DISTRIBUTION OF ENERGY CONSUMPTIONS BY USAGES AND ACCORDING TO THE TYPE OF SYSTEM IN AIR CONDITIONED OFFICE BUILDINGS

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Air conditioning systems, office buildings, energy consumptions, energy usages.

ABSTRACT

In order to estimate the energetic performances of several air conditioning systems, metering devices, installed in five office buildings located in the business area of La Défense near Paris, have been recorded all a year round. Four systems, among the most representatives in France, have been selected : fan coil units, induction units, Variable Air Volume, water to air reverse cycle heat pumps.

The importance of some energy usages has been clearly pointed out :

- cooling needs for computers,
- lighting,
- consumption for domestic hot water when produced by the same generator that for premises heating,
- electric consumptions of conveying devices such as pumps for hot or chilled water, fans.

These consumptions are compared to those needed for heating or cooling the offices.

INTRODUCTION

On site surveys concerning nearly one hundred air conditioned office buildings have been carried out some years ago by the C.S.T.B. , they permitted to identify the moste representative air conditionning systems in France and to determine the mains characteristics of the buildings.

For a large part of this sample, the total energy demand has been assessed for each type of energy ; it showed a significant deviation that cannot be attributed only to the variety of the solutions adopted by designers. A more accurate investigation implies to determine the distribution of energy consumptions by usages for each type of energy, and particularly for electricity.

For this purpose, five office buildings have been monitored all a year round.

Presentation of the buildings and of the systems.

The main characteristics of the five buildings and of the corresponding air conditioning systems are presented in the table below.

Building	A	B	C	D	E
Site	Business area of La Defense near Paris				
erection year	1983	1983	1969	1982	1972
storey number (super-structure)	8	15	27	8	32
total floor area m^2	9 840	33 500	32 300	10 000	92 000
heat generation	hot water network of La Defense				
gold generation	chilled water network of La Defense				
air condi-tioning system (offices only)	fan coil units	loop connected water to air heat pumps	induction units	variable air volume	variable air volume
controled parameters	ambiant air temperature exhaust or recycling air humidity				
aeraulic system	mechanical ventilation (supply and exhaust) hygienic air change		mechanical ventilation hygienic air change + recycling (3 to 4 ach)		

Metering means

Different ways of metering have been employed, depending on the existing means and on the possibilities.

Every installation was initially equiped with energy meters for bill purposes of the hot water and chilled water suppliers. Periodical readings of these counters lead to the assessment of the energy amount needed for premises heating and domestic hot water heating on one hand, premises cooling and computer cooling on the second hand.

Setting up other energy meters has not been allowed, so some hypothesis were necessary to go further ; heating demand is only for domestic hot water during the very summer (except for building C where domestic water is heated electrically) ; in the same way, cooling demand is only for computers during the very winter.

Some electrical counters were initially installed, those for the technical maintenance areas lighting, lifts, conveying devices of the air conditioning systems and other auxiliary equipments) and those for the cafeteria. In addition, counters indicate the total electrical consumptions of all the companies.

As far as possible, additional electrical or horary counters were installed in order to get a more accurate distribution.

Result

The results given here after are obtained from monthly readings of all the metering devices ; they concern one year, from July 1986 to June 1987.

In order to facilitate comparisons between buildings and between these installations and other with boilers and chilled water groups, energy consumptions for heating and cooling are derived from the data appearing on the energy suppliers bills using a multiphying factor equal respectively to 0,85 (boiler efficiency) and 3 (frigorific efficiency).

Consumptions expressed in kWh are divided by the total air conditioned floor area (including infra and superstructure).

When analizing the results, it is of great importance to distinguish three type of premises :

- offices which represent more than 80 % of the total (including meeting rooms),

- computer rooms, equiped with a particular cooling system,

- cafeteria, equiped with a separate ventilation system.

Results are presented in figures 1 to 5 showing, for each building, consumptions by usages in the upper part, and distributions of these consumptions for offices only in the bottom part.

Comments

The examination of the upper graphes clearly shows that considering only the total annual consumptions for each type of energy does not allow to appreciate adequately the performance of an air conditioning system in an office building. Some other energy usages have to be assessed and these consumptions must be deducted from the total.

Electricity supply for computers may fluctuate from 30 to nearly 100 kWh/m^2.an, involving a corresponding cooling demand (ie electricity consumption approximately equal to one third of the computer supply). The cooling needs for the computer rooms may be three times higher than those for the offices. Internal heat gains due to computers is of the same ordre of magnitude than lighting.

Energy amounts required for domestic water heating presents also a wide deviation, from 2 to 25 kWh/m^2.an (the figure for building A is not reliable). Two main parameters may affect these results : stopping the domestic hot water delivery inside the whole building (replaced by local heating when necessary in buildings C and E)., use of electricity instead of district heating, at least during the cooling period (building C).

Electricity consumptions for the cafeteria, essentially for cooking, seem particularly fluctuant too (5 to 20 kWh/m^2.an), but considering a more appromicate ratio - kWh/an per meal prepared - this figure stays approximately constant at about 400.

The lower graphes concern only the offices ; fans consumptions have been shared between offices computer rooms and cafeteria and the whole of the other usages have been attributed to the offices (ie lighting, pumps, lifts and cooling towers).

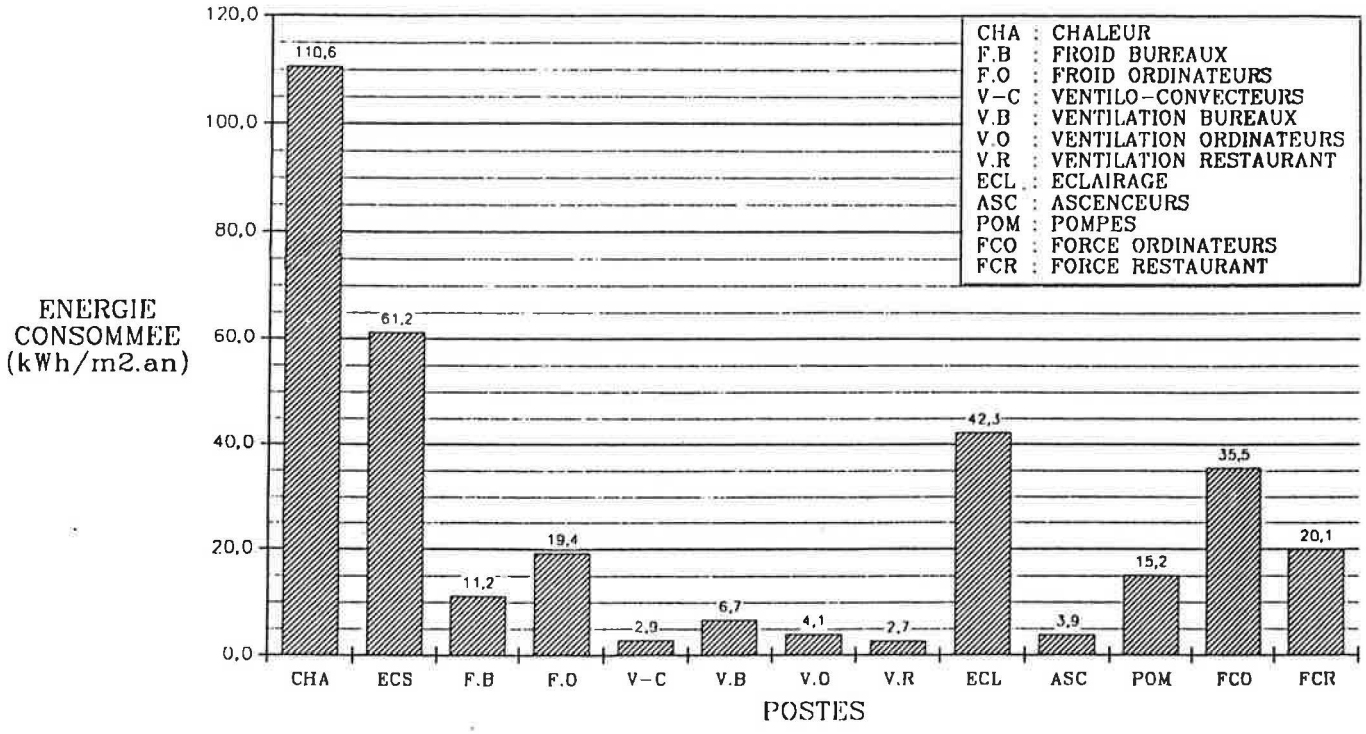
As far as the climatic conditions are identical, the energy consumptions for heating and cooling would be linked to the characteristics of the buildings and to the expected performances of the air conditioning systems. However, according to the results of this study, this relationship does not appear very strong. Besides the numerous uncertainties on measurements due in part to the hypothesis, some other preponderant factors may explain these discrepancies : system management (nigth setback, air recycling, maintenance ...), comfort level (ambiant air temperature and moisture), occupant behaviour (windows openings, action on thermostats ...). As previously mentionned, heat energy meter in building A is highly suspected to be wrong.

Electricity consumptions for water chillers stay always under 15 kWh/m^2.an, these figures are rather low and of the same order of magnitude than pumps or fans (without recycling). It represents less than 5 % of the total energy demand for offices.

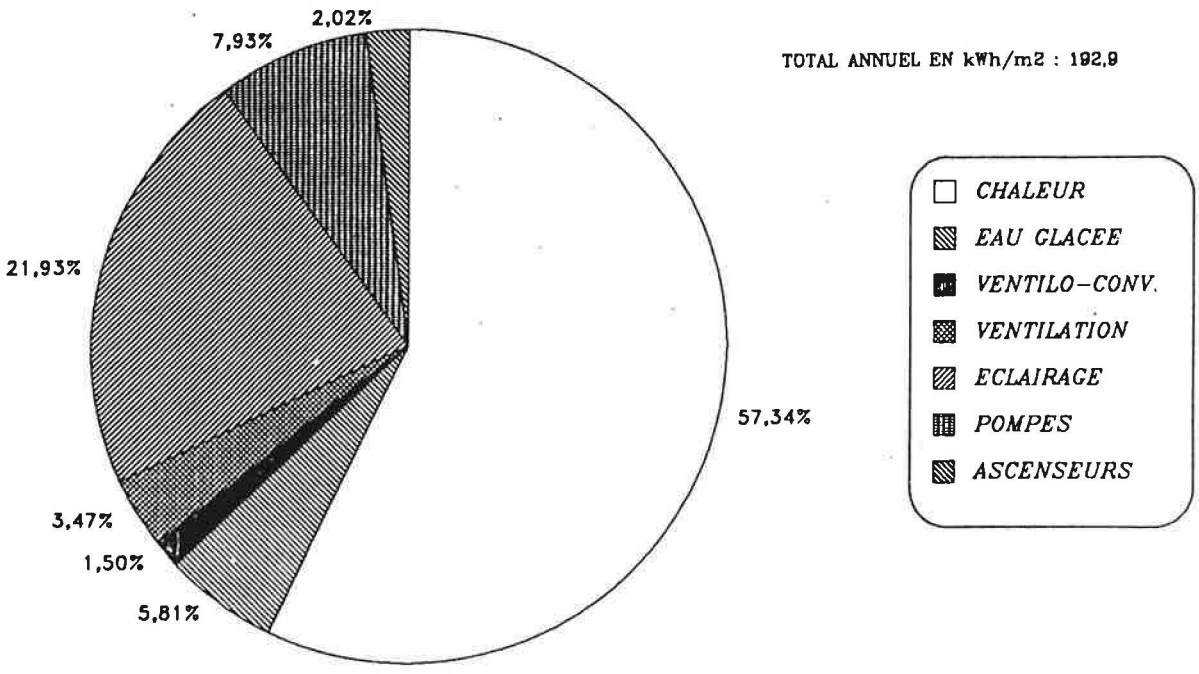
Lighting represents about one third of the total consumptions, the average annual consumption is 50 kWh/m^2.

BUILDING A

Energy consumptions by usages.

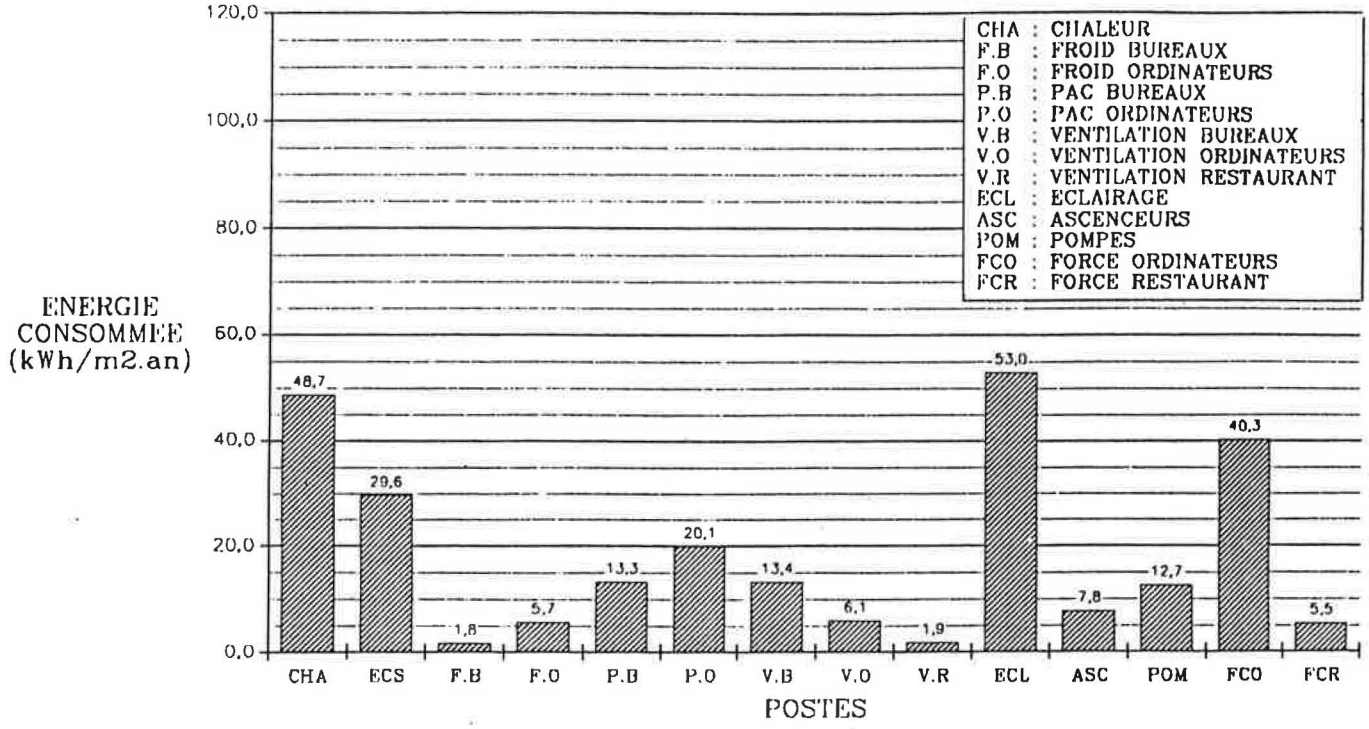


Distribution of energy consumptions (offices only).

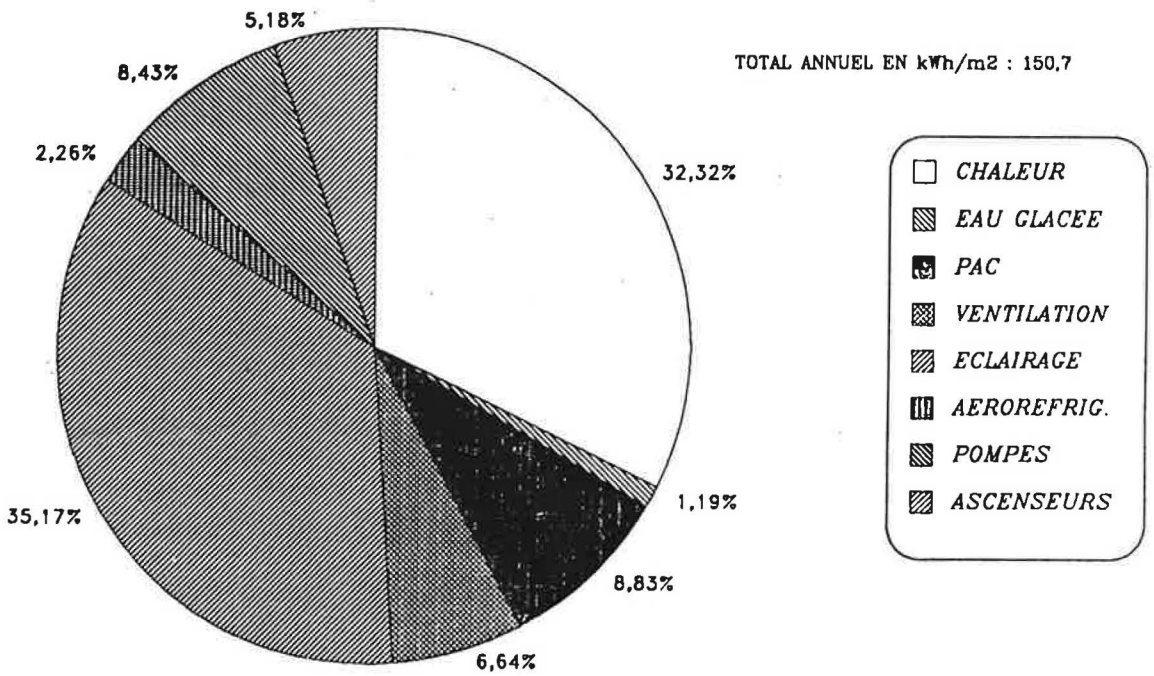


BUILDING B

Energy consumptions by usages.

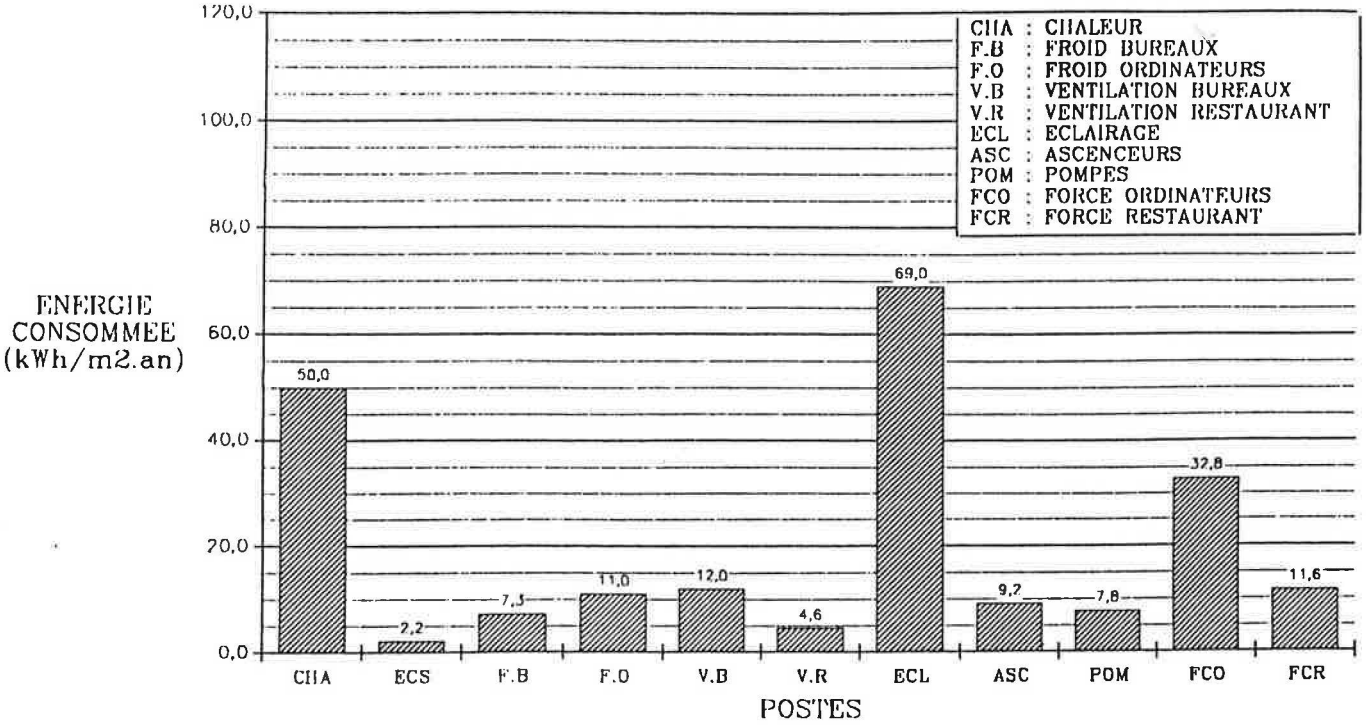


Distribution of energy consumptions (offices only).

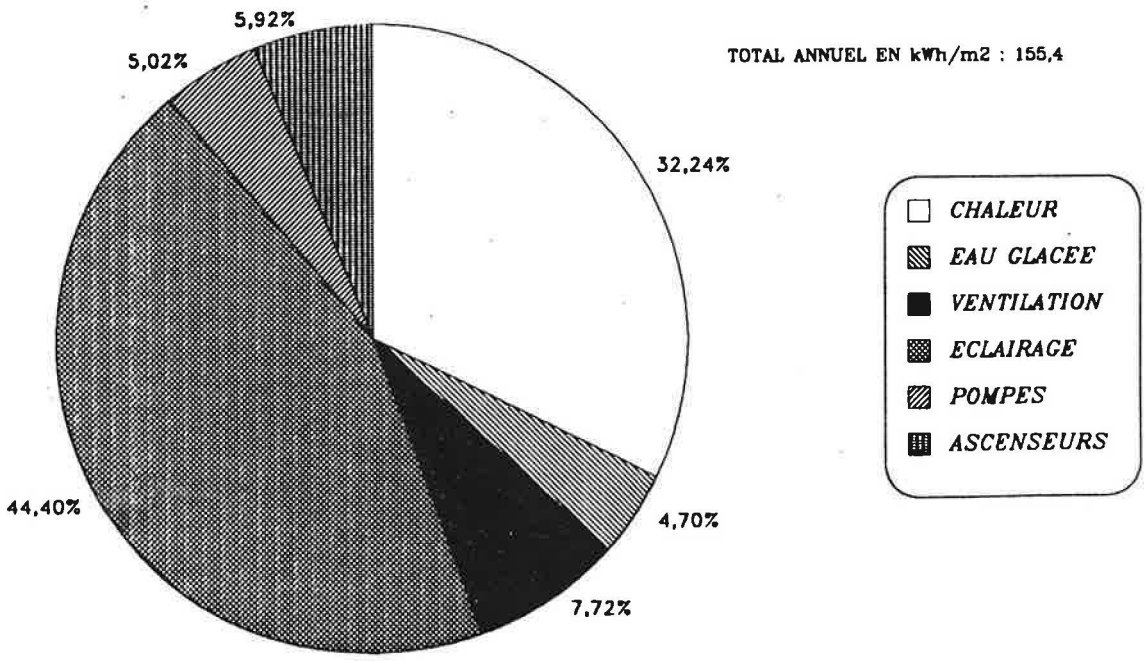


BUILDING C

Energy consumptions by usages.

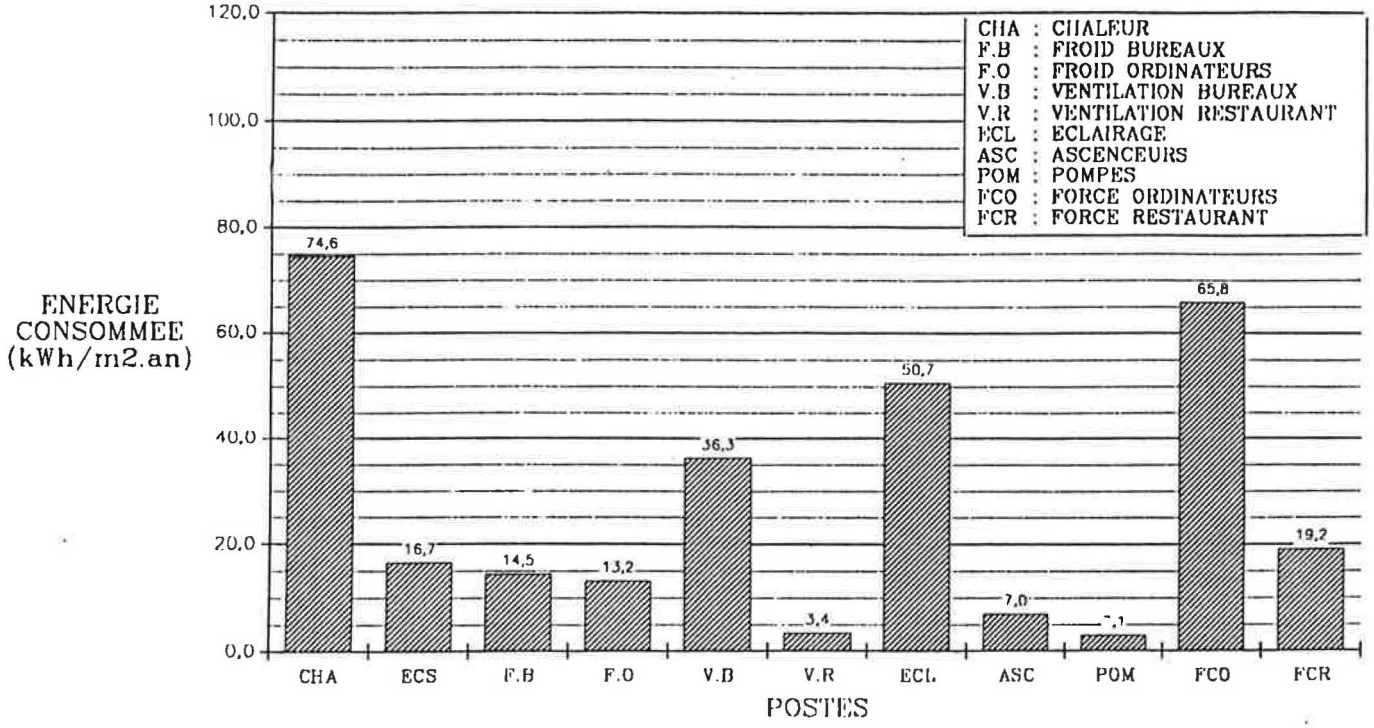


Distribution of energy consumptions (offices only).

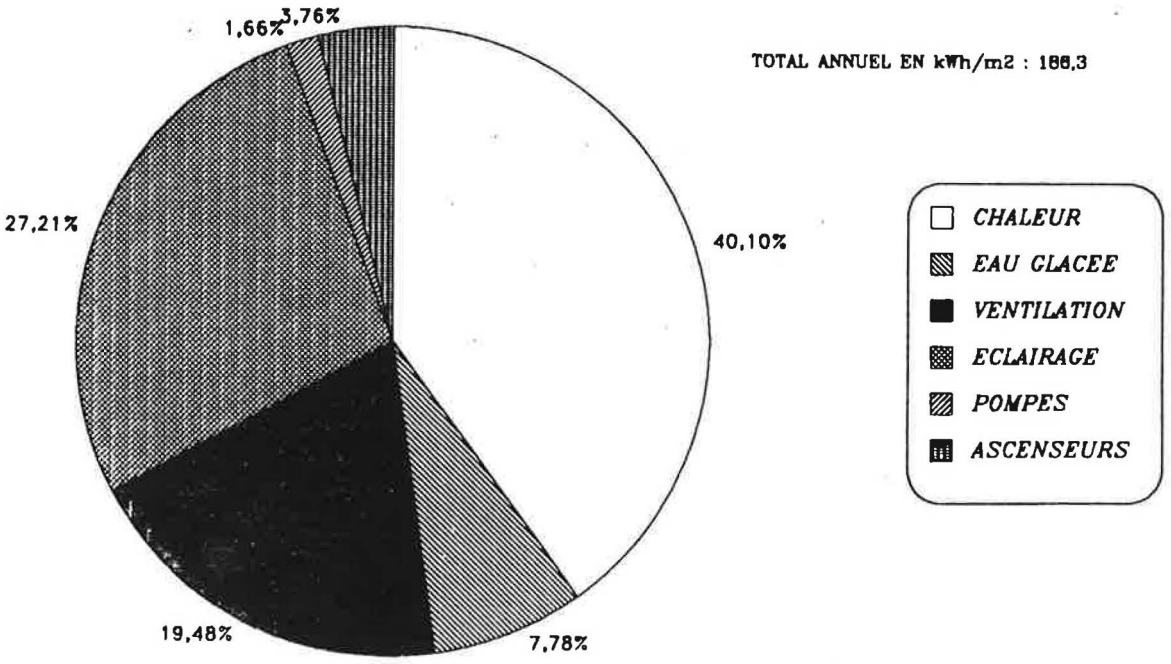


BUILDING D

Energy consumptions by usages.

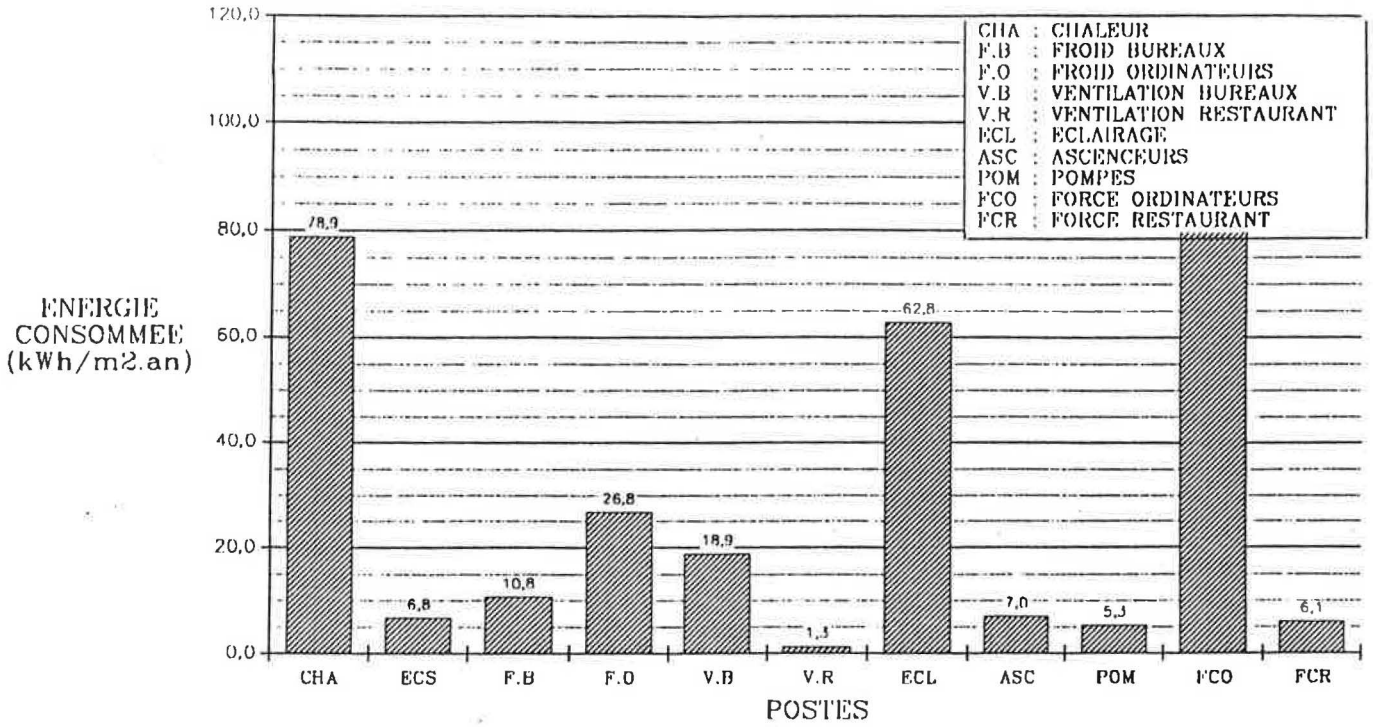


Distribution of energy consumptions (offices only).

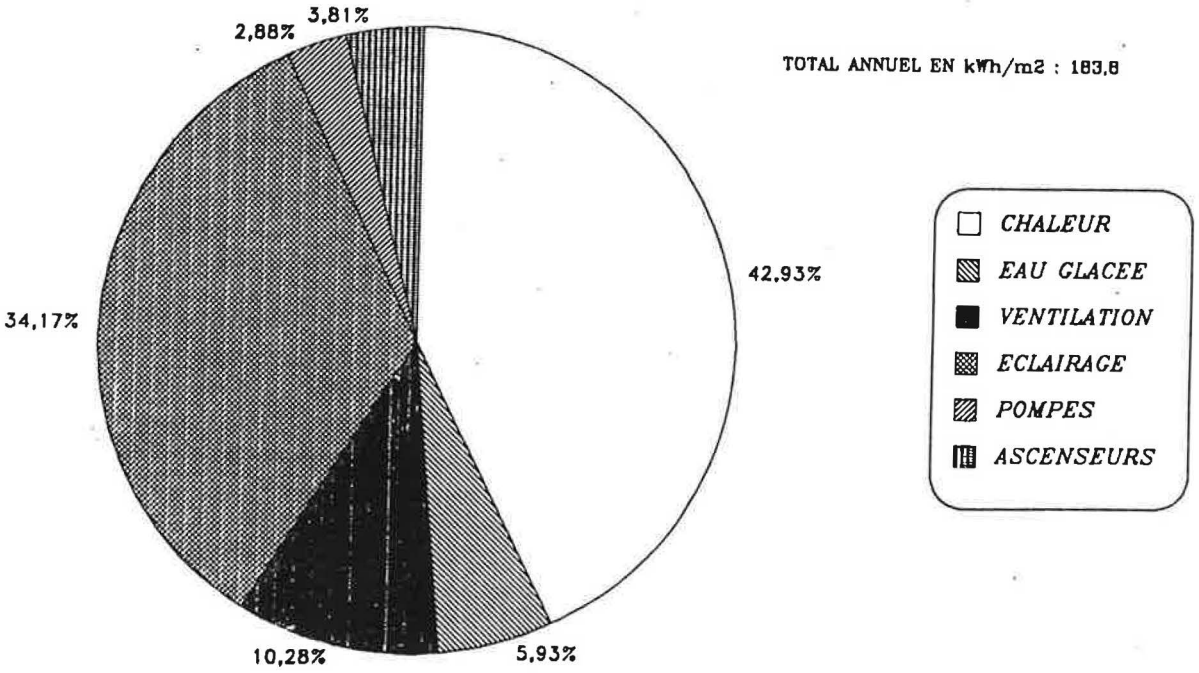


BUILDING E

Energy consumptions by usages.



Distribution of energy consumptions (offices only).



CONCLUSION

For a proper evaluation of an air conditioning system in an office building, some care must be taken ; generally additional energy meters must be installed because some usages are energy consuming at the same level than heating and three to four times more than cooling.

Better assessments will be undertaken by the C.S.T.B. taking into account for the ambiant comfort and all the operative parameters.