METHODOLOGY FOR BUILDING MODELLING AND CALIBRATION FOR WARM CLIMATES

A. Pedrini* and R. Lamberts**
*Dept. of Architecture, The University of Queensland, Brisbane, QLD 4066 - Australia: alp4@bne.comcen.com.au
**Dept. of Civil Engineering, Universidade Federal de Santa Catarina, Florianópolis, CxP 476 CEP 88040-900 - Brazil: lamberts@ecv.ufsc.br

ABSTRACT

In the last seven years, a method has been developed to analyse building energy performance using simulation, in Brazil. The method combines analysis of building documentation, and walk-thought visits, electric and thermal measurements, with climate analysis and the use of an energy tool (DOE2.1E code). The method was used to model more than fifteen office buildings (more than 200 000 m²), between 12.5 and 27.5° of South latitude. The paper describes the basic methodology and justifies it, using some results.

INTRODUCTION

A building model is often examined by some software, which allows the evaluation of current energy use as well as the prediction of the impact of energy saving actions in hypothetical refurbishments. As the reliability of these results is intrinsically related to the model's accuracy, it is necessary to consider how much effort (and resources) are necessary to produce a satisfactory model. This is the starting point for this paper, which presents a modelling and calibrating method with successive increasing levels of complexity and their impact on the results. Emphasis is laid on "input" and "output" tasks, since the software itself exists, it is well recognized and validated. The "input" aims to represent the building as an abstraction of the reality and this process determines the accuracy of the results. On the other hand, the "output" consists of reporting results of the simulations. The method was initially based on procedures reported in internal reports by Kaplan Engineering (Kaplan, 1991; Kaplan, 1992), and articles such as Haberl and Komor (1990), Koran et al., (1993), Corson (1992) and others and the first proposal was presented in the master thesis of Pedrini (1997), in the Building Energy Efficiency Laboratory (LABEEE/ UFSC/ Brazil). Since then, the method has been modified to allow variations, adapting itself to different building cases.

METHODOLOGY

The process starts with a collection of available information, continued by an audit in loco, it is improved with monitoring and air conditioning efficiency determination. The main parameter of model acceptance is the comparison of monthly energy consumption between the real and simulated performance. The phases of this process are described in the following paragraphs.

The first step involves an evaluation of the building documentation, without actually visiting the site. The intention is to use only existing information to avoid unnecessary expenses, and to estimate the potential saving for the building before investing into trips to the location. As the analyst need no contact with the building, the distance of the building is irrelevant. This is a strong advantage for countries like Brazil and Australia, due the continental distances between cities. The checklist for this task is:

- Architectural plans: used to identify geometries and lay-outs, construction layers, window areas and others, derived from site and floor plans, sections and construction details such as roof , wall, windows and exterior shading.
- Electric lighting system: the information sources are electrical project plan and the nominal characteristics of luminaries available in catalogues.
- Air conditioning secondary system: air distribution plan, and report with design characteristics such as cooling and heating set points, supply air and exterior air flows for each zone, total and sensible cooling capacity, EER and fan nominal power and flow.
- Air conditioning primary system: cooling water distribution plan, chiller characteristics such as model and year, COP as well as efficiency at 100%, 75%, 50% and 25%, cooling capacity, chilled water supply temperature, cooling management, chiller schedule report (this is routinely monitored every day).
- Building schedule for lighting, occupants (total number of occupants) and air conditioning.

- Equipment inventory: number of computers and other equipment with considerable energy consumption.
- Historical monthly energy consumption (at least one year).
- Hourly energy consumption for a representative period, usually available from the energy supply company.
- Building component properties: special features must be characterized in detail (such as windows in buildings with large window/wall ratio), which must be available in catalogues and manuals published by the supplier.

Using all these information, the first model is built using a software. Far too often inputs are assumed, due to lack in documentation. In this situation, a good library with appropriate defaults is extremely useful. Results of the first model (Figure 1) usually differs from the measured monthly consumption, but it is enough to identify discrepancies.

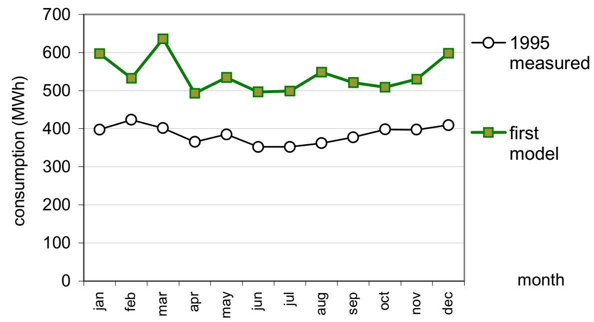

Figure 1: First model

The main sources of thermal loads and energy consumption are identified and the documentation is revised. The hourly energy consumption is also derived and compared with the monitored data. The differences are questioned and an audit walk-through is prepared.

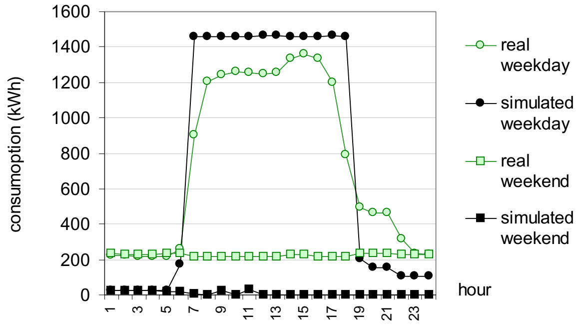

Figure 2: Hourly energy consumption comparison: simulated x real

The second step is referred to as “Walk-through audit phase”. Using observations derived from the previous step, the analyst visits the building with a technician, who must be familiar with the operation of the building. Supplied with current plans and some colour pens, the analyst classifies the zones following criteria such as type of use, artificial lighting and climate control (Figure 3). Whenever possible, the analyst must confirm information about use, questioning the users, mainly cleaners and system operators.

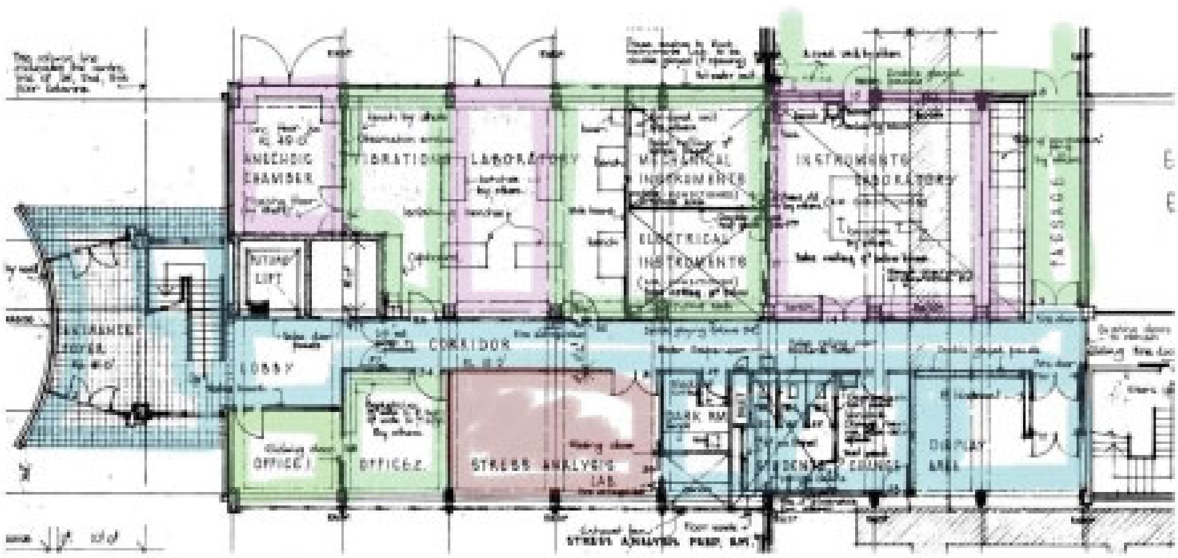

Figure 3 – Zones classification.

During the visit, some measurements must be carried out. The first ones are instantaneous measurements using hand-held instruments (Figure 4) to check lighting levels, air flow, temperature, reactive and active power, and power factor in equipment, and representative sample of artificial lights. Frequently, nominal values for lighting power differ from the real ones especially with discharge lamps. This must be followed by measurements over a period (days, weeks or even month) for which accurate dataloggers are the appropriate tool ((Figure 4)

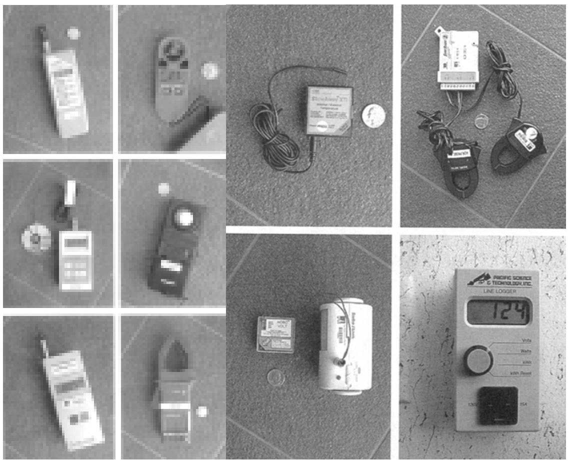

Figure 4: Hand-held and diminutive dataloggers instruments (Watson, Crosbie et al. 1997)

Sensors of temperature dataloggers are installed close to the air return in fan-coils chambers to measure an average temperature of the zones and the records quantify the setpoints and the schedule, as can be seen in the Figure 5, which has different curves for distinct zones. Also, the records can indicate if the air conditioning is properly doing its function. Equipment such as lifts, water pumps and others that can have excessive energy consumption must also be checked using some current meter dataloggers.

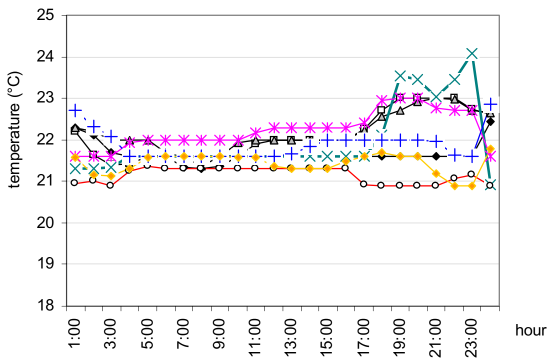

Figure 5: Temperature monitoring for different office rooms

The results obtained in this phase are utilized to tune inputs such as lighting power density, equipment power density, cooling set point and use schedules.

The third step consists of schedule calibration and it is referred to as the “End-use energy consumption phase”. It consists of spliting the total energy consumption in to energy end-use by lights, equipments (plug-in type) and air conditioning, such as the typical weekdays energy consumption represented in the Figure 6. Usually, these measurements can be done in the transformer or main switch room, if the electrical system is sufficiently refined to identify circuits for each purpose. The results are utilized in the model schedule tuning.

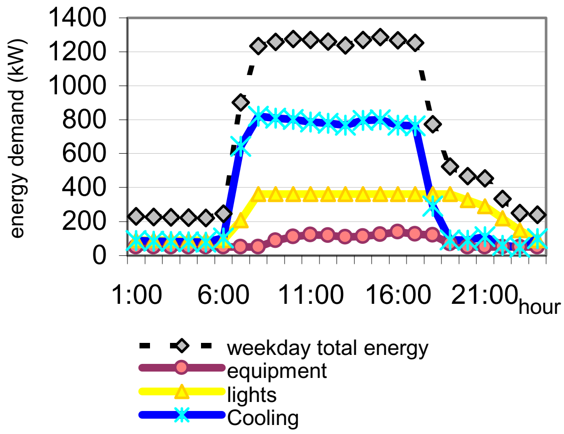

Figure 6: Total and end-use demand energy

The fourth and last step aims to calibrate the cooling system characteristics: “Air conditioning system characterization”. The process begins with current recordings in pumps and cooling tower. At the same time, the water temperatures in the chillers, water flow and power consumption are monitored. Using the standard (ARI, 1998), the COP is calculated for similar conditions.

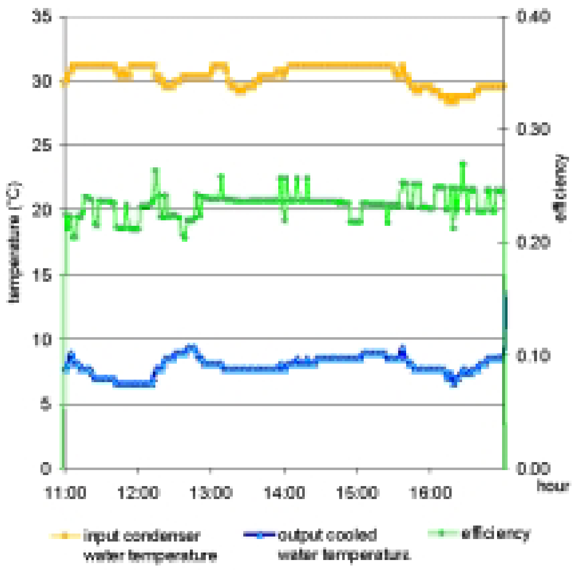

Figure 7: Temperature and efficiency curves

CONCLUSIONS

All phases successively increase the model accuracy and the influence of each one depends on the quality of information and the building type. Just to illustrate the consequence of common errors during the model and simulation, the analysis of energy end use is presented for the Eletrosul building (Figure 8), relative to the four steps of modelling. In every calibration, the simulated results match the real consumption, as shown in Figure 9.

Figure 8: Eletrosul (10 000 m²)

The first model uses one data available in documentation, the second uses also monitoring information to redefine the schedules, the third uses energy end-use monitoring and the fourth models the cooling efficiency determination (COP) through measurements in situ. The results, presented in Figure 10, show an overestimate of lighting energy consumption, which decreases with the refinements of the model. On the other hand, plug-in equipment and HVAC are underestimated in the first model and successively increase in proportion. The main improvement is the energy end-use determination, while the COP estimate corrects cooling energy consumption. This modelling behaviour was checked again for 12 other buildings (analysed during 1996 and 2000) in Brazil, and all of them demonstrated the importance of monitoring.

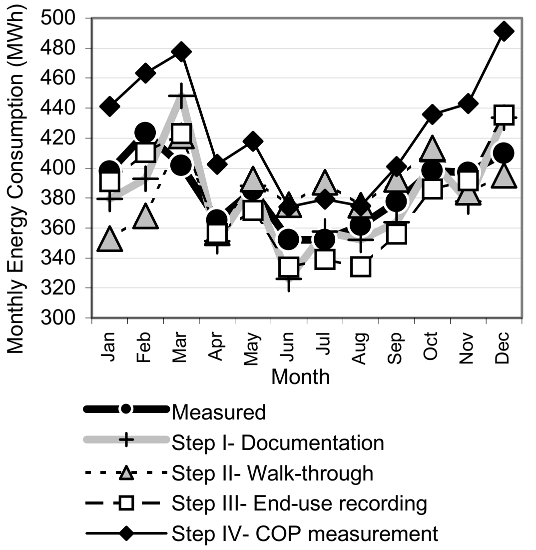

Figure 9: Model calibrations

The discrepancies between the first and the last model evidence the potential errors about building behaviour, when it is modelled. The information supplied by building occupants, as documents and reporting, and the walk-through audit are probably not enough to produce a reliable model, which can be obtained only from measurements and monitoring. The errors in energy end-use profile during a retrofit analysis can result in significant errors in payback estimate, sometimes of an unacceptable magnitude. The analyst must be conscious of the model limits and he/she must look for an appropriate balance between level of detail and reliability.

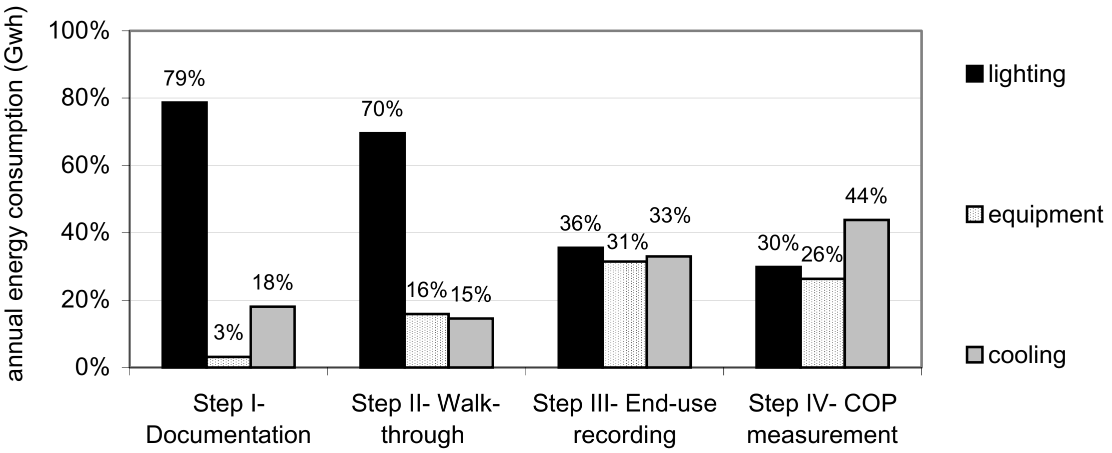

Figure 10: End use energy for different levels of modelling.

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