power load of the Argon Laser. A "hidden standby mode" lies in the fact that this appliance needs 1 h to 2 h powered on to reach conditions of use*

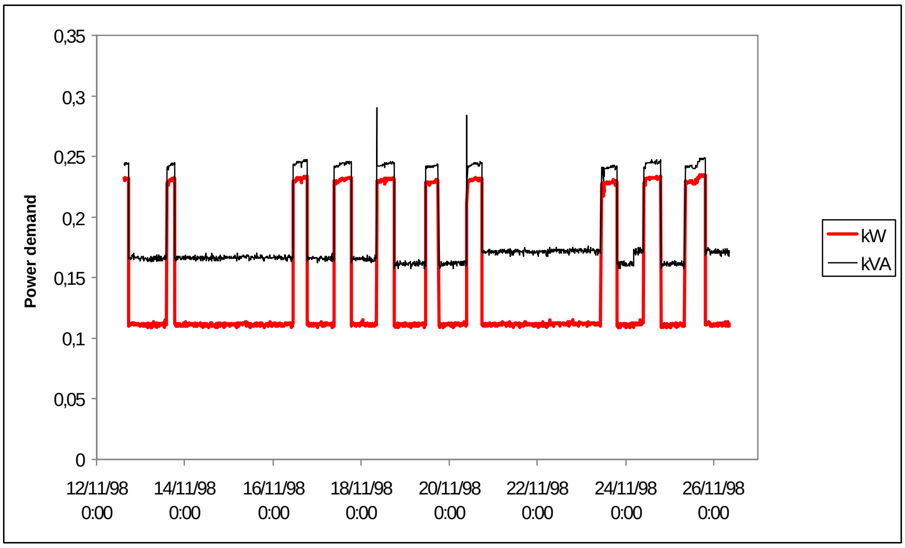

Figure7 *Apparent and active power load of the Laser Diode*

Measured hourly electricity and water use were precisely extrapolated to a yearly basis (figure ZZ3), from the annual time of use read from time counters (1630 h/year for the monitored Argon Laser). Water and energy annual balance shows clear advantage of the replacement of Argon technology by diode technology, leading to a gain of 85 MWh/year and about 3300 m^3/year. Annual costs were evaluated from measured daily periods of use combined with electricity tariffs for France, and from estimated direct cost of water supply. Payback time is about 5 years. It must be noticed that payback time would be longer with small frame Lasers, or with fewer hours of use during the year, but it may be much shorter (some 3 years) when water is supplied at higher cost from municipal networks rather than from university own water production.

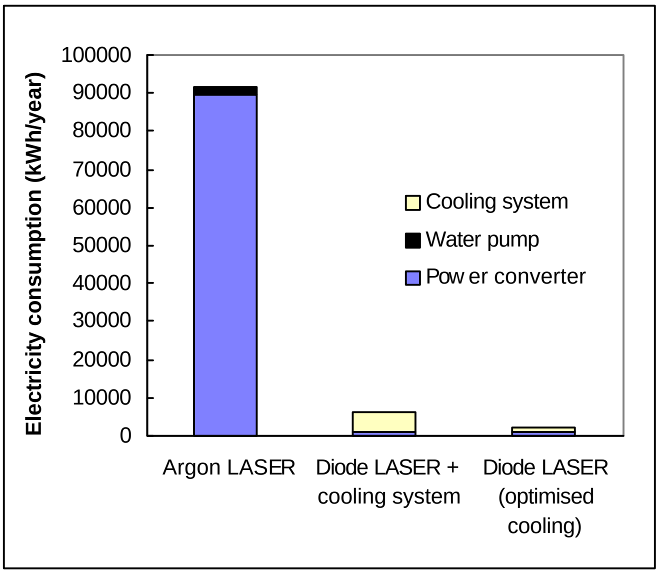

Figure 8 - Annual electricity consumption of monitored Argon Laser and Laser Diode

8 - IMPROVEMENT

As shown in Figure 9, the Laser Diode system, although it shows a high energy efficiency, reveals significant remaining savings potential, especially through a better control of the cooling system associated to it. A simple timer control could lead to a 60% reduction of the global energy consumption of the system (payback time is about 2 weeks). Figure 8 also shows, for the Laser Diode the weight of standby electricity consumption as well as the apparent potential of improvement of the power factor. These aspects are another example of the "Watt/VA problem" as well as the power converters standby efficiency problem. On a per annum basis, standby consumption of the Laser Diode itself is about 50%.

Although, depending on the quality of optical beam required for experimentation, only a part of Argon Lasers may be substituted, this study clearly shows the important savings to be expected from the replacement, which also appears economically profitable to universities. The potential for improvement of the high efficiency system illustrates the kind of savings to be expected from smaller equipment (100 W - 1 kW), if standby consumption and watt/VA problem are taken into account in a global characterisation approach .

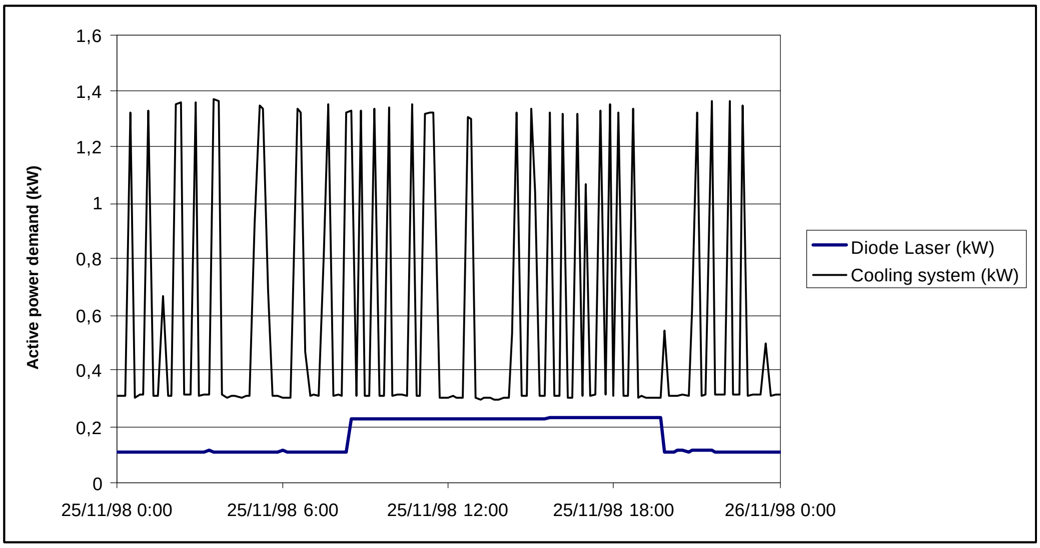

Figure 8- 24 hour power load of the Laser Diode and its cooling system : cooling is not controlled and operates even when Laser is not used

9 - SECOND EXAMPLE : CASE OF AIR EXTRACTION IN A CHEMISTRY R-D BUILDING

9.1. General context

One of the risks run by chemists is related to air contamination in the work environment from the gaseous by-products given off in experiments and there is a permanent necessity to reduce this. Recent work carried out to bring the Chemistry Research and Development Building up to regulation standard shows that energy considerations were not taken into account in the list of priorities :

- Regulation standards (hygiene, security, environment),
- Technical aspects (feasibility),
- Human aspects (comfort, security).

A centralised air extraction system controlled by individual users has been partially installed : only 30% of the installation planned (68 extraction points over 4 renovated half-floors) is working at present.

9.2. System installation analysis

The air extraction ventilators are placed at the exit of the 15 columns in use (out of a total of 32), each one supplying 7 extraction points (fume hoods). These points have 2 extraction flow rates (400 or 1200 m^3/h) depending on the opening of the mobile screen for the hoods[1]. The installation also includes air compensation modules that have two functions:

- to draw new air into the building by means of a ventilator to avoid the depression phenomenon caused by the extraction of polluted air,
- to preheat the air entering the building by means of an electric battery during cold weather to maintain the level of comfort.

The fact that the system is centralised means that the regulation of the extraction ventilator rotation speed in function of demand on the column is automatic. It must be possible to work the air extraction and the compensation modules simultaneously and of course to have « ventilator » or « electric battery » breakdowns indicated. In order to carry out an energy audit while at the same time analyse how the system works, two measurement campaigns were performed (1) to estimate the annual consumption of electrical energy required in normal working conditions and (2) to understand the system better and suggest improvements if necessary.

9.2.1. Energy impact of the air extraction system

In Figure 10 showing the general shape of the electric load curve of the system, the intensity of the current is seen to vary relatively little and remains at a high level. On this basis, the annual consumption of the system varies between 300 and 400 MWh, i.e. about 30.000 Euro p.a. which could reach 1 to 1,5 GWh, i.e. about 90.000 Euro p.a. when the whole system is installed and working. With an installed capacity such as this (48 % of the final subscribed capacity) there are significant overloads, posing the problem of the probable under-dimensioning of the General Low Voltage Table (P_{TGBT} = 630 kVA). Furthermore, this consumption seems to be reflected in the overall electricity bill of the University, if the increase in consumption during the first 5 months of the year 1998 is considered (+ 7,4 % for areas 1&2 compared to the same period the previous year). The cost of such a system means that it is impossible to simply replace the equipment. It was therefore necessary to look into possible improvements at the user/equipment interface level. Here it is possible to reduce consumption by at least 15 % which would represent a saving of around 16,000 Euro p.a. on consumption alone, such money savings being equivalent to the salary of one scientist during 0.5 year.

9.2.2. How the fume hoods are used

In order to determine how the fume hoods are used, readings were taken by day and during the night : 65% are used to stock products (400 m^3/h), 25% are empty (400 m^3/h) and 10% are used for experiments (1200 m^3/h). Storage cupboards are not available on all levels and the fume hoods used to stock products are very much dispersed. The XP X 15-203 standard (Sept. 96) fixes the values for air circulation speeds in front of the fume hoods called : *frontal air speeds* (and not flows) which should be over or equal to 0,5 m/s. The speeds observed for a position with the screen lowered are quite clearly above the level stipulated. The corresponding rate imposed, (188m^3/h) consequently draws in light objects on the work surface. The user does not totally lower the screen thus maintaining the extraction flow at a « theoretical »1200 m^3/h ([2]).

[1] according to regulations, the screen should be closed under normal working conditions
[2] In fact the ventilator operating curve shows that the minimum rate is 1600m3/h and not 400m^3/h.

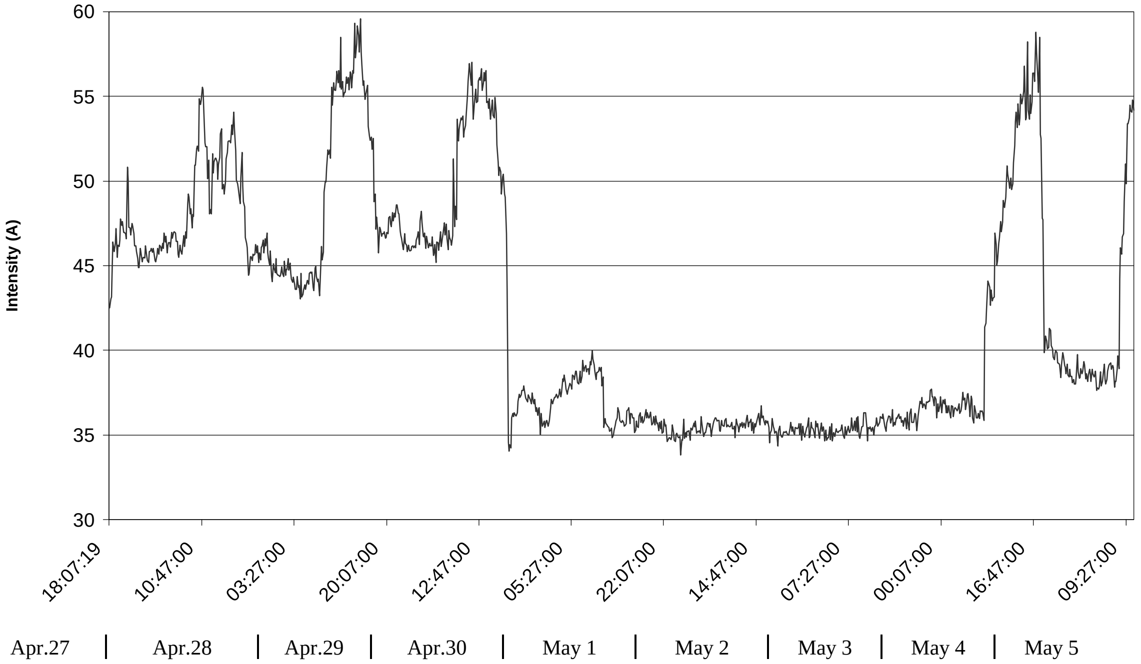

Figure 9 – Air extraction installation of Chemistry Research Laboratory : current intensity

9.3. Recommendations

Several solutions can be envisaged to optimise the system and reduce energy consumption :

- **Impose and technically control** the frontal speed at 0,5 m/s whatever the height of opening and thus limit the air flow in low positions.
- **Use screen position sensors** that emit an electrical signal proportionate to the surface of the opening and that controls the regulating organ of the outflow.
- **Maintain the frontal speed constant** by adding a by-pass grill that is totally closed in high position of the screen and which opens up progressively when the screen is being closed.
- **Rationalise the use of fume hoods** (on-off, position of screen, hierarchy of risks in relation to the nature of the products and integration of environmental criteria in experimental protocols)
- **Limit the storage** of products in fumes hoods, by organising a column for this purpose and / or designating a suitable room.
- **Optimise the compensation mode** (battery operating time via thermostat contact)
- Choose **Centralised Technical Management** (CTM) to supervise the air extraction system, via a modem to determine the electrical consumption (for each fume hood, room, laboratory, service) and to observe how the fumes hoods are used so that users can be informed of any technical faults.
- **To ensure an adaptation of the tarification contracts** with Electricité de France (EDF) in relation to how the system evolves.
- **To post up information concerning electricity consumption** to encourage a dynamic management of power demand.

10 -FURTHER WORK

At present, the exhaustive inventory of all electric equipment of a 10 000 m² R-D building (4000 appliances inventoried, 100 of them monitored) has shown the great variety of appliances, leading to a large potential of specific environmental issues. However, advanced analysis of the collected data as well as significant case studies led to the conclusion that the problem could be greatly reduced using classification and suitable methodology, yet to be fully implemented. Continued work will implement and test a new methodology specific to the analysis of scientific equipment problems. The broad framework of the methodology, briefly presented here, would potentially include increased scientific co-operation with research laboratories that are not involved in energy management research, such as equipment users or physical process specialists. If student projects are integrated (case studies of appliances), the work would also have high educational benefits.

10.1. Methodology for further work

i. Identification of different categories of scientific equipment, classification of equipment, definition of simple criteria for a priori identification of appliances to be analysed.

ii. Preliminary measurement (whether direct or indirect) of appliances to be analysed, concerning basic energy characteristics (apparent and active nominal power, apparent and active standby power) and water use.

iii. Selection of target appliances, which show apparent savings potential or environmental impact improvement potential (criteria : power factor, standby rate, scale effect of small but widespread appliances, etc...).

iv. Energy characterisation of chosen equipment :

- extended measurement,
- description and analysis of the functioning of appliances, and evaluation of the orders of magnitude of energy flows in the different parts of appliances,
- analysis of real energy demand of equipment for a given service to users : useful energy, different and successive energy conversions (elec. → elec., elec. → light, elec. → force, elec. → magnetism, elec. → heat, etc...).

v. Analysis of the different physical processes able to produce the same service. For this part, physical process fact sheets will be conceived, preferably in a collaboration with members of the scientific community as “aware end-users of equipment”.

vi. Identification of existing technologies (discussion with users, technological data sources, co-operation with technical laboratories). For this part, simplified technology fact sheets (eg current conversion, vacuum production, etc...) will be designed.

vii. Depending on the problem encountered for an appliance, different options will be considered :

- contact and co-operation with public or private research laboratoriess to encourage new efficient technology,
- contact with appliance constructor for improvement (timers, ergonomic aspects, etc...),
- broad diffusion of results among users, though the usual channels of scientific communication.

The results of the present preliminary work is expected to provide the basis of a possible environmental labelling programme of scientific equipment now being investigated by the Ecocampus team at the University of Bordeaux 1.

11 -CONCLUSION

From a statistics approach, to date the most common method used for calculation, the French electricity demand of the Higher Education sector represents about 2 % of the total demand also showing a significant annual growth (10 % in the last 2 years). In the present work, metered data were systematically used to characterise the electricity demand in each end-use activity represented on a university campus both for teaching and research as well as for related social activities. For the first time to our knowledge, a preliminary study of several types of scientific equipment was made, taking into consideration their most significant electrical specifications such as Power Load, Power Factor, Time-Of-Use, Unit Energy Consumption, availability of Standby modes, … Two main findings are then pointed out (i) in terms of consumption the lowest loads can contribute more intensively than the largest ones (ii) a significant stand-by consumption is commonly present. Then, similar to other previous analyses concerning office equipment (ROT 98) or white goods appliances, it has been decided to start a preliminary labelling programme study. Finally, as a non-negligible by-product of the present work, basic knowledge concerning the DSM issues has been transferred to the large number of members of the scientific, technical or management staff that were met during the metering campaigns or interviews. Sustainable Development, presently investigated as a fundamental part of the management of the University of Bordeaux 1, appears in a much more concrete manner, since extra benefits such as a decrease in the electricity and/or water bills or in the costs of waste management, have been demonstrated.

12 -ACKNOWLEDGEMENTS

The present work was made possible thanks to the important participation of many colleagues mainly from the Physics Department and Chemistry Department. It is a pleasure to greatly acknowledge in particular, not ignoring their staff, Dr. Eric FREYSZ, from CPMOH for his deep interest in the laser study and Dr Alain BARROT, Head of the Facilities Department, for his great help and useful discussions specially concerning the metering of both electricity and water consumption. The authors also wish to underline, for her comments and improvements regarding both English grammar and syntax, Mrs Gil FAUCHER

13 -REFERENCES

BEN 98 Benke G. "EFFICIENT UNIVERSITIES : WHERE DO WE GO" Conference Graz (Austria) Sept. 1998 (benke@eva.wsr.ac.at)

COP 97 Winkelmann H. P. "Presentation of the Copernicus Action Plan" in THE ROLE OF UNIVERSITIES FOR SUSTAINABLE DEVELOPMENT - Utrecht NL Sept. 1998 (hpw@infu.uni-dortmund.de)

DEL 98 Delport J. and Calmeyer J. Private communication (jdelport@postino.up.ac.za)

FAU 98 Faucher P. et al. "IMPLEMENTING ENERGY-EFFICIENT AND ENVIRONMENT-SAFE PROGRAMS IN THE MANAGEMENT OF EUROPEAN UNIVERSITY CAMPUS AND RESEARCH LABORATORIES : Case-Studies from the ECOCAMPUS collaboration" ACEEE Summer study, Asilomar (CA) Aug. 98 (faucher@cenbg.in2p3.fr)

HAB 96 Haberl. J et al. "MEASURING ENERGY-SAVING RETROFIT : EXPERIENCE FROM THE TEXAS LOAN STAR PROGRAM Report ORNL/Sub/93-SPO90/1 (Feb.1996) (jhaberl@esl.tamu.edu)

IAU 93 Pietracci F. Private communication (pietracci@uno.org)

ROT 98 Roturier J. "ENERGY-EFFCIENT OFFICE TECHNOLOGIES IN EUROPE" - Final report of the MACEBUR Workgroup (EC-SAVE/PACE Programme) (roturier@cenbg.in2p3.fr)

ROT 99 Roturier J. "ECOCAMPUS : a "Practice-What-You-Preach" European collaboration - Final report of the ECOCAMPUS Workgroup - EC-Thermie Programme (roturier@cenbg.in2p3.fr)

---

[i] Ecocampus is a Trade mark of University of Bordeaux 1
[ii] COPERNICUS is a network created in 1989, by CRE, the Conference of European Rectors of Universities
[iii] [iii] under Contract STR 1006 – 96 FR (Project Manager : I. SAMOUILIDIS. A more complete analysis, and detailed data, may be found in the ECOCAMPUS final report (ROT 99) and/or from co-authors having managed each case-study.