CONSOCLIM A SOFTWARE PACKAGE TO CALCULATE ENERGY CONSUMPTION OF AIR CONDITIONED BUILDINGS, FIRST COMPARISONS WITH IN SITU MEASUREMENTS

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ABSTRACT

A simplified tool, called ConsoClim, has been developed for estimating energy consumption of air conditioned buildings and for comparing HVAC and building solutions. Its main aim is to be used at the early stage of the design process. It means that algorithms have been developed to be used with minimum and quite simple inputs that are available in manufacturers' catalogues or can be fixed at typical default values. The aim is to check that building design options and HVAC system choices lead together to an efficient global energy performance.

A prototype of the software package using ConsoClim algorithm library has been achieved. First comparisons of the results with in situ measurement are reported in this paper. As a first step, the comparison deals only with heating and cooling building demand. Thus, an existing building connected to an urban hot and chilled water distribution network is used. Its energy demand is read at the heat exchanger and full year monthly data file is available.

The building is described. But there is no measurement of the internal gains. Electrical appliances are estimated by monthly electricity consumption. Moreover, little specific information is available about occupancy. Then, its scenarios are based on typical office building hours. The uncertainty about some input values is therefore very large. Uncertainties about each input are estimated. Heating and cooling demands are thus estimated by ConsoClim simulations and compared, on a monthly basis, to the measured delivered energy. Results give conclusive elements about validation and show how energy calculation is sensitive to the choice of conventional input data.

KEYWORDS

Air conditioned building, energy requirements, validation, in situ measurements, simulation tool.

INTRODUCTION

In order to estimate energy consumption of an air conditioned building large information is needed, such as building and its system characteristics, the hourly profile of occupancy with occupant's behaviour. All, these data are the inputs of interconnected modules and reliability on energy consumptions and level of comfort is conditioned by the level of confidence of such data.

A simulation tool, called Consoclim [1], is developed for estimating energy consumption in air conditioned buildings with a minimal set of available data. The aim of this paper is to present a first case of comparison realized with a prototype of the software package.

CONSOCLIM DESCRIPTION [1]

Consoclim runs with hourly meteorological files, which can be real or conventional, and internal load profiles. Some variables, unusual in building simulation tool, can also be considered, such as, building permeability, interactions between natural and artificial lighting, surface temperatures to evaluate inside conditions and inside wetness calculated by modeling physical phenomenon.

Firstly the building is split in different zones, called UTH, according to the type of activity and occupancy profile, the air handling systems and thermal behavior. For this last point, to gather rooms into a same zone, they must have similar thermal characteristics. Then, calculations are done considering building/systems interaction at each simulation step, following the chronology below:

- Meteorological data and internal loads are introduced
- Thermal behavior of each UTH is determined
- Air is treated according to selected systems
- Actual running point between building and system is calculated
- For each production system, balance on distributed fluids is done
- Consumptions are added

In the following work, only building energy demands relative to heating and cooling are studied. Thus, actual running point is determined by request energy in order to respect set point temperature.

COMPARISON OF AN OFFICE BUILDING HEATING AND COOLING DEMANDS

Thanks to an enquiry [2], characteristics of the building, such as, building specifications, occupant average behaviours, air change rate and inside comfort conditions, are described. Furthermore, this building is connected to an urban hot and chilled water distribution network with heat exchangers. Monthly energy bills were collected. Thus, 1991 monthly hot and cold required energy is available.

But a few high energetic influence inputs are unsure. So target values are straddled by one or two variants in order to lead to a high probability event interval. Then office blocks, with each interval border, are modelled. Results lead to a scale of estimated energy needs. In the same way monthly collected demands are bracketed in order to be compared with calculated ones.

The Building and its Inputs

This building was open in 1973. Two overlapping blocks of 28 and 32 levels compose it (Figure 1). The maximal high is 92 meters. Its area is 74 400 m^2 and its volume 19 500 m^3.

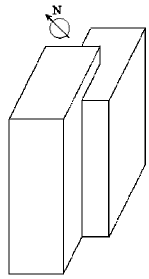

Figure 1 : office building design and orientation

Walls heat transfer coefficient, called U_{mur}, is 1.1 $W/m^2/K$ calculated. Because of unknown parameter, such as insulator performance, this value is +/- 20 % estimated. Windows are made of simple glass with aluminium joinery. Their heat transfers coefficient, called U_{baie}, is 5.6 +/- 0.4 $W/m^2/K$ evaluated. The roof is considered adiabatic because of the last level occupied by non air conditioned technical rooms.

Wall solar factors are calculated with the method presented in Th-S rule [3] with an absorption coefficient estimated at 0.4. The solar factor of glazed surface is estimated at 0.6. However, on southern sides, the presence of inside blinds decreases it appreciably at 0.5. In order to have a larger estimation of consumptions, 0.5 and 0.6 values, whatever the orientation, are tested.

According to Th-I rules [3], none or one heavy surface lead to light or medium thermal inertia, which are both tested. The lack of permeability measures leads to a high uncertainty. Thus, the value proposed in Decret °2000-1153 [3], 1.2 $m^3/h/m^2$, under 4 Pa, per outside surfaces excepted low floor, is used with a 0.5 $m3/h/m^2$ tolerance.

Influence of Occupants

The building is considered only as office. Building and offices open hours are, respectively, from 6 am to 8 pm and from 8 am to 7h30 pm, from Monday till Friday all year long. During occupation, people number is 3000. This figure is an average over the year, which includes vacations and days off.

According to the administrator, indoor temperatures are ordered at 22 and 24 °C respectively for heating and cooling. A more thrifty estimation is also tested, with a heating temperature set point of 18 ° C during building inoccupation periods.

Monthly electricity bills, give an idea of internal gains contribution of electrical appliances. But, the whole electrical consumption is not to be taken as internal gains. Usual sensible points, such as fans, lifts or pumps, and the computing hall autonomously cooled are listed. Anyway, the absence of detailed invoices makes difficult to appreciate internal gains precisely. Thus, the energy amount used as input is only 80% +/- 5 % of electric consumptions.

In inoccupation, internal contributions are five times lower than during activity. This estimation although weak, is justified, by important part of lighting (40% [4]) and office equipment in global electric consumptions.

According to the investigation, ventilation operates only during building opening period. However, a free cooling system works night and day in mid-season if outside temperature is lower than inside set point. In order to cool spaces, it multiplies by 2.5 the nominal air flow. Now, this way of running is not modelled. Thus, air flow importance during free cooling led to work with 94 m^3/s and 102.2 m^3/s, which represent nominal flow, respectively, 20% then 30% up.

TABLE 1 summarises selection of significant input data with their tolerated margins.

TABLE 1 : sensitive input data and their variation

simulation name	input data					
	description	unit	initial value		variation	
base						
	solar factor		UTH orientation		UTH orientation	
			south	north	south	north
Fs plus			0.5	0.6	0.6	0.6
Fs moins					0.5	0.5
lock_hot_T_18	set point temperature	°C	open hours	lock hours	open hours	lock hours
			hot 22	hot 22	hot 22	hot 18
			cold 24	cold 24	cold 24	cold 24
light inertia	inertia		medium inertia		light inertia	
permea max	permeability	m^3/h/m?	1.2		0.5	
permea min					-0.5	
Api max	electric internal contributions	W/m?	42		2.6	
Api min					-2.6	
QVA max	change air	m3/h/m?	4.55		0.4	
U baie max	U windows	W/m?/K	5.6		0.4	
U baie min					-0.4	
Umur max	U walls	W/m?/K	1.1		0.2	
U mur min					-0.2	

Building modelling and simulations results

According to Consoclim method, the building can be split into units thermally homogeneous. Previous information, about homogeneity of hygro-thermal behaviour, customs and air conditioning systems, leads to divide it according to orientation. Thus, in order to make sure of the air flow way, four areas, north-east, south–west, south-east and north-west, for intake fresh air and a symbolic one for exhaust air, are created. Fresh air is separated from air conditioning. Then a central station air handling unit blows it, without any preliminary treatment, nor losses in the network, in entrance areas via a double hygienic stream.

About HVAC systems, heat and cold requirements are available upstream building. So energy losses by inside network are included in consumptions and do not need to be evaluated. Furthermore, electric consumption of auxiliary heat and cold systems are included in invoice values. So only energy transmitter kind could have an influence, which is rather poor because of all air conditioning system. Thus the modelled system is composed of four pipe units connected to unlimited power boiler and chillers in order to provide necessary energy.

In order to decrease errors due to weather conditions, simulations are done with direct and diffuse radiations and outside temperatures of 1991 year in Trappes (F 78). A few lacking data, especially in January and December, were replaced by values of a typical year.
Then, each input variation tested leads to energy consumptions, scattered around calculated ones with target inputs (Figure 2). Thus influence of tested parameter can be measured. Influence of lock set point is major. In spite of narrow variations of internal contributions, their impacts on energy needs are consequent.

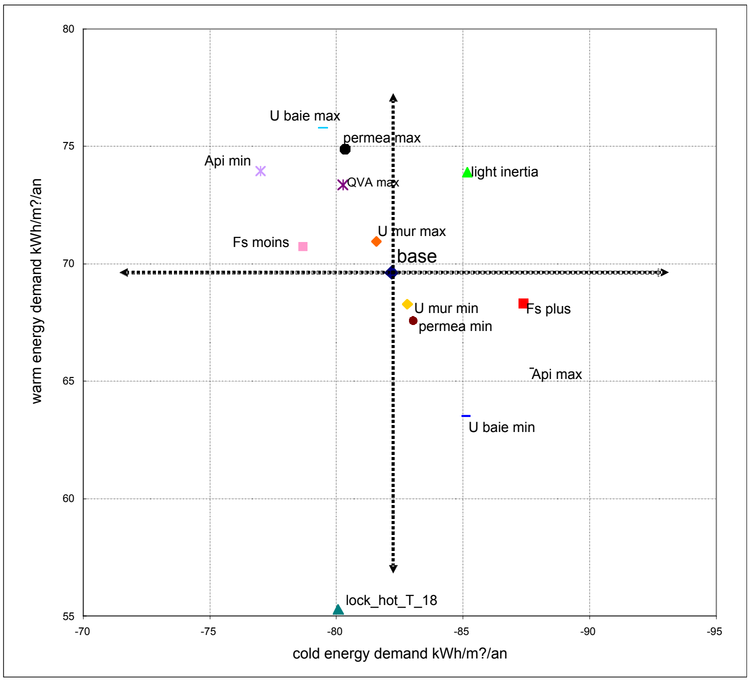

Figure 2 : heat and cold demands calculated for each input

Inputs, which lead to warmth and cold extreme needs, are then put together (TABLE 2). Consoclim simulations give interval borders of calculated energy needs, which will be compared to bracketed measures.

TABLE 2 : input date used for calculated extreme needs

input description	unit	input value			
		max-warm	min-warm	max-cold	min-cold
solar factor		0.5	0.6	0.6	0.5
locked hours hot set point temperature	°C	22	18	22	18
inertia		light	medium	light	medium
permeability	m^3/h/m?	1.7	0.7	0.7	1.7
electric internal contributions	W/m?	39.4	44.6	44.6	39.4
change air	m^3/h/m?	4.95	4.55	4.55	4.95
U windows	W/m?/K	6	5.2	5.2	6
U walls	W/m?/K	1.3	0.9	0.9	1.3

Measures Uncertainties and comparison

Influence of computer room consumptions is not considered, because its uncertainty was included before while reducing electric contributions. Thus, measured cold needs in February, the coldest month, do not seem justified. Then, this cold reserve is removed to monthly and average values. Moreover, a 10 % margin is used for monthly value because of statements dates' ignorance. Measure errors of warmth and cold request are 5 % estimated. TABLE **3** recapitulates coefficients used in order to determine the high and low borders of measure intervals.

TABLE 3 : coefficients to determine limits of measured values

	Hot		Cold	
	minimum	Maximum	Minimum	Maximum
Monthly values	Value x 0.85	Value x 1.15	(value-reserve)x 0.9	Value x 1.1
Average values	Value x 0.95	Value x 1.05	Value-reserve	Value x 1.05

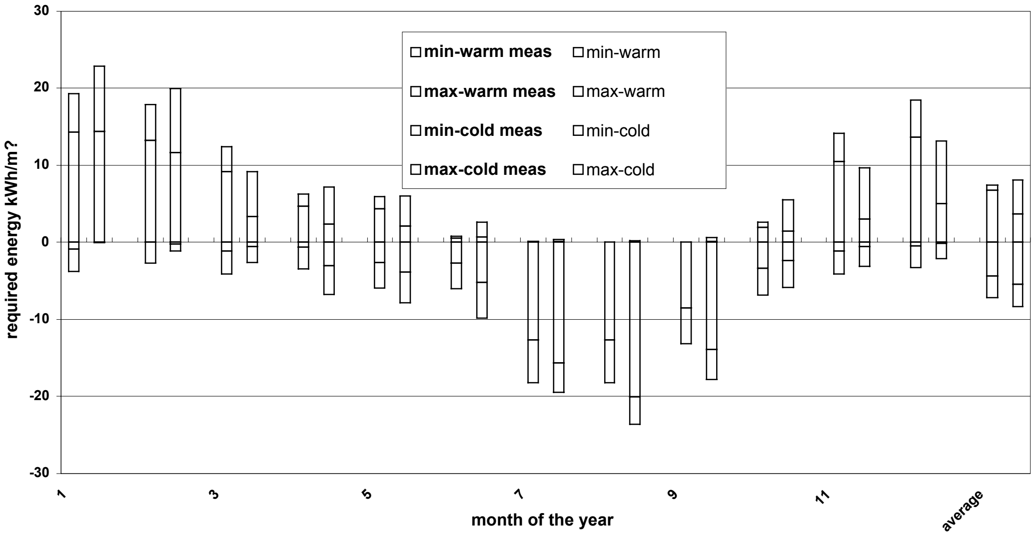

Figure 3 : comparisons of ranges of calculated and measured values

Calculated annual profile and average values, are in good agreement with measures (Figure 3). Observed low level of warmth, calculated at the end of the year, may be due to low electric consumption statements. Margin on calculated hot demand is due to a reduction of set point temperature during inoccupation. On TABLE 4, heat consumption, measured annually, are included in calculated interval. Moreover, in spite of a narrow tolerance for cold demands, calculated and measured values are overlapping.

TABLE 4 : annual energy demands (kWh/m^2/year)

	hot		cold	
	low	high	low	high
calculated border	44	97	66	100
measured border	81	89	52	86

CONCLUSIONS AND FURTHER WORKS

A simplified multi-area model of an air conditioned building is simulated with Consoclim. Furthermore, in spite of a reduced inputs number, comparison results between calculated and measured energy demands are conclusive. A similar work, about HVAC systems, is in process, in order to check that their choices and building design options lead together to an efficient global energy performance. However better knowledge of occupant behaviours and inside request conditions should reduced in a striking way intervals of calculated energy.

Acknowledgements

This research is supported by ADEME (Agence de L'Environnement et de la Maîtrise de L'Energie) and ML (Ministère du Logement).

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