Commissioning-orientated building loads calculations. Application to the CA-MET building in Namur (Belgium).

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ABSTRACT

The parallel use of whole building simulation and monitoring of building energy consumptions (heating, cooling, lighting and other electricity consumptions) represents a potential "high-level" commissioning tool in order to verify, either as a one shot campaign or as a continuous process, the correct operation of a building. The most advanced approaches use on-line building simulation to continously compare the real performance of the building to a base line provided by simulation.

In that context, different levels of building loads calculation can be used, ranging from rough methods like eg degree day methods to detailed multizone building simulation. The former methods use aggregated information about the buildings ("global" parameters like the heat loss coefficient for instance) and provide as outputs average quantities (energy consumption for a given average controlled temperature) while the latter require a high number of parameters and deliver very detailed results (hourly evolution of demands in each zone of the building). A major question concerns the suitability of the different approaches in a commissioning context.

This papers illustrates the use of different calculation methods (heating and cooling loads) for the particular case of an office building located in Namur (Belgium), which is the object of an intensive re-commissioning activity for several years. Very global methods are used as well as detailed computer simulations using TRNSYS Multizone building types 46 and 56. In the latter case, the model is calibrated using reference periods and can serve as a baseline indicator of the energy consumption in the building. The complexity of the building (300 m long, modular architecture, presence of an atrium-like internal street) required some simplifications in the modelling associated to a specific methodology to extrapolate the results got from the simulation of a relatively small part of the building to the whole picture.

The paper will explain the adavantages and disadvantages of each approach, the required information and the limits of the results. The potential use of the different calculation levels for the implementation in a continous commissioning process will be examinated as conclusion of the work.

1 INTRODUCTION

Commissioning is a complex activity that can take place using different approaches. Among others, the distinction between "bottom-up" and "top-down" approaches can be operated. Observing the overall energy consumption of a building and comparing it to a baseline (provided by reference data or a reference calculation) is one of those "top-down" methods which proves to be helpful while relatively easy to implement in the daily practice. While measuring the global energy consumption of a building might appear relatively straitghtforward, obtaining a reference consumption (or loads) figure is more challenging: different tools can be used, ranging from "simplified" to very detailed dynamic simulations and the question is how far to go in the complexity of the calculation in order to reach the required capacity.

This question is adressed in this paper, starting from an example of typical belgian office building: different building loads calculation are applied and the results are compared to a reference calculation which itself is calibrated against measurements in the building. The paper will proceed with a quick presentation of the building. Then the reference model (Multizone Building calculation) will be presented and the simulation results on a reference period will be calibrated against measurements. Finally, the use of simplified calculation methods, in an increasing complexity, will be illustrated and the results will be compared to the reference calculation in order to suggest conclusion of the work.

2 PRESENTATION OF THE BUILDING AND METHODOLOGY OF THE WORK.

The building called "CA-MET" (**C**entre **A**dministratif du **M**inistère de l'**E**quipement et des **T**ransports) was designed between 1993 and 1995 and was built between 1997 and 1999 on the site of the Namur railway station. It hosts the administration of the Ministery of Equipment of the "Région Wallone". The building was planned for a thousand of occupants and consists of 11 modules representing 24000 m² offices.

This building is quite complex, made of a collection of architectural modules (fig. 1) organized along an internal street (or atrium) , 300 m long. fig. 2shows the sketch of the building at the preliminary design stage while fig. 3 shows an internal view of the atrium.

This building was used as support to the belgian participation to several IEA Annexes (IEA/ECBCS 30, IEA ECBCS 34, IEA/ECBCS 40). A more detailed presentation of the charatceristics of the building can be found in the final reports of those projects [1], [2], [3].

The methodology followed in this work includes the following steps:

- development of a modelling strategy for the building
- first verification of the reference model
- calibration of the reference model
- overview of the different approaches and comparison with the reference model

fig. 1 View of the « CA-MET » building

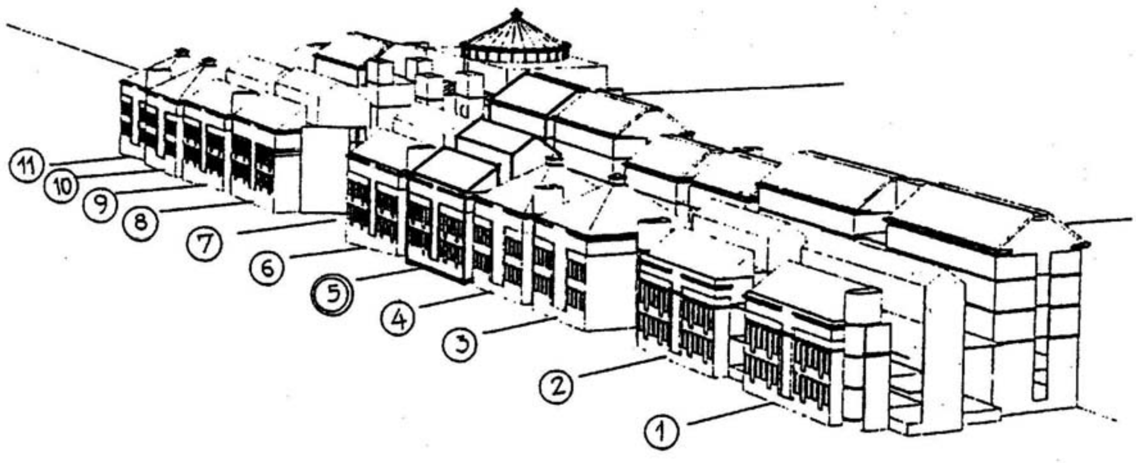

fig. 2 Sketch of the "CA-MET" building showing the different modules

fig. 3 Views of the atrium (03_3161 and 03_3166 © MET D434)

3 DEVELOPMENT AND FIRST VERIFICATION OF A REFERENCE MODEL

3.1 Method

In order to provide the baseline for the comparison of the different modelling approaches, it is necessary to select a reference model and to calibrate it using measurements obtained in the building. A sufficient level of confidence must indeed be obtained before drawing conclusions from the use of a model.

In this case, the modelling will make use of a TRNSYS compatible component (the "unofficial" Type 46) which was developed for the MBDSA software [4] and already used in earlier studies concerning this building (among others within the IEA Annex 30). Later on, Type 46 was modified (and renamed Type 56) before "official" integration in the TRNSYS package [5](starting with version 13.2).

The description of the modeling principle is given in the next paragraph. Based upon that model, the methodology included the following steps:

1. Building modelling
2. Selection of calibration periods including verification of their quality
3. Calibration of the model for the calibration period
4. Extrapolation to yearly values and verification of the results

3.2 Building modelling

The modelling principle was developed in the frame of the IEA 30 project [6].

The CA-MET is a modular building which is approximately 300 meters long. It is composed of 11 different modules named from "A" with "L". The module "M" is not taken into account because it represents a zone not used (technical rooms). To simulate all the building is rather difficult and a very important simplification had to be realizd in order to limit the data.

By gathering modules of smaller size and by reorganizing these modules, the CA-MET can be reconstituted starting from the module "G" (see fig. 4). The CA-MET is considered as the sum of 10 times the "G" module ":

Consequently, the energy demands of the building can be estimaated from the energy demands of the "G" module multiplied by a factor 10.

To model of the entire module "G" would be too tiresome. So, the module "G" will be devided one more time.

Three multi-zone simulation approaches were carried out:

- "Slice": Succession of 7 zones (northern office, northern corridor, office at the north of the atrium, atrium, office at the south of the atrium, southern corridor, southern office) on the same axis going from north to the south of the building.
- "Section": Vertical stacking of slides from the ground floor to the last level (32 zones).
- "Level": Slices at the same level (35 zones).

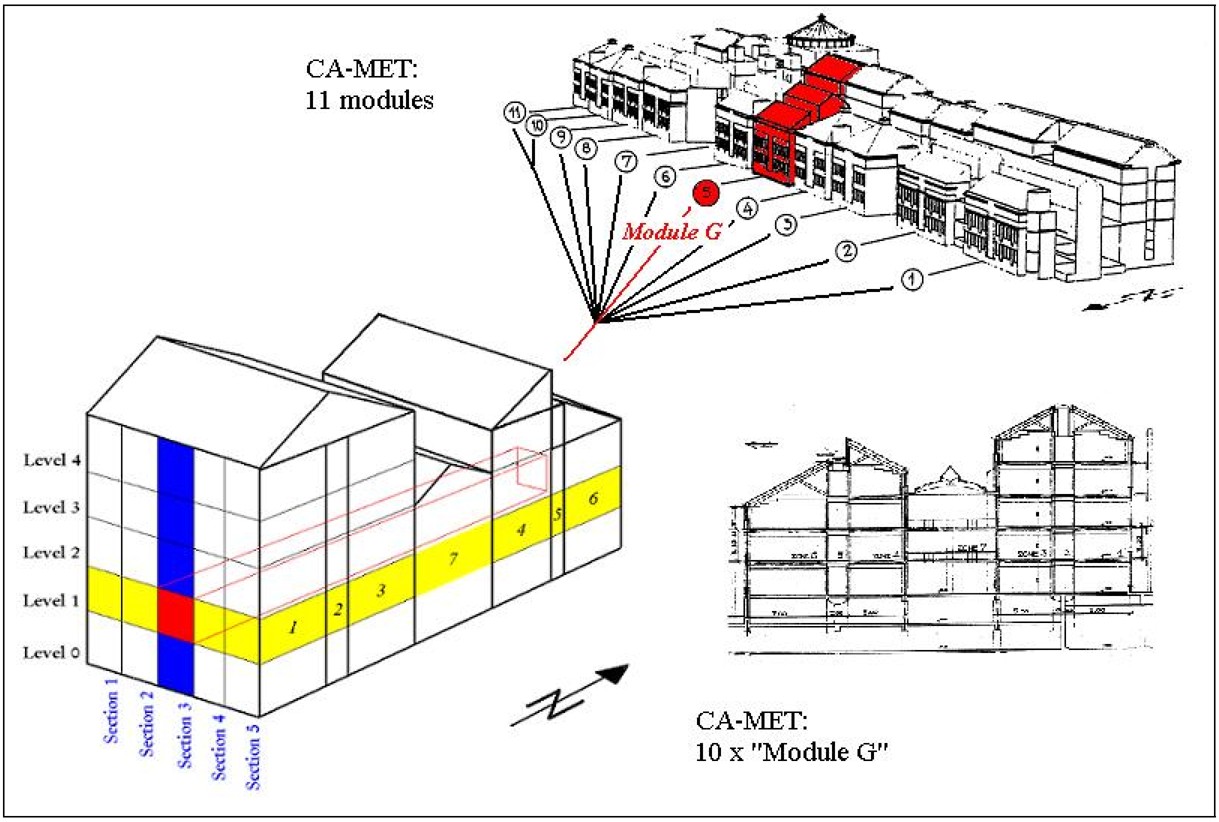

fig. 4 Scheme of the different building zoning strategies

The heating and cooling demands of the whole building are an image of the demands of a representative slice of the representative module (module "G"). A reference slice is located at the intersection of the first level and central section of the module. The heating and cooling demands of this reference slice are calculated using the first multizone model. Then, the second model is applied and allows to calculated the demands of each zone of the section with respect to the reference slice. Finally, the third model is applied and allows to calculate the demands of each zone of the level, again with respect to the reference slice. Combining both approaches end up with a propotionality factor for each "slice" (in the module) with respect to the reference slice.

This set of ratios forms the heating or cooling demand matrices. The sum of the ratios gives us for each demand the proportionality factors between the demands of the reference slice and the total module demands.

$$Coefficient_{heat} = \sum_{niveau,section} ratio_{heat}(niveau, section)$$

$$Coefficient_{cool} = \sum_{niveau,section} ratio_{cool}(niveau, section)$$

The global heating and cooling demands of the building are estimated from:

$$Q_{heat\_tot} = Q_{heat}\, tranche\_de\_référence \times 10 \times Coefficient_{heat}$$

$$Q_{cool\_tot} = Q_{cool}\, tranche\_de\_référence \times 10 \times Coefficient_{cool}$$

table 1 Proportionality factors

Section 3: Simulation of the heating demand

	S1	S2	S3	S4	S5
N4			11564346		
N3			10209763		
N2			17205091		
N1			10877894		
N0			32888121		

Section 3: Simulation of the cooling demand

	S1	S2	S3	S4	S5
N4			-3135813		
N3			-5963573		
N2			-7569119		
N1			-7533332		
N0			-3782979		

Niveau 1: Simulation of the heating demand

	S1	S2	S3	S4	S5
N4					
N3					
N2					
N1	39870420	29346413	28974997	31313885	27226340
N0					

Niveau 1: Simulation of the cooling demand

	S1	S2	S3	S4	S5
N4					
N3					
N2					
N1	-5599294	-7722753	-7775797	-7602082	-4963988
N0					

Heating demand matrix:

	S1	S2	S3	S4	S5
N4	1.463	1.077	1.063	1.149	0.999
N3	1.292	0.951	0.939	1.014	0.882
N2	2.176	1.602	1.582	1.709	1.486
N1	1.376	1.013	1.000	1.081	0.940
N0	4.160	3.062	3.023	3.267	2.841

Cooling demand matrix:

	S1	S2	S3	S4	S5
N4	0.300	0.413	0.416	0.407	0.266
N3	0.570	0.786	0.792	0.774	0.505
N2	0.724	0.998	1.005	0.982	0.641
N1	0.720	0.993	1.000	0.978	0.638
N0	0.362	0.499	0.502	0.491	0.321

Proportionality coefficient:
41.146

Proportionality coefficient:
16.083

3.3 Selection of parameters

During the pre-design and design phases of the building in the ’90s, modelling of the building made use of the following control parameters:

- Occupation period: from 9h to 17h, from Monday to Friday (included)
- Heating period: from 6h to 17h, from Monday to Friday (included)
- Cooling period: from 9h to 17h, from Monday to Friday (included)
- Heating temperature set point:
  - Offices: 21°C (heating period) or 13°C (otherwise)
  - Atrium: 18°C (heating period) or 10°C (otherwise)
- Cooling temperature set point:
  - Offices: 24°C (cooling period) or 40°C (otherwise)
  - Atrium: 24°C (cooling period) or 40°C (otherwise)
- Heating emisison power:
  - Offices: 1500 W/zone
  - Atrium: 4000 W/zone
- Cooling emisison power:
  - Offices: 1850 W/zone
  - Atrium: 1000 W/zone

With such parameters, calculation yields a total heating and cooling demands of 1525MWh and 245MWh with an evolution shown by fig. 5. The maximum heating and cooling powers are 4000kW and 710kW. The proportionality factors are for this case equal to 41.032 for the heating demand and 13.843 for the cooling demand.

In order to simulate the current situation of the building (after construction), the following control parameters were adapted. The objective of the modifications is to adapt the simulated maximum powers of each zone and the set points of the building according to the installed equipements. Thus, we have:

- Occupation period: from 9h to 17h, from Monday to Friday (included)
- Heating period: from 5h to 17h, from Monday to Friday (included)
- Cooling period: from 9h to 17h, from Monday to Friday (included)
- Heating temperature set point:
  - Offices : heating period: from 5h to 6h: 18°C
    from 6h to 7h: 19°C
    from 7h to 8h: 20°C
    from 9h to 17h: 21°C
    or otherwise: 17°C
  - Atrium: 18°C (heating period) or 10°C (otherwise)
- Cooling temperature set point:
  - Offices: 24°C (cooling period) or 40°C (otherwise)
  - Atrium: 24°C (cooling period) or 40°C (otherwise)
- Heating emisison power:
  - Offices: 1500 W/zone
  - Atrium: 4000 W/zone
- Cooling emisison power:
  - Offices: 1850 W/zone
  - Atrium: 1000 W/zone

In this second case, i.e. after construction, the total demands simulated during one standard year are 1472MWh for heating and 439MWh for cooling. The simulated maximum powers are 3670kW for heating and 910kw for cooling. The proportionality factors are slightly differents: 41.146 for heating and 16.083 for cooling. This slight increase is due to the change in the control parameters. A longer and more progressive heating start leads to savings in required power.

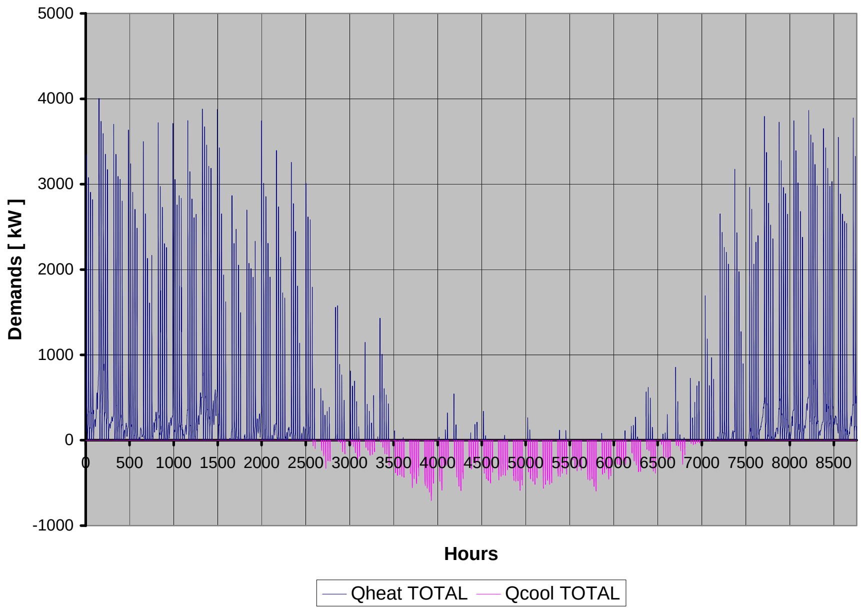

fig. 5 Simulated energy demands of the CA-MET during one standard year (before construction)

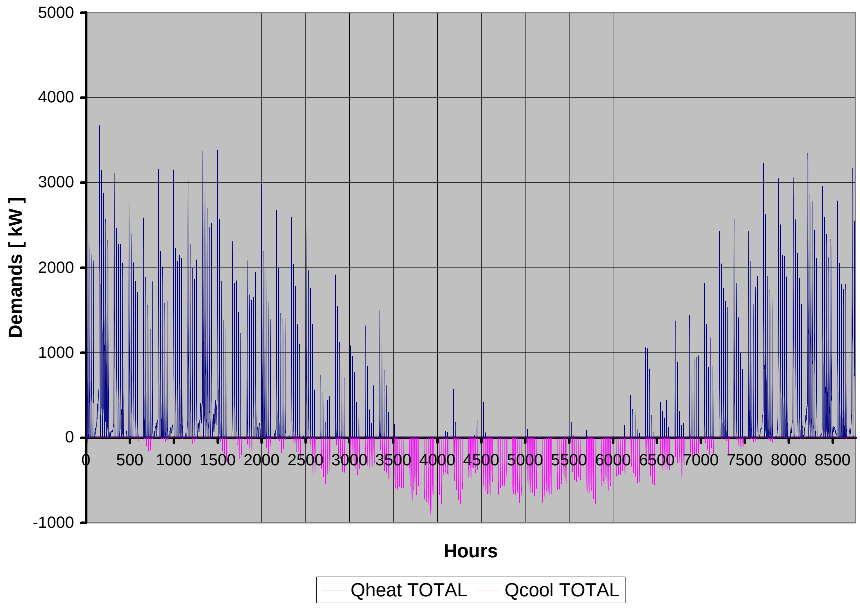

fig. 6 Simulated energy demands of the CA-MET during one standard year (after construction)

4 VERIFICATION AND CALIBRATION OF THE REFERENCE MODEL

4.1 Available measurements

4.1.1 Measured data and reference period

The objective of this analysis is to check if the curves of heating and air-conditioning of this building are rational or not and to calibrate the simulation model accordingly.

The reference period for an energy study in the case of buildings is one year. In this case, the selected reference period is one 12 months period for which energy data are available.

The available data are :

- overall gas consumption, measured instantaneously (time of the consumption of each gas m³) (GAS).
- total electric consumption recorded every 10 minutes.
- the electric consumption of the two refrigerating units (every 10 minutes).
- the occupancy rate of the building
- outside air temperature
- thermal comfort conditions of the buildings
- external climate: temperature and moisture of the air and solar radiation.

The rationality of the measured energy demands will be assessed by calculating the correlation between the heating (resp. the cooling) demand and the ambient temperature. Indeed, the ambient temperature is included in the control laws of the temperature set points of the HVAC plant. This correlation corresponds to the concept of heating and cooling curves.

The choosen reference period is the annual period during which measurements of energy consumption and the ambient temperature are both available, i.e. from the 08/02/2001 to the 07/02/2002.

4.1.2 Analysis of the measurements data

fig. 7 represents the consumptions of gas (boilers) and electricity (refrigerating units). Those consumptions were calculated with a constant boiler efficiency (85%) and a variable COP (variable according to the ambient temperature: see fig. 8). This COP evolution was determined by the application of a simulation model [7].

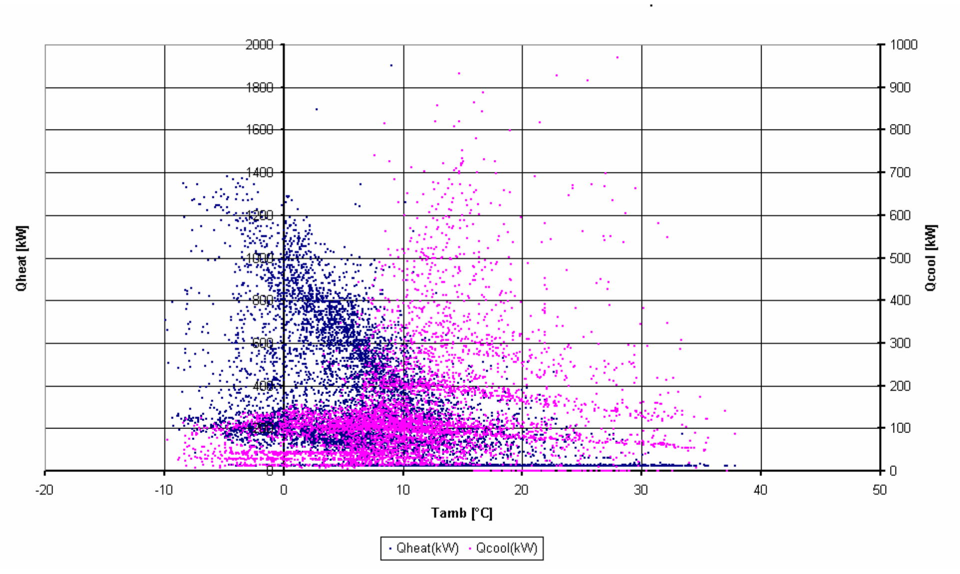

fig. 7 Heating load (Qheat) and cooling load (Qcool) of the CA-MET according to the ambient temperature (Measurements)

After having deleted the points representing consumption occuring the non occupied periods, we obtain fig. 9 which makes it possible to better understand the behaviour of the building.

The gas consumption decreases with the increase in the temperature according to a linear law which approaches very well the temperature control law of the BEMS (full power at -10°C, stop at 18°C). A polynomial law however better approaches this heating curve.

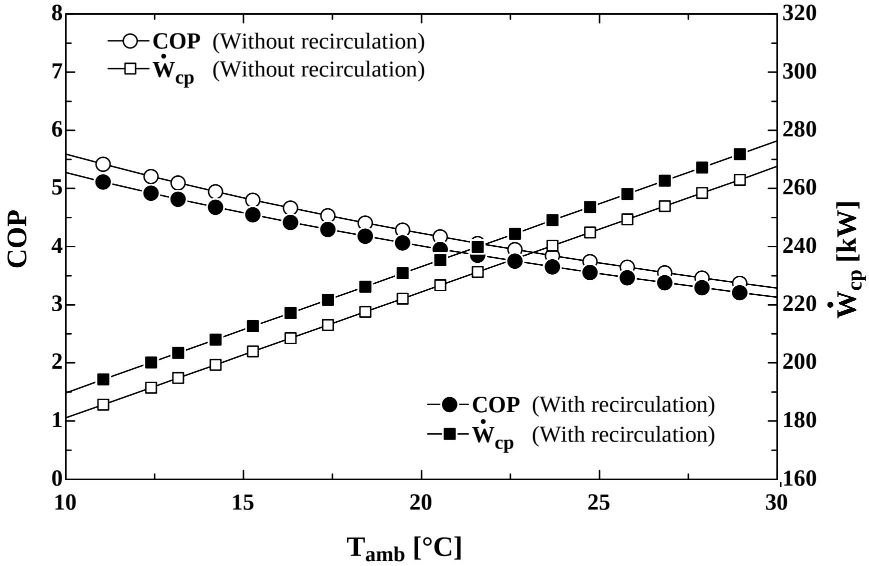

fig. 8 COP evolution according to the ambient temperature (Simulation)

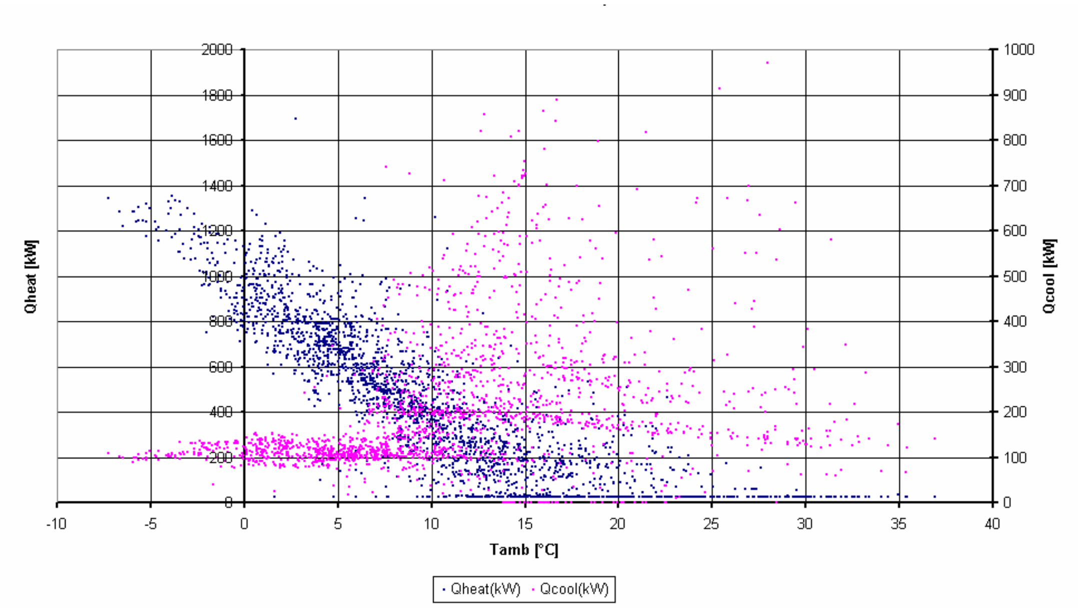

fig. 9 Heating load (Qheat) and cooling load (Qcool) of the CA-MET during occupation periods according to the ambient temperature (Measurements)

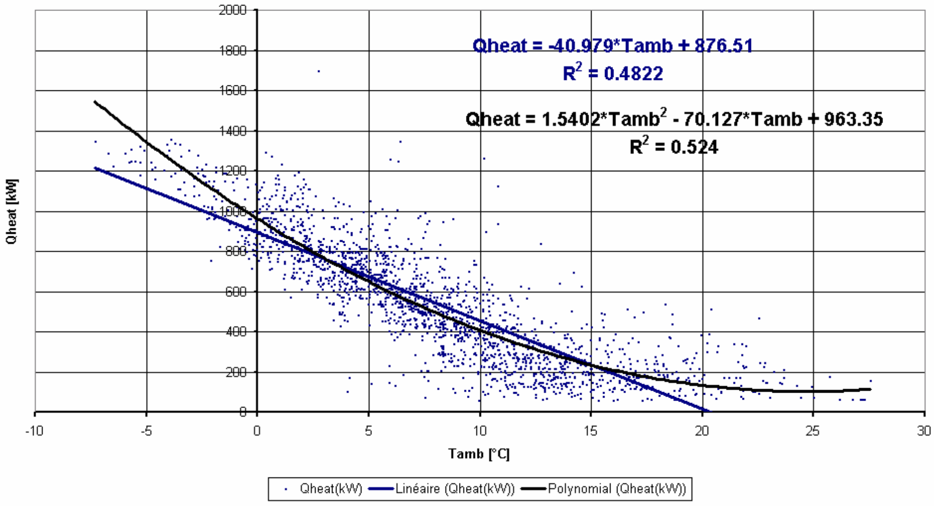

fig. 10 Heating curve of the CA-MET

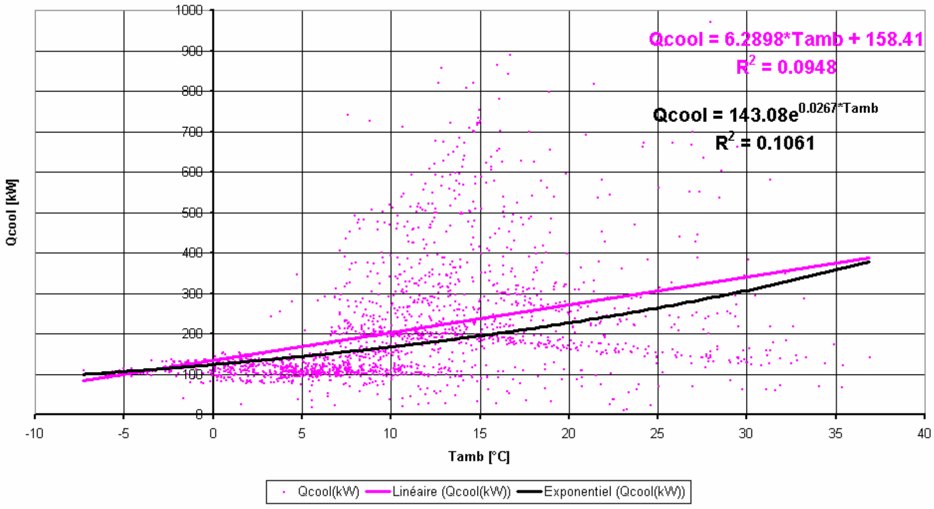

fig. 11 Cooling curve of the CA-MET

As regards the cooling curve (fig. 11), it is not easy to observe something which is organised. From -5°C to 10°C, the curve is horizontal around 125kW. If the ambient temperature rises above 10°C, the distribution of the refrigerating power becomes random. This situation translates/means very well the fact that there are no balance between cooling load and production. This observation appears already in other reports on this building: the management of the cooling demand is not yet rational and the cooling load is not satisfied. Consequently, it is impossible, specially for the cooling demand, to calibrate a model using the yearly measured energy consumption. Instead, shorter periods will be used to verify and calibrate the model.

4.2 Selection of calibration periods

In order to validate the model of the building, the energy consumptions measured during a hot period and a cold period will be compared with the simulated demands from available weather data.

The measured consumptions are:

- Natural gas consumption in m³/h, which can be translated into energy consumption asuming:
    - Energy content of the gas = 37500 kJ/m³
    - Efficiency of combustion = 85%
- The electrical consumption of the refrigerating units in kWh/h (time average consumed power) which can be translated into cooling demand assuming:
    - COP = 3 (as above)

The selected measurement periods are:

- November and December 2002 (cold period)
- June to September 2002 (hot period)

The lack of weather data for this perios obliges us to use the data available in Arlon (measured by a permanent installation). The available weather data are:

- The ambient temperature of the air measured every 10 minutes in Arlon
- The total solar radiation measured on a horizontal plane every 10 minutes in Arlon

4.2.1 Cold period: November and December 2002

fig. 12 shows a representation of the available weather data in Arlon. The ambient temperature varied from -7°C to 14°C. The global solar radiation on a horizontal plane reached a maximum of 371W/m². These are good winter conditions making it possible to evaluate the building in a cold period. However, it is not a very long cold period which characterizes the traditional design of a heating system.

fig. 13 shows the total electrical consumption of the building without the consumption of the two refrigerating units. Two levels can be identified: one when the building is occupied (461kW) and the other when it is not (209kW). During November 11th and 15th (public holidays) as well as Christmas, we observe that the building was partially occupied. We could evaluate the occupancy rate as being proportional to this consumption:

- 0% of occupation if consumption is equal or lower than 200kW
- 100% of occupation if consumption is equal or higher than 450kW

Let us note that yp to now, a 100% occupancy rate was considered during the office hours (9h-17h) except the weekends.

In fig. 14, we find the measurement results and the simulation results concerning the cold period. We notice that the measured heating production of the building does not exceed 1500kW and the simulated heating demand (on Monday morning) exceeds 2000kW every weeks. During these two months, the cumulated heating demand of the simulated building reaches 362MWh and the culumated heating production reaches 633MWh. These figures translate the fact that the management of the building is different from the strategy which is supposed for the simulations.

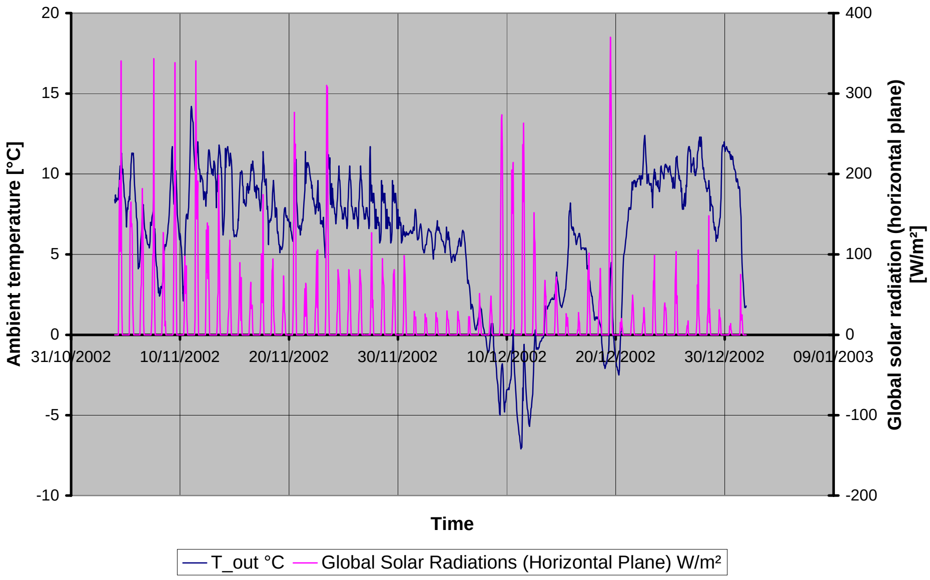

fig. 12 Available weather data in Arlon (November and December 2002)

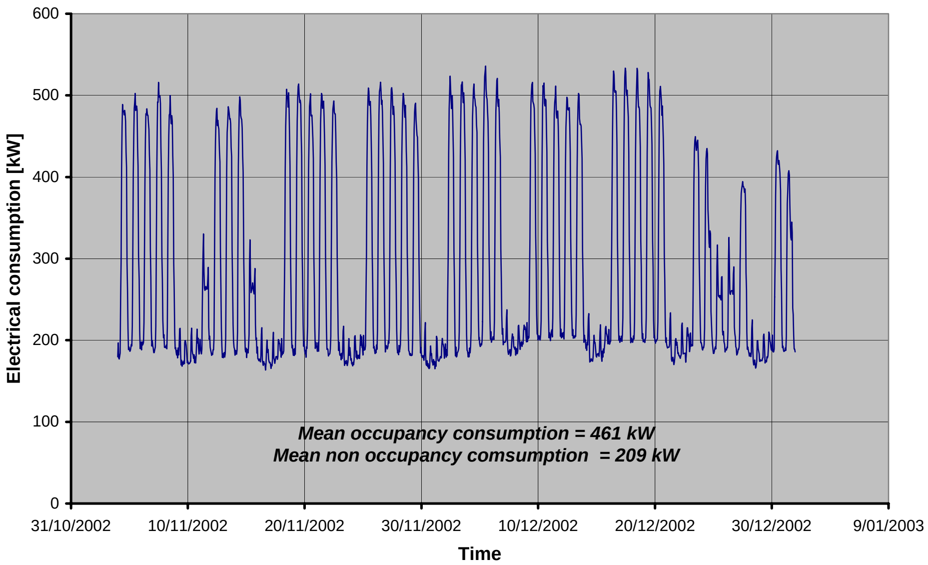

fig. 13 Measurement of the electrical consumption (without the refrigerating units consumption) (November and December 2002)

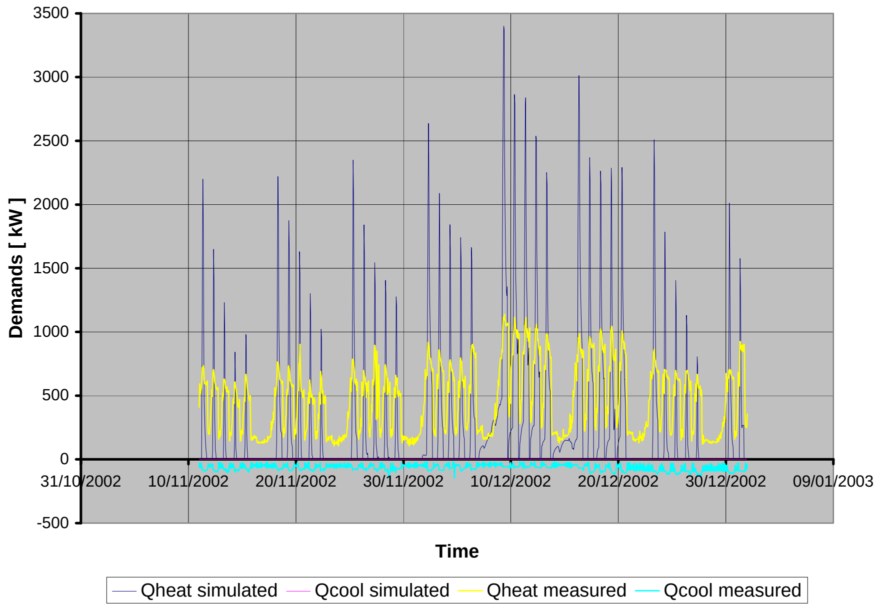

fig. 14 Heating and cooling demands and productions (November and December 2002)

4.2.2 Hot period: June to September 2002

The selected hot period extends from June to September 2002. The weather data are again measured in Arlon and are showed by fig. 15. The temperatures are included between 7.1°C for the coldest night and 34.8°C for the hottest day. The maximum value of the solar radiation was reached on June 28 with 1017W/m². It is not a dry heatwave nor a wet heatwave but a succession of weeks presenting similar conditions. Two very hot weeks are emerging:

- From Saturday 27th to Tuesday July 30th
- From Wednesday 14th to Monday August 19th

The total electrical consumption of the building without the consumption of the two refrigerating units is included between two quite distinct levels (see fig. 16). These levels are 199kW and 443kW (mean values). When this consumption is close to 443kW, the occupancy rate of the building is considered as close to 100% while a 0% is assumed when the consumption is below the threshold of 199kW.

The results of measurement campaign and the results of simulation concerning the hot period are presented in fig. 17. We notice that the maximum simulated cooling demand is approximately twice larger than the measured cooling production. During the period, the maximum cooling powers (simulated and measured) reached 1090kW and 707kW. Although the levels of the simulated and measured cooling demands are radically different, the cumulated cooling energies are close. The building required 247MWh of cooling energy for its air-conditioning and simulation evaluated this quantity to 296MWh.

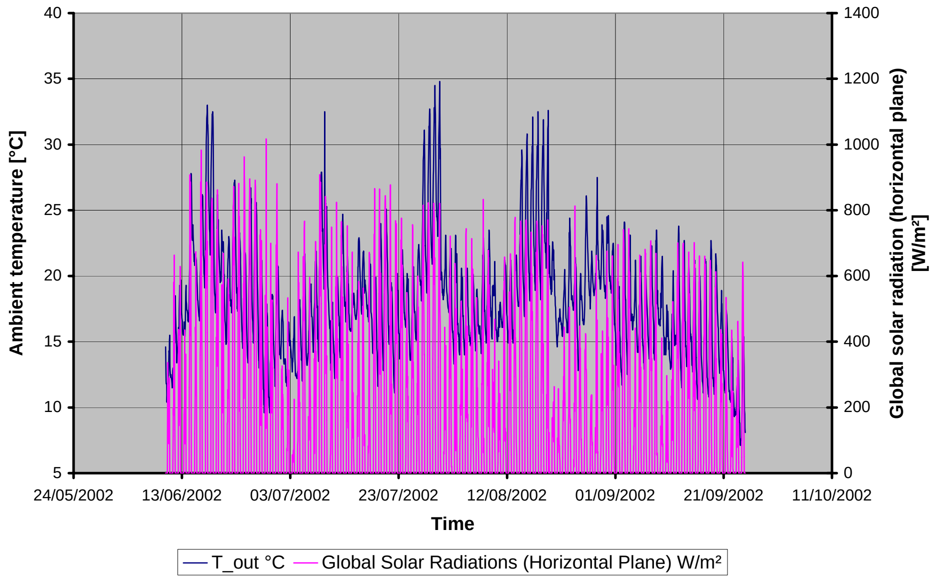

fig. 15 Available weather data in Arlon (from June to September 2002)

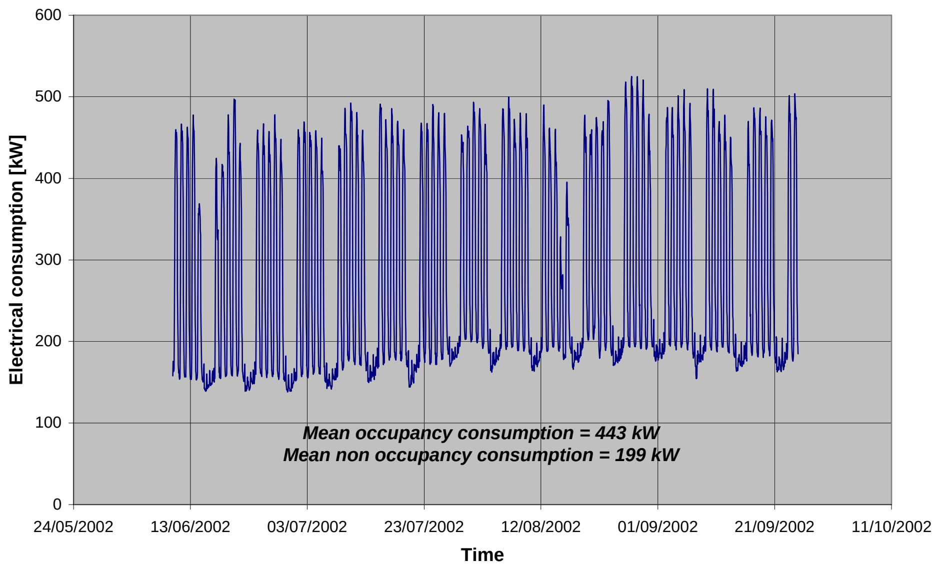

fig. 16 Measurement of the electrical consumption (without the refrigerating units consumption) (from June to September 2002)

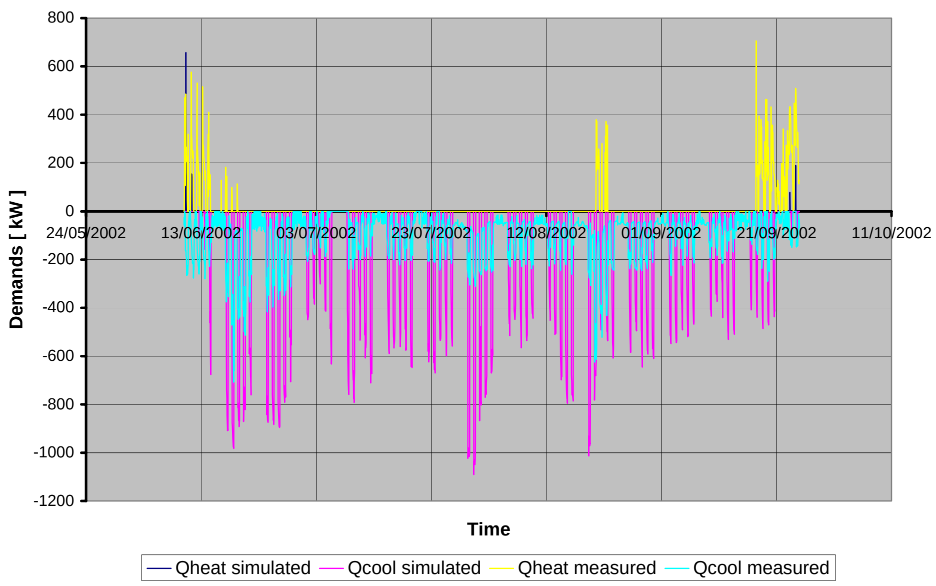

fig. 17 Heating and cooling demands and productions (from June to September 2002)

table 2 summarizes the comparison between measured and simulated results(using the non calibrated model) for both periods:

table 2 Comparison between measured and simulated energies and powers, non calibrated model

Period	Energy (kWh)		Power (kW)	
	Measured	Simulated	Measured	Simulated
Winter	633	362	1138 kW	> 2000 kW
Summer	247	296	707	1090

These results show the calibration of the model is not good enough at this stage. This will be confirmed by a more advanced analysis, using the correlation between the demands and the ambient temperature (heating and cooling curves) and also using the correlation between measured and simulated demands.

4.2.3 Evaluation of the demands correlations

In fig. 18 and fig. 19, the correlations between the simulated demands and the measured production are represented for the periods of occupation of the building: from 9h to 17h, all the days exept weekends.

We observe that the relation between the simulated heating demand and the measured heating production is almost linear but that the proportionality factor is not one. The measured production remains limited between 500kW and 1250kW whereas the simulated demand sweeps all the interval authorized by the nominal power of the boilers (3MW). When we examine more in detail the daily profile, we can say that the measured demand remains present throughout the 24h whereas the simulated demand evolves in “teeth of saw” at the frequency of the morning revivals. It is this difference in control which explains this particular correlation.

Between the cooling demand and production, there is no correlation. The points of the graph are scattered. The zone extends from 0kW to 900kW as regards the measured production and from 0kW to 1100kW as regards the simulated demand.

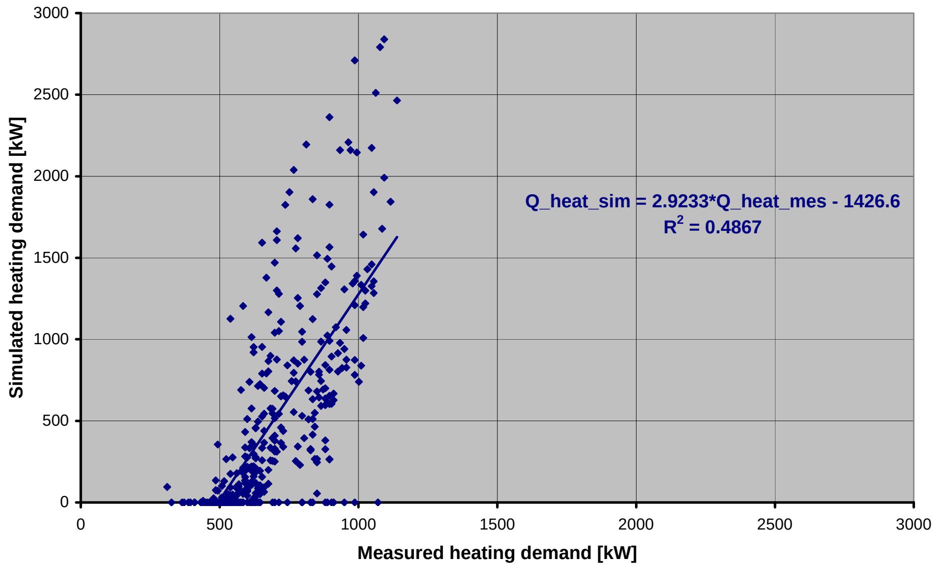

fig. 18 Correlation between heating simulated demand and measured production (from 9h to 17h without weekends)

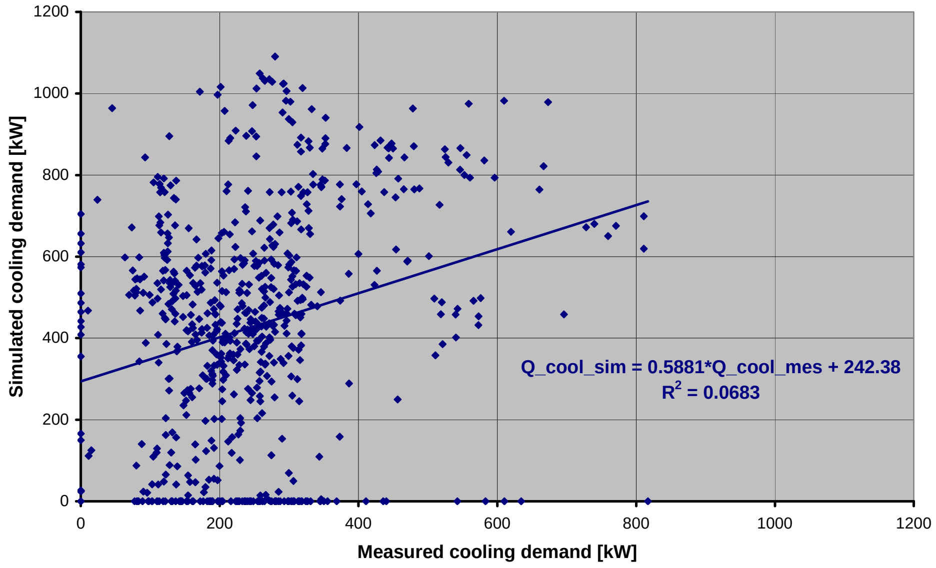

fig. 19 Correlation between cooling simulated demand and measured production (from 9h to 17h without weekends)

4.2.4 Heating and cooling curves analysis

fig. 20 and fig. 21 represent the heating and cooling demands during the occupation period according to the ambient temperature.

We focus first of all on the heating demands. The measured production is proportional to the ambient temperature. The relation obtained is almost perfect. The simulated demand deviates a little more from the linear relation of the measured production curve. These points are due to the regulation of the building which needs more energy on the morning. The regulation installed in the BEMS allows the operation of the boilers during the non occupation period. This mode of management decreases the maximum powers called on the morning but generally increases total consumption (633MWh are measured instead of 362MWh which are simulated for this winter period of November and December 2002).

Next, we observe the evolution of the cooling demand which is completely different. The measured demand decreases very slightly with an increase in the ambient temperature. Moreover, for many points, the measured electrical consumption is null. Those strange results are explained by a very poor control of the cooling demand. The simulated demand is much more realistic. It is null for an ambient temperature lower than 10°C and is reached a maximum of 1090kW towards 28°C. We observe values higher than 1MW beyond 30°C.

All these results show the simulation model appears not enough calibrated at this stage.

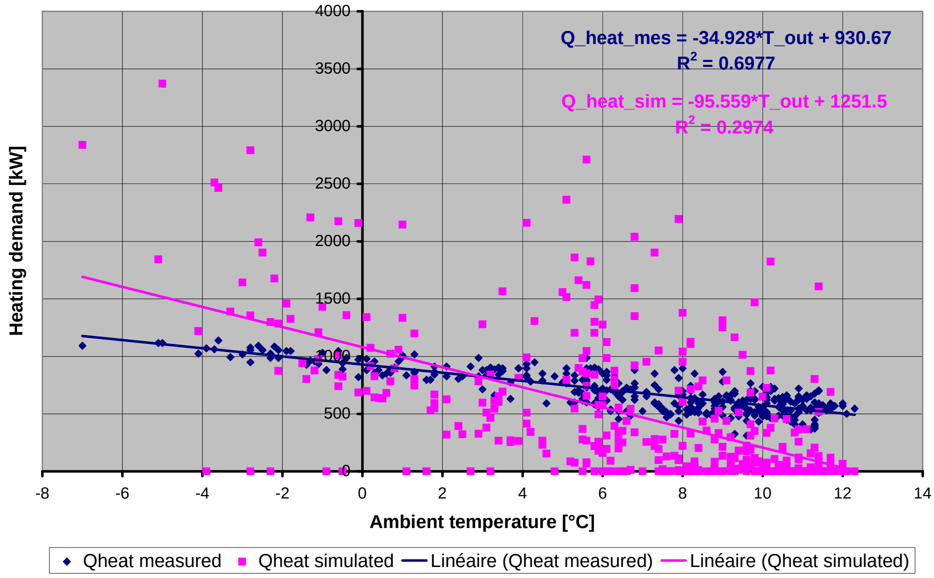

fig. 20 Heating curves (from 9h to 17h without weekends)

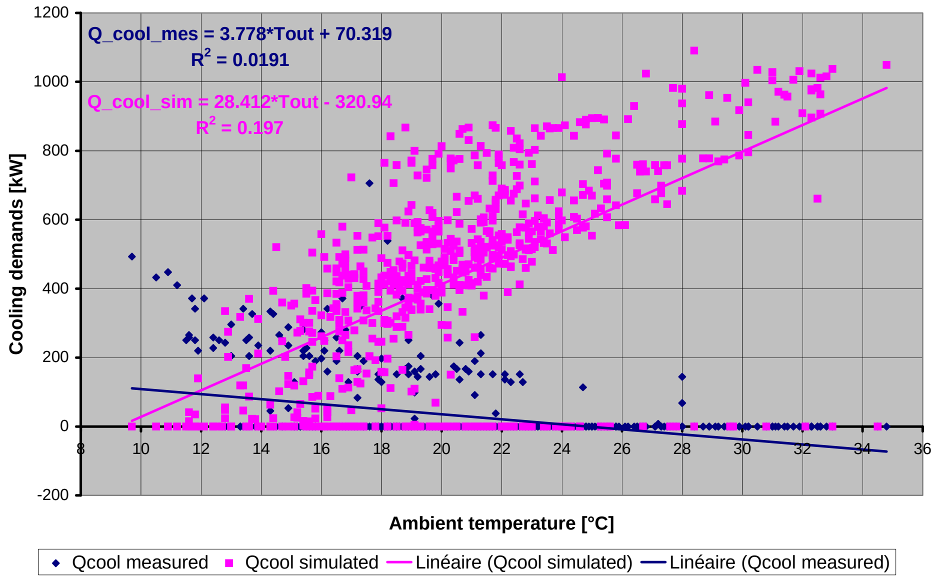

fig. 21 Cooling curves (from 9h to 17h without weekends)

5 CALIBRATION OF THE REFERENCE MODEL

During the analysis of the measured heating production, we realize that control does not correspond to that we was considered for the simulation. Moreover, the number of people present in the building is unknown. We can all the same evaluate the occupancy rate on the basis of total electrical consumption of the building without the consumption of the refrigerating units. Previously, we supposed 2 people per office. Now, it would be more logical to suppose 1 person per 1 to 3 offices. Indeed, the building is never completely occupied. Moreover, some zones are physically gathered and occupied by only one person at the same time. So, we reduce the theoretical demands for fresh air and correct the heating and cooling demands.

New occupancy parameters are selected on the basis of those considerations:

- Occupation rate (100% = 2 persons per office):

from 8h to 9h :	10%
from 9h to 10h :	20%
from 10h to 16h :	40%
from 16h to 17h :	20%
otherwise :	0%

- Heating period: from 2h to 24h, from Monday to Frinday (included)
- Cooling period : from 9h to 17h, from Monday to Frinday (included)
- Heating set point temperature profile:

	Offices	Atrium
from 0h to 2h :	17°C	15°C
from 2h to 3h :	17.6°	15.4°C
from 3h to 4h :	18.2°C	15.8°C
from 4h to 5h :	18.8°C	16.2°C
from 5h to 6h :	19.4°C	16.6°C
from 6h to 20h :	20°C	17°C
from 20h to 21h :	19.4°C	16.6°C
from 21h to 22h :	18.8°C	16.2°C
from 22h to 23h :	18.2°C	15.8°C
from 23h to 24h :	17.6°	15.4°C

- Cooling set point temperature:
  - Offices: 24°C (cooling period) or 40°C (otherwise)
  - Atrium: 24°C (cooling period) or 40°C (otherwise)
- Heating emisison power:
  - Offices: 500 W/zone
  - Atrium: 1000 W/zone
- Cooling emisison power:
  - Bureaux : 850 W/zone

- o Atrium : 850 W/zone

We recompute then the proportionality factors from simulations of the first level and the third section of the module selected (“G”) for the cold and hot standard periods (see table 3).

table 3 Formation of the matrices and the "adapted" proportionality factors

Heating demand matrix:

	S1	S2	S3	S4	S5
N4	1.113	0.943	**0.938**	0.980	0.910
N3	0.967	0.819	**0.815**	0.851	0.791
N2	1.814	1.537	**1.529**	1.597	1.483
N1	**1.186**	**1.005**	**1.000**	**1.045**	**0.970**
N0	3.306	2.801	**2.787**	2.911	2.703

Proportionality coefficient:
36.801

Cooling demand matrix:

	S1	S2	S3	S4	S5
N4	0.297	0.397	**0.405**	0.392	0.281
N3	0.746	0.997	**1.016**	0.984	0.705
N2	0.802	1.071	**1.092**	1.057	0.758
N1	**0.735**	**0.981**	**1.000**	**0.968**	**0.694**
N0	0.169	0.226	**0.230**	0.223	0.160

Proportionality coefficient:
16.384

Although focussing on the heating demand, the proportionality factors were re-computed for the cooling demand as well and very similar values as before were obtained, which shows that the change in the heating control strategy has no effect on the cooling demand.

The graphical results of the building simulation during the cold reference period are given in fig. 22. The measured and simulated heating demands are similar. The maximum powers are observed at the same moment: December 9th at 10h. The measured demand is 1138kW and the simulated demand is 1214kW. During those two months, the building consumed 633MWh. Simulation gives us a very close value: 599MWh. The cooling demands are not significant during this period. fig. 23 represents a zoom over one week (25/11/2002 to 02/12/2002).

The correlation between the simulated and measured hourly heating demands is now better with a slope of 1.4 (see fig. 24).

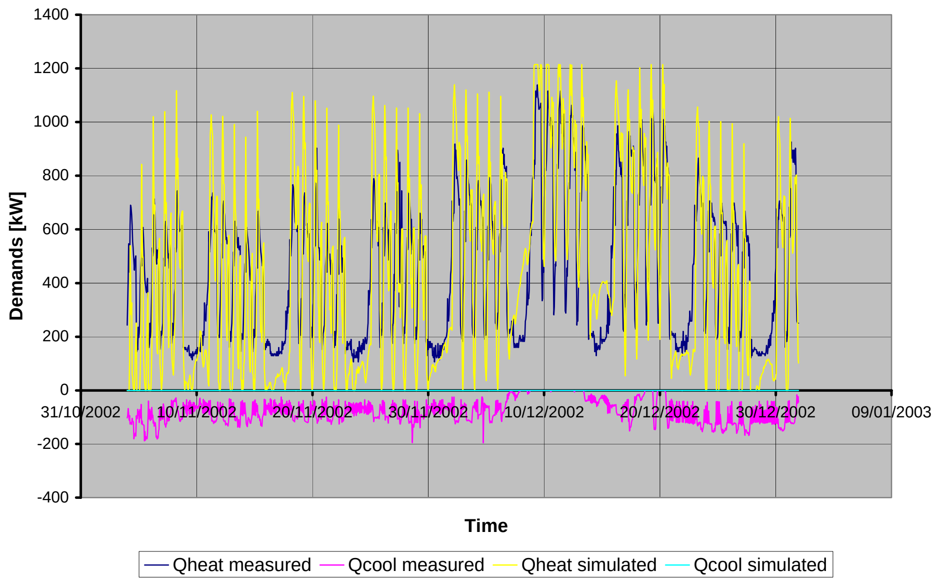

fig. 22 Heating and cooling (“adapted”) demands and productions (November and December 2002)

table 4 summarizes a comparison between measured and simulated heating energy consumption and power, using the calibrated model:

table 4 Comparison for the winter period using the calibrated model

Period	Energy (kWh)		Power (kW)	
	Measured	Simulated	Measured	Simulated
Winter	633	599	1138 kW	1214 kW

This table shows a substantial improvement of the results.

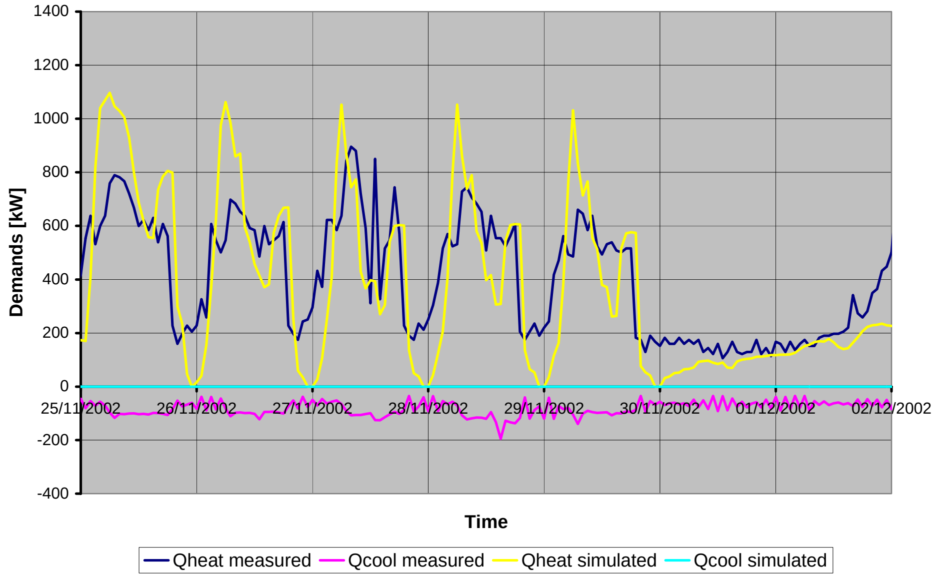

fig. 23 Heating and cooling ("adapted") demands and productions (November and December 2002): from 25/11/2002 to 02/12/2002

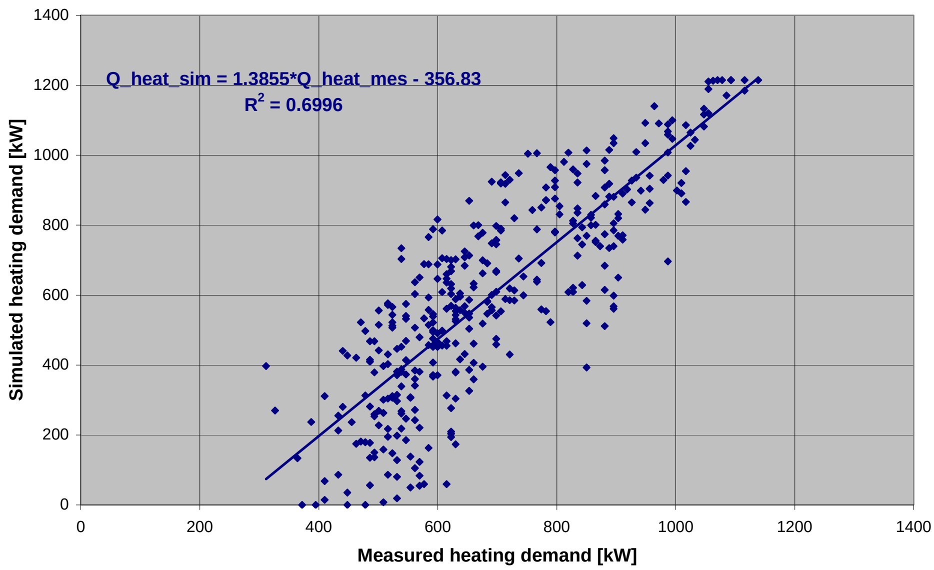

fig. 24 Correlation between heating "adapted" demand and production (from 9h to 17h witout weekends)

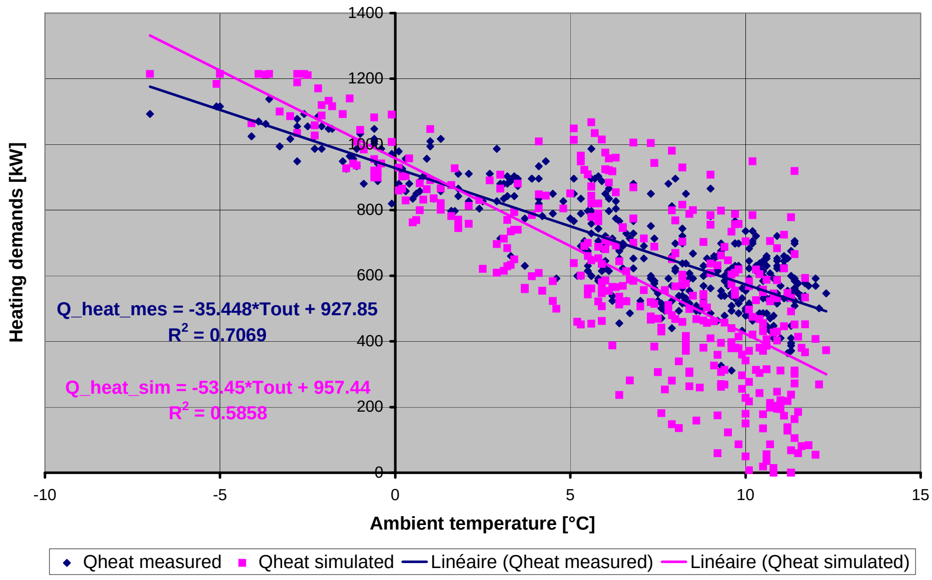

fig. 25 "Adapted" heating curves (from 9h to 17h witout weekends)

As mentioned above, changes to the control strategy did not influence a lot the cooling demand and compative results shown by table 2 are still valid (and still meaning less because of the lack of rationality of the measured demand).

5.1 Extrapolation to yearly energy demands

Using the calibrated model, the yearly heating and cooling demands can be extrapolated, assuming the occupancy assumptions used above are still valid.

This extrapolation yields the following results:

- Heating demand: 2402 MWh (measured value: 2438 MWh)
- Cooling demand: 208 MWh (this value is nevertheless questionable)

6 SIMPLIFIED CALCULATION OF HEATING AND COOLING DEMANDS

6.1 Overview of possible approaches

Different tools can be used in order to calculated building loads. The most basic approaches use the “degree-day” concept which consists in a static calculation characterized by:

- a one zone building model
- the agregation of the climate data in a daily value
- the appraisal of the internal gains through a reduction of the required comfort temperature

Basic degree-days methods don’t take solar gains into account. An improvement of the method consists in considering solar gains through an artificial increase of the ambient temperature, resulting in the so-called the “equivalent” degree-days method.

Another improvement consists in changing the time scale, going down for instance to hourly values of the climate data: this leads to the “degree-hour” concept which is available as a standard feature in the TRNSYS software for instance. In the latter, the degree-hour concept is furthermore associated to an explicit consideration of the internal gains.

The next step is to represent separately the different heat flows occuring in the building. This can be done with different levels of complexity in terms of:

- number of zones
- static or dynamic characteristics

This leads to the following possibilities:

- one zone static calculation
- multizone static calculation
- one zone dynamic simumation
- multizone dynamic simulation

The results of the application of the degree-day method is illustrated in the following paragraphs.

6.2 Degree-day methods and degree-hour methods

Application of the degree-day method yields the following heating demand: 232 MJ/m².an (2677 MWh) which appears as close to the value calculated by a reference dynamic simulation (2402 MWh). But, the degree-day model presents some differences:

- the fresh air rate is fixed to 0.75 vol/h,
- the temperature set point is 19°C,
- the internal gains are equal to 5.42 W/m² (electrical consumption and people activities),
- the heating system is running all the time.

The heating demand of the building should be different if the real parameters are integrated in the degree-day method. Those are the new parameters:

- the fresh air rate is calculated from the fresh air flow rate (55000 m³/h for the whole building): 0.42 vol/h,
- the temperature set point is 21°C,
- the internal gains are equal to the sum of the global electrical consumption and the people activities (proportional to occupation rate (30%)): 6.75 W/m²,
- the heating system is running all the time.

With those assumptions, the degree-day method gives the following result: 175 MJ/m².an (2008 MWh).

With a dynamic simulation of a multi-zone model, sometimes some zones require heating and others require cooling. With a degree-day method, the resulting demand is a balance between the heating and cooling demands of each zones.

7 CONCLUSIONS

The use of a simulation model as a tool for "high-level" (in a top-down approach) commissiong of the enery demand of a building requires the use of a reliable simulation model. For that purpose, different approaches can be carried out, ranging from very detailed multizone building simualtions to simplified approaches based upon the degree-day concept. As a first step, the verification and calibration of a reference model is a mandatory step in order to get reliable results and to provide a baseline for the application of more simplified (and less time-consuming) approaches. The verification and calibration of the reference model was presented in this paper together with the use of the degree-days method while the application of other intermediate methods will be tackled in the future perspectives of the work.

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