ROLE OF THE MODEL USER IN RESULTS OBTAINED FROM SIMULATION SOFTWARE PROGRAM

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ABSTRACT

Within the framework of the validation methodology of our computer software CLIM2000, we asked 12 users to do the same validation exercise (prediction of energy consumption of a residential house) in order to evaluate the influence of the model user on the simulated results. The first part of this article describes the conditions in which this exercise was carried out. The second part of this article presents the results in two ways : a comparison with the average value of the results and a comparison with the results obtained from a reference modelling. Then, an analysis of the discrepancies in the results is also presented. Finally, we tried to give some remedies to reduce such errors in the future.

1 - INTRODUCTION

The CLIM2000 software environment was developed by Electricity Applications in Residential and Commercial Buildings Branch of the French utility company EDF (Electricité De France). This software operational since June 1989, allows the behaviour of an entire building to be simulated.

The validation methodology of CLIM2000 has been in place for many years. It consists of : examination of the theoretical basis and algorithms used in the considered model, comparison of solutions to analytical tests with simulated results, testing individual thermal processes using sensitivity analysis and uncertainty analysis, comparing different models (inter-model comparisons), and analysing discrepancies between CLIM2000 output and high quality measured data using tools for residual analysis based on spectral analysis. To be complete in this methodology, we have to take into account the role of the model user.

Up to now, we did not focus our validation work on the role of model user on the results obtained from simulation software program. It is what we wanted to do with such validation exercise for our computer software CLIM2000.

2 - EXERCISE DESCRIPTION

Twelve CLIM2000 users took part in this validation exercise. The panel is representative of CLIM2000 users. The panel constitution is given in Table 1.

The exercise consists in predicting the energy consumption of a real house situated in Lisses (30 kms south of Paris) for the heating season given by French thermal regulations (October 1st 00:00:00 - May 21st 00:00:00). This house has been rented by EDF. Long-term experiments are carried out in it with particular regard to energy-related measurements made on the electric heating system.

This house Valeriane is a new cottage complying with the 1989 French thermal regulations and is equipped with electric convectors. It is fully representative of all new dwelling units in France (floor area 100 m²) (Figure 1 and Figure 2).

A brief description of the house is given in a companion paper **[7]** and a complete description is given in **[5]**.

The model to be developed on CLIM2000 by the participants has to be a thermal monozone model i.e. the volumes of the different rooms are grouped together in a single volume equal to the sum of each room volume). The meteorological data to be used are from a station close to Lisses site.

It is intended to include difficulties such as those that would be encountered in practice. The same document package was given to each exercise participant. This package contained different documents : one for the detailed description of the house, one for the windows modelling on CLIM2000, one for the heat transfer coefficients, one on the way to be used for modelling walls in contact with non-heated room and one for the French thermal regulations.

A hot-line was offered to each participant in order to give essential modelling information if, in spite of the care to the constitution of the document package, it was omitted in this package. If any information is given to one of the participant, it is given to every other participant. In order not to corrupt the results, each participant has been asked not to communicate with the other participants during the time needed for the exercise.

At the end of the validation exercise, each participant gives a short memo containing the required results and the assumptions and simplifications made during the modelling.

3 - RESULTS

3-a - Comparison with average value

The results obtained from the different participants are given in Table 2.

A first comparison is made on the basis of the average value of predicted energy consumption which is equal to 11090 kWh (std=2235 kWh). We can see that the prediction of energy consumption varies from -41% to +39%, which represents a range in absolute value of 2:1.

The aim of this validation exercise was to emphasize the influence of the model user on the simulated results : this first comparison shows that this effect is far from negligible.

Nevertheless, this variation is less than the one observed by BRE (Building Research Establishment, U.K.) in a similar exercise with the same comparison **[2]**. Indeed, in this English exercise carried out by 25 users, the energy consumption of a large complex building varied from -46% to +106% (4:1 in absolute values).

The difference between these two ranges of values can be explained by the complexity of the building itself. A residential house is easier to model than an office building. Then, it is normal that errors are less frequent and the variation lower for such kind of house.

3-b - Comparison with « reference modelling »

Here, the comparison is made on the basis of the results obtained from that we call « reference modelling ».

This « reference modelling » was done in October 1995 and we have predicted in blind way (no knowledge of experimental data) the energy consumption of Valeriane house. The predicted energy consumption was 13004 kWh **[4]**.

In October 1996 , we have compared experimental results with simulated results obtained with the « reference modelling » in 1995. At that time, the aim of such validation exercise was to validate the CLIM2000 software, not to validate the user. Because the error was very low for the entire heating season (5.3%)**[6]**, the user was an expert and the possibilities to improve modelling almost non-existent at that time, we have considered that this modelling was the best one we can do, to represent numerically the real behaviour of this house. That is the reason why we have called such modelling, « reference modelling ».

Obviously, the participants did not have the knowledge of such « reference modelling ». They have studied this house like in a real project (virtual house). The results and the comparison related to the « reference » energy consumption value are given in Table 3.

This comparison shows that all the participants have underestimated the energy consumption for this real case. Such error in a pre-project could be source of non satisfaction of resident when the house is built. We can advise user of software programs to be very considerate and precise with their modelling to avoid such discrepancies.

3-c - Expertise of participants

We have shared the panel into four different categories. We have attempted to classify the results versus the expertise of each participant. This is presented in Table 4.

We can see that the results range is narrow for the category Cat 1. This is due to the fact that these users have the same culture and the same way to approach problems. We find this in the kind of errors done by this population.

It is surprising to see the divergence between the results of the category Cat 1 and the one of the category Cat 3, because it is more or less the same population. We can say that, even if students are assisted closely by people accustomed to CLIM2000 use, we can't exclude definitively their own errors.

The large range of results for the category Cat 2 is not a surprise, because these people are not very familiar with CLIM2000 studies and have not a great culture in this domain.

For the category Cat 4, the large range is quite surprising because those people are very familiar with CLIM2000 use . In fact, three of these 4 people are familiar with the development of elementary models and with the resolution of thermal problems. They are not very familiar with French regulations which are the basis for some of the program input values like thermal bridges.

3-d - Analysis of encountered errors

We have analysed in precise way the modelling of each participant so as to determine what kind of errors have been done. The analysis was carried out on different points :

- connection between elementary models,
- kind of modelling used,
- parameters values.

Then, many categories of errors were identified :

- thermal bridges,
- ventilation,
- windows and French windows,
- constitution of wall between entrance and garage,
- modelling of ground floor,
- constitution of external walls,
- surface coefficients,
- heaters,
- solar fluxes transmitted in the room,

The Figure 3 shows the distribution versus the kind of errors, with no relation to the category of population.

It is interesting to note that errors mostly encountered are related to the part of modelling where the participants have used the thermal regulations, for lack of anything better. That is the case for thermal bridges and U-values of windows. Indeed, at present CLIM2000 does not offer the possibility of modelling precisely this kind of thermal component. Also, we can say that there exists a certain freedom amongst the participants in their interpretation of regulations. The errors encountered for thermal bridges, windows and ventilation stay in the following points :

- thermal bridges are omitted or the values are too low or too high,
- the U-values of windows are often false. That is the same for absorptivities and transmittivities.
- the rate of ventilation flow is too high or too low.

For external walls, it seems that errors are due to lack of attention or to fast checking of the modelling before simulation. They stay in the following points :

- values of surfaces different along the same wall or inversion of surface (north surface instead of south surface,
- constitution of walls non in appropriateness with the detailed description given in **[5]** (omission of material; thickness too high or too low,..),
- external surface coefficients non modelled or in non appropriateness with emissivity (global external coefficient and emissivity non equal to 0).

The others errors are due to lack of attention as well. There are errors on values of interior surface coefficients (bad values for vertical and horizontal walls), on the value of heating power (often too low).

The Figure 4 shows the distribution of errors versus the participant categories. It is difficult to give a conclusion on the basis of such results, because there is a good homogeneity of errors, except for windows where we can see a very high number of errors.

3-e - Remedies

For reducing such errors in the future, we will work on different points :

- thermal bridges : in a first time, to give a warning message for the user, in order he doesn't omit thermal bridges in his study. In second time and this part is now engaged, to develop reduced models of thermal bridges (Moore method) which allows to reproduce in a simple way, the dynamic behaviour of 2D model,
- windows : this work is engaged as well, to develop very detailed elementary models of windows. With this kind of models, we will need no more regulations, because the physics will be precisely described.

To avoid errors in data input values, it will be interesting to develop special assemblies of elementary models available in CLIM2000 (the so-called Macro Type which is an assembly of basic models called Formal Types) with fixed parameters : for instance, complete wall models with fixed constitution and parameters.

A new version of the CLIM2000's user interface is under development. It will allow to sketch the building in three dimensions. Then, the geometrical dimensions errors (length, thickness of each layer, surface, ...) will be reduced because the real shape of the building will be shown directly on computer screen (this is not possible nowadays). In addition to this, a concept of technological component will be available in this new interface. It means that the user could have access to a library of trade mark components (heaters, windows, ventilation system, HVAC system, ...). These components will be related to physical modelling including correct parameters. Then, errors related to the modelling of such building components will be totally cancelled.

We could also integrate a database into CLIM2000 including physical properties of materials, surface coefficients, and any data input value needed for the modelling. This will allow to have in a single tool all parameters needed for thermal studies. A specific tool could be developed for calculating the rate of ventilation as well.

More generally, we invite the model users one more time to be attentive and precise, and to invite a third party to verify the modelling before submission of simulation job. The procedure « modelling - verification - approbation » before submission of simulation job is a quality way to avoid errors in thermal studies.

CONCLUSIONS

The aim of this special validation exercise applied to the thermal simulation software program CLIM2000 was to evaluate the influence of model user on the simulated results. It was intended to include real difficulties as those that can encounter a software user who have to study the thermal behaviour of real building in a project.

For 12 participants using a single simulation model of a residential house, the predicted annual energy consumption varies from -41% to +39% of the average value. This represents a variation in absolute value of 1:2. These results show that the model user is non negligible in the results obtained from thermal simulation programs.

The results analysis versus the participant expertise shows that it exists a good homogeneity category by category, explained by the fact that the same culture gives similar interpretation of problems.

A lot of errors are encountered for the modelling of thermal bridges and for windows. It is interesting to note that these errors are related to participants' use of the thermal regulations to calculate data input values where no better source exists.

These results are important if we consider a general methodology of validation. We have to take into account such effects in the techniques of validation. Off course, a simple solution could be to remove the user for removing the subjective effect of him on the results but that is not possible ! We can't exclude definitively the subjective judgements of the users. We can't exclude the ambiguities necessarily related to the description of a real building.

We give some remedies to remove or to minimize the subjective judgements of the users, especially for the use of regulations in description of building. For thermal bridges, we will develop reduced models of thermal bridges (Moore method) which allows to reproduce in a simple way, the dynamic behaviour of 2D or 3D model. For windows, we develop very detailed elementary models of windows. With this kind of models, we will need no more regulations, because the physics will be precisely described.

ACKNOWLEDGEMENTS

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Figure 1 : Drawing of Valeriane ground floor

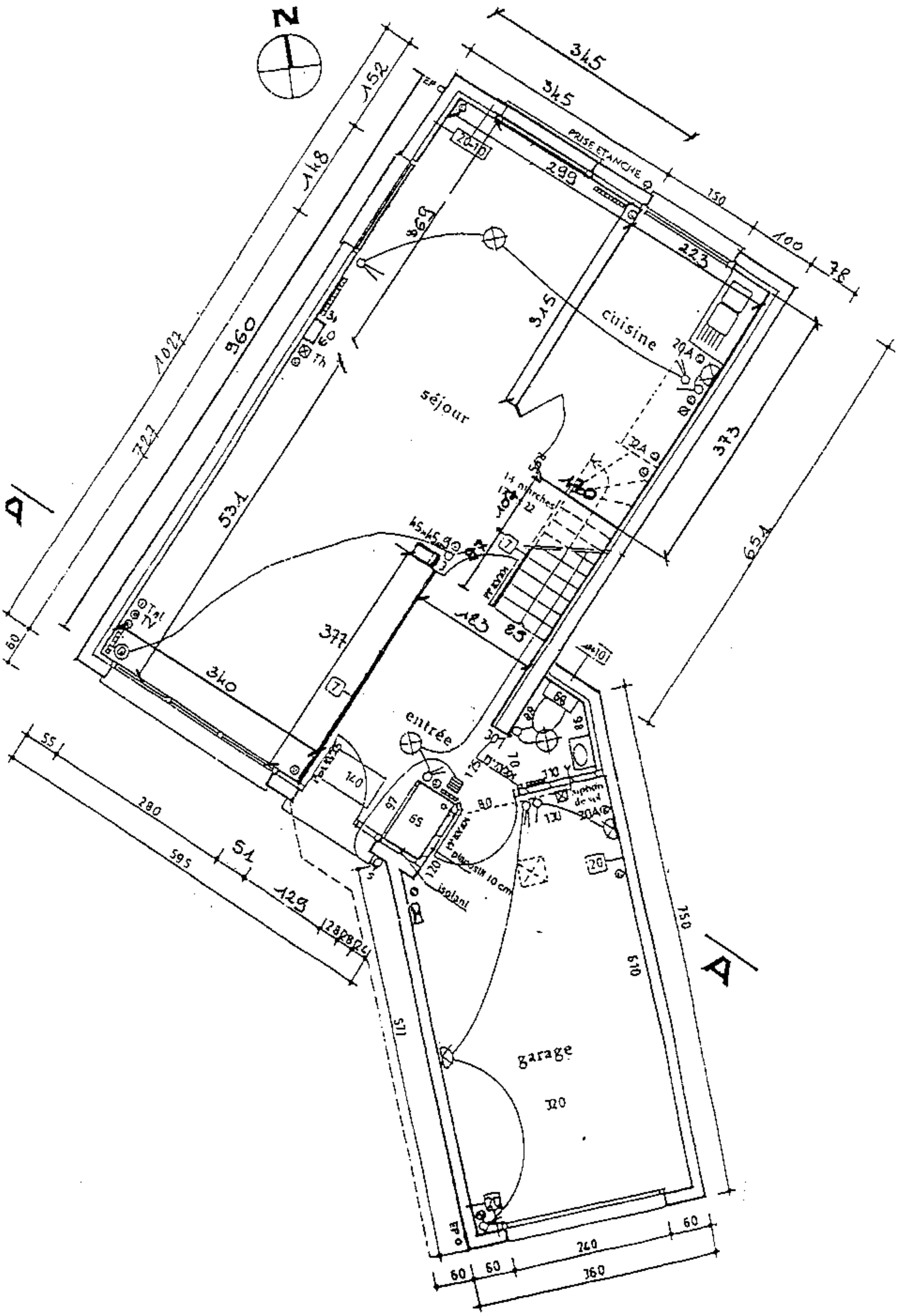
N
séjour
cuisine
entrée
garage
PRISE ETANCHE
siphon de sol
placoplâtre 10 cm
isolant
14 marches
A
A

Figure 2 : Drawing of Valeriane first floor

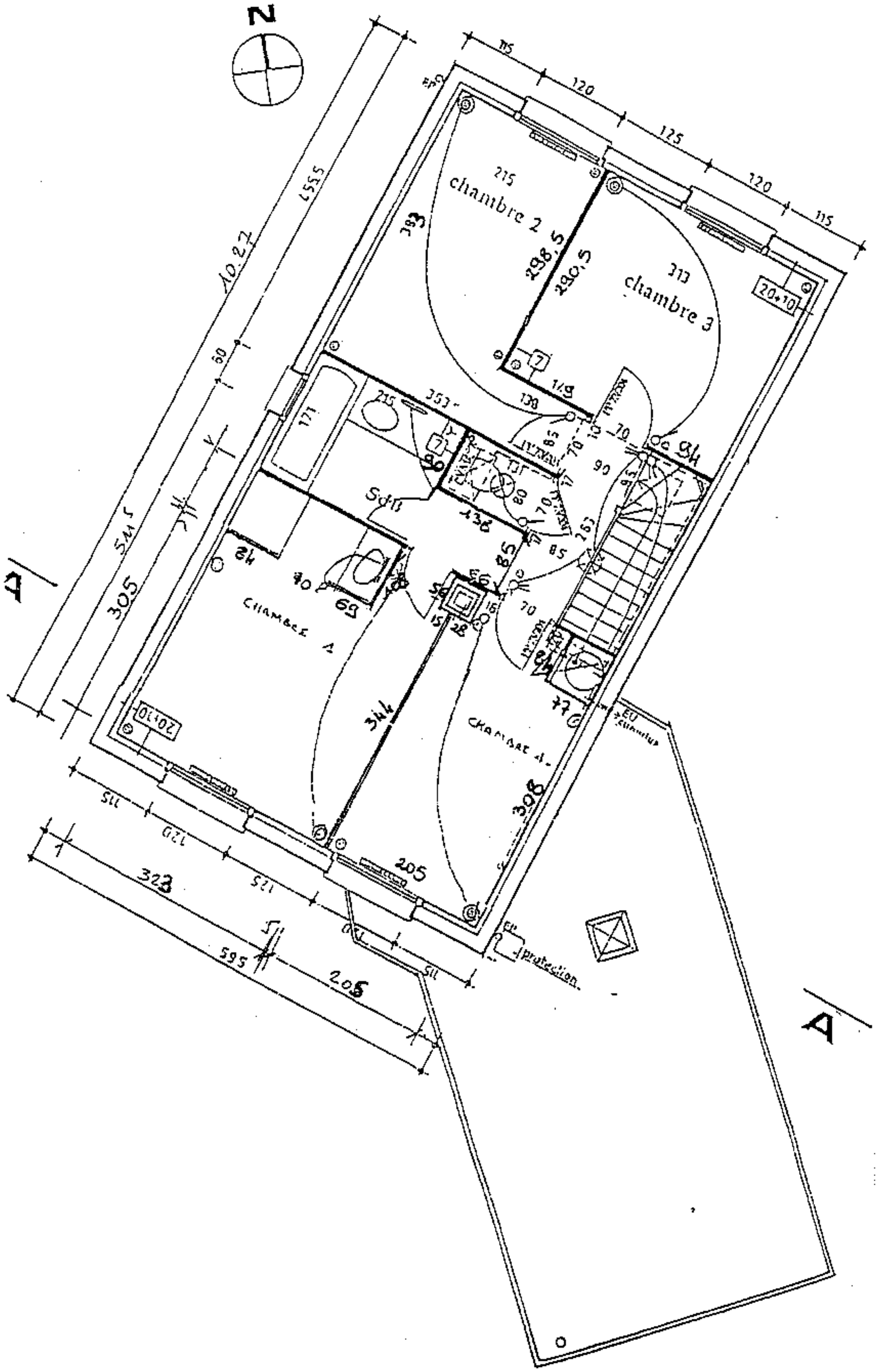

Figure 3 : Distribution of encountered errors

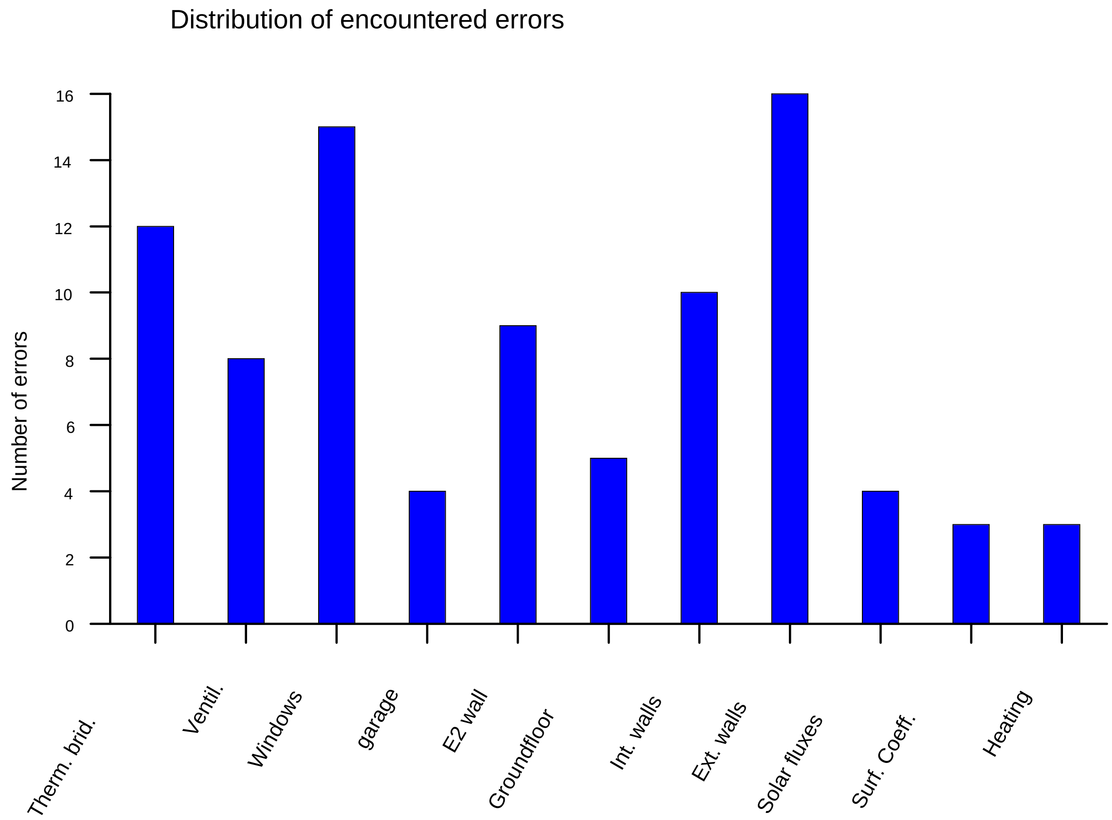

Figure 4 : Distribution of errors versus users

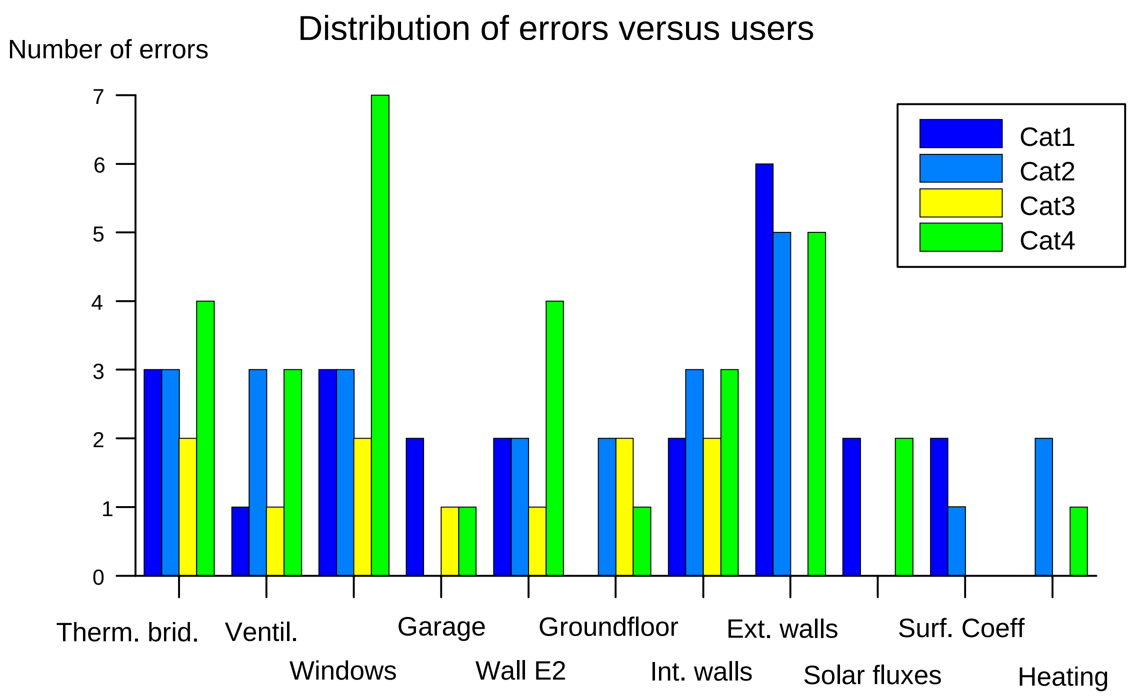

Table 1 : Panel of participants

Reference	Description	Number
Cat 1	EDF people accustomed to CLIM2000 use for studies	3
Cat 2	EDF people accustomed to CLIM2000 use but not for studies	3
Cat 3	Students with the help of people accustomed to CLIM2000 use for studies	2
Cat 4	Exterior consultants accustomed to CLIM2000 use	4

Table 2 : Results obtained and comparison with the average value

Average value : 11090 kWh
Standard deviation = 2235 kWh

	User1	User2	User3	User4	User5	User6	User7	User8	User9	User10	User11	User12
Cons. kWh	12862	11256	9060	9987	10419	13000	15367	11861	8744	6510	12392	11626
variat^n/ avg	+16%	+1.5%	-18%	-10%	-6%	+17%	+39%	+7%	-21%	-41%	+12%	+5%

Table 3 : Comparison with the « reference modelling »

	User1	User2	User3	User4	User5	User6	User7	User8	User9	User10	User11	User12
Cons. kWh	12862	11256	9060	9987	10419	13000	15367	11861	8744	6510	12392	11626
variat^n/ ref. val.	-1%	-13%	-30%	-23%	-20%	0%	+18%	-9%	-33%	-50%	-5%	-11%

Table 4 : Participants distribution

Reference	Description	Users	Variation/ mean value	Variation/ reference
Cat 1	EDF people accustomed to CLIM2000 use for studies	1, 8, 12	+5 to +16%	-11 to -1%
Cat 2	EDF people accustomed to CLIM2000 use but not for studies	9, 10, 11	-41 to +12%	-50 to -5%
Cat 3	Students with the help of people accustomed to CLIM2000 use for studies	4, 5	-10 to -6%	-23 to -20%
Cat 4	Exterior consultants accustomed to CLIM2000 use	2, 3, 6, 7	-18 to +39%	-30 to +18%