TEACHING BUILDING PERFORMANCE SIMULATION USING GENERIC SIMULATION MODEL

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ABSTRACT

Building performance modeling and simulation is quite complex matter. In order to obtain plausible results good knowledge of building physics and advanced computer skills are required. In case of students the complexity of simulation software can represent serious problem. This issue can be addressed through tailored "generic" (underlying) models controlled via external user-friendly interface. The generic models are simulation models developed using existing simulation software and controlled by an external application. The external application is facilitating the change of some selected variables or making even possible selection from among several pre-modeled HVAC systems without having to learn the simulation software.

INTRODUCTION

It is obvious that each building physical problem can be treated with several levels of accuracy, e.g. one-dimensional steady-state / transient simplified / detailed approach (manual or computer aided calculation) or two / three dimensional steady-state / transient simplified / detailed approach (manual or computer-aided calculation). Provided the building physical models are correct, the computer-aided simulation delivers far more precise results than simplified calculation methods. This can be advantageous not only in the advanced design phase, when searching for detailed solutions, but also during the initial design phase, when crucial constructional and technological decisions are made. Though the advantages are obvious, architects and very often other building professionals do not make use of them. The obstacles, which keep them from using computer simulation methods on a larger scale, usually are:

- The complexity of quality software, e.g. for dynamic computer simulations, which requires advanced computer skills and good knowledge of building physics.
- The amount of time needed to create building physically correct simulation models.
- Over-standardization in terms of too many different standards related to specific building physical problems.

The distance between architects and the software can be made shorter by developing generic models focused on a particular type of building, building component or technical equipment that we want to explore. From conventional models, the generic models differ in that it is possible to operate them from outside, e.g. change calculation parameters, run the simulation and process outputs through a simplified interface designed for the particular type of building, building component or technical device, without the user having to enter into the software, within which the generic models have been developed. Then non-experienced users would be able to perform accurate building performance simulations, as the generic models are based on existing, scientifically proven software. The notion "generic model" is neither fixed nor widely used term. Rather, it is a working description of simulation models designed to allow multiple routine calculations with varying parameters or components and controlled through a simplified tailored-made interface. Actually, the idea of facilitating building performance simulation by using pre-made models via simple user-friendly interface is relatively new. Therefore, there are not too many published sources dealing with this simulation approach. On the other hand, there are several solutions developed by some software and consulting firms (e.g. Physibel, TESS) facilitating non-users of their software the work with simulation models. For example, the software TRNSYS provides a tool called TRNSED that "allows users to develop customized graphical interfaces for specific applications and then distribute those applications to non-TRNSYS users. These "web-page like" TRNSED applications allow non-TRNSYS users to change system parameters, run simulations, and process output without having to learn the intricacies of the entire TRNSYS environment". TESS developed several TRNSYS-based TRNSED applications that are available at its website. This way the generic models can give the users high certainty that the achieved results are correct and can also contribute to the improvement of their knowledge, experience and feeling for simulation. This contribution describes a simple generic model controlled via Excel Workbook. The model can be used for assessment and optimization of the energy efficiency and indoor comfort of detached modular houses. The described generic model developed in Capsol (simulation software) can also be used separately from the Excel interface. Advanced Capsol users can use it as a base for creating their own modified models, as it contains prepared schemes of the heating and cooling operations. For such cases, the Excel interface is useless. While its purpose is to facilitate working with Capsol, it doesn't have to be used necessarily. Capsol is Physibel's program to calculate multi-zonal transient heat transfer. Table 1 introduces examples of the best known solutions to control simulation software via an external interface.

Table 1 Examples of the best known solutions to control simulation software via an external interface

SOFT-WARE	EXTERNAL INTER-FACE	INFORMATION ABOUT EXTERNAL INTERFACE
Design-Advisor	http://DesignAdvisor.mit.edu	
EnergyPlus	DesignBuilder	designbuilder.co.uk
TRNSYS	Trnsed	www.trnsys.com http://tess-inc.com/home

GENERIC MODEL

The principle of the application is based on the fact that Capsol input and output files are stored as text files and can be manipulated by external programmes, such as Visual Basic for Applications (VBA) available in Excel. Hence the Capsol model can be "overloaded" with modelled wall types, heating and cooling systems and climate data. Not all of them must necessarily be used in single calculation run. Such model can be named generic model. The selection of parameters or systems is then made via an external tailor-made building-type specific interface (Fig. 2), which is in this case programmed in Excel using VBA.

The user can either define (green fields, e.g. areas, orientations or roof slopes) or choose (yellow fields) some design parameters or pre-modelled operation of heating/cooling systems:

- Building type, which can be either brick-based or lightweight construction. The building type is already defined by selection of the initial Capsol file, but can be changed at this point. The possible change affects the thermal insulation thickness of the building walls as the brickwork wall composition is of a different thickness compared with the lightweight one.
- Climate data (in principle calculations can be made for any climate data, provided they are organized in the form required). The version currently available contains climate data of three cities - Bratislava, Brussels and Stuttgart, which can be edited, should particular calculations be required.
- Even though the basic geometry of the detached modular house is given (Fig. 1), the user can define the areas of walls, windows, roof planes, ceiling, base plate, interior partition walls and volumes of the ground floor and attic as well. Of course, the point of the compass can also be defined.

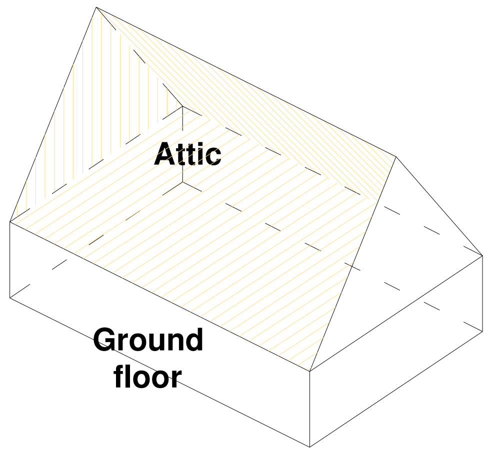

Fig. 1 Geometry of the modelled detached modular house

- Thermal insulation thickness, where the selection can be made from among 100, 150, 200, 250 and 300 mm in case of brick-based, and 140, 190, 240, 280 and 330 mm in case of lightweight, construction. The thermal insulation is a part of the predefined wall compositions. The same applies to the roof construction, the thermal insulation of which is, in both cases, 220, 250, 275, 275 and 300 mm and automatically changes with the selection of the wall insulation thickness, so that if the wall insulation is 150 mm in the case of brickwork or 190 mm in the case of lightweight construction, the roof insulation is 250 mm (Table 2).

Table 2 Thermal insulation thickness [m] of the main parts of building envelope

BRICKWORK CONSTRUCTION					
Base plate	0.020	0.020	0.020	0.020	0.020
Walls	0.100	0.150	0.200	0.250	0.300
Roof	0.220	0.250	0.275	0.275	0.300
LIGHTWEIGHT CONSTRUCTION					
Base plate	0.020	0.020	0.020	0.020	0.020
Walls	0.140	0.190	0.240	0.280	0.330
Roof	0.220	0.250	0.275	0.275	0.300

- Quality of windows (glazing having the U-Value of 1.09 or 0.8 W/(m^2K)).

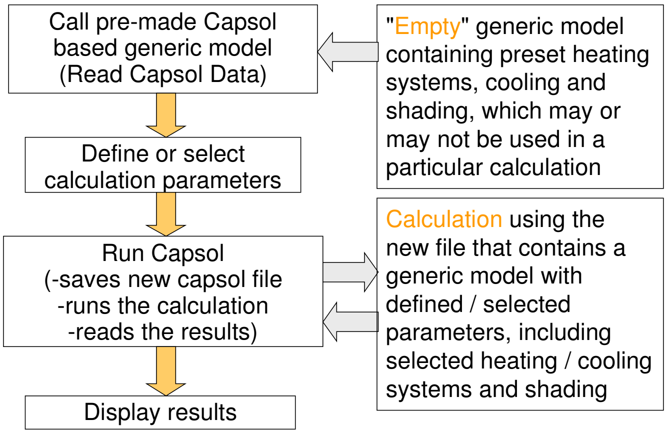

Fig. 2 Simplified working scheme of the Excel VBA based interface

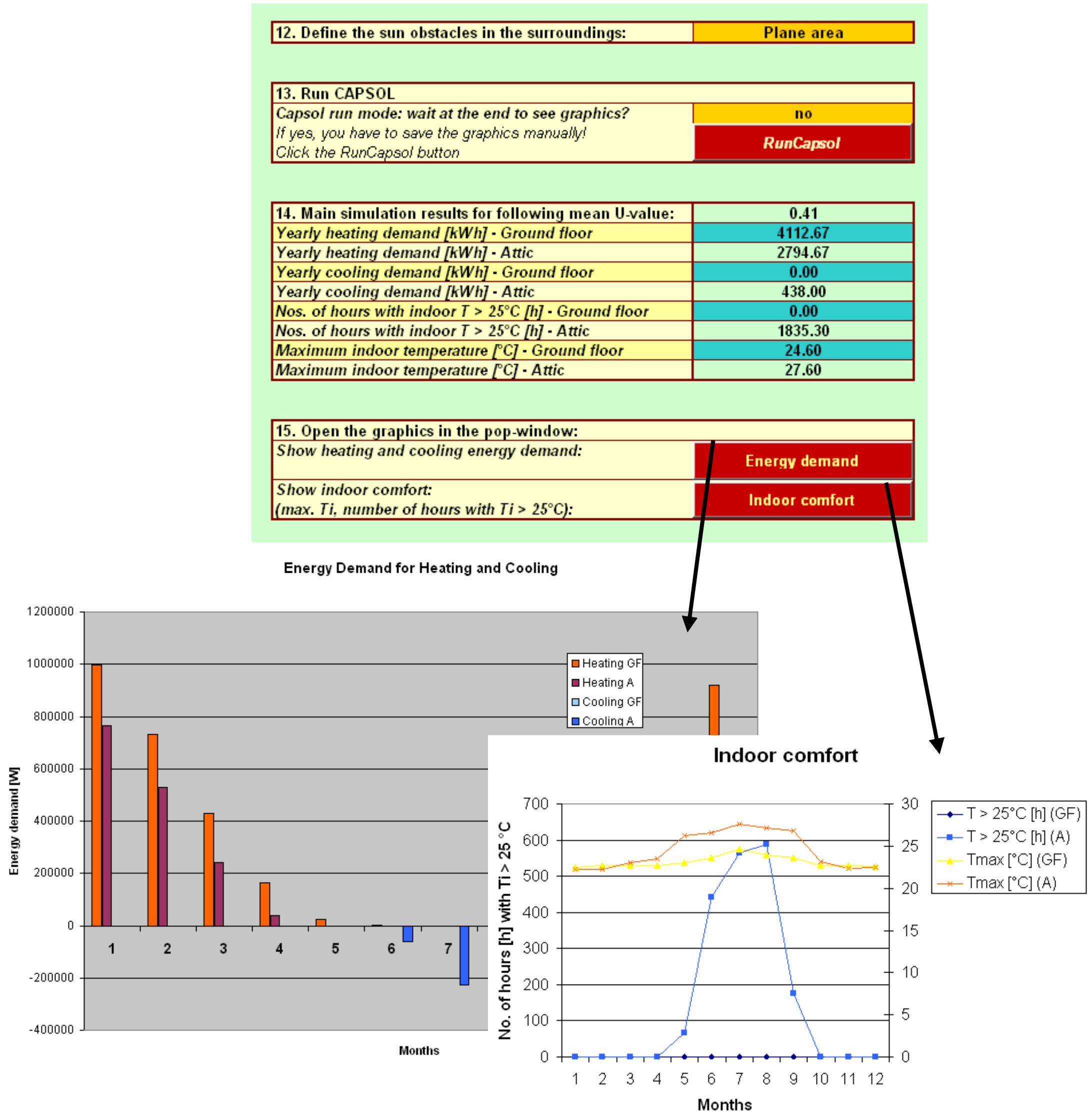

Fig. 3 Excel VBA based interface of the generic model for the assessment of the heating and cooling energy demand of detached houses - final table with selected result types and two buttons displaying either energy demand or thermal comfort chart (the abbreviation "GF" means Ground Floor and "A" stands for Attics)

- Heating system operation defined as air heating with or without heat exchanger. If the heat exchanger is applicable, the system is considered to be intermediate, having different target comfort temperatures for daytime and night. The heating system without heat exchanger can be either intermediate or without difference between the day and night target temperatures. Either way the required target temperatures (either a single value, if there is no difference between day and night, or values for daytime and night in case of intermediate heating) and the available heating power must be inserted. The expected necessary heating power can be assessed based on the steady-state calculation of the transmission and ventilation heat losses.
- Cooling system operations offering three options - an air conditioning, natural ventilation and an outer movable shading of windows. Each option can be used separately or in any combination with the other two. The principle of the air conditioning is basically the same as the one behind intermediate heating. Natural ventilation, if applicable, means simply opening the windows, and is switched on and off at the inserted target comfort temperature (the natural ventilation should not be confused with the so called “hygienic” ventilation to outdoors, which is active the whole year round and set to 0.5 of total interior volume per hour whereas 30 per cent of the ground floor volume is ventilated via the attic (both floors are connected through the staircase)). The movable outer shading applies to all windows of the given facade, gable or roof and, if selected, is switched on and off at the solar radiation intensity of 200 W/m^2.
- Sun obstacles in the surroundings defined as plane area, hilly country and forest / city, which correspond to maximum altitudes of 5°, 20° and 40° respectively of the foreseen obstacles.

After the definition and selection of the parameters / systems have been completed, the Capsol software is started using the button “Run Capsol” (Fig. 3). This command initiates the creation of a new Capsol file based on the generic model with user-defined and selected data, the actual calculation in Capsol and the import of required results back to Excel. As the purpose of this generic model is to investigate the heating and cooling energy demand and indoor thermal comfort, a special final table and two buttons displaying either energy demand or thermal comfort chart have been arranged. The basic generic model developed in Capsol can also be used separately from the Excel interface. Advanced Capsol users can use it as a base for creating their own modified models, as it contains prepared schemes of the heating and cooling operations. For such cases, the Excel interface is useless. While its purpose is to facilitate working with Capsol, it doesn’t have to be used necessarily. The techniques used for modelling the single operations of heating and cooling systems are described in detail in the Capsol Manual and the Physibel Pilot Book (Standaert, 2004 & 2010).

CASE STUDY

The developed generic model can not be used for calculations directly related to the issuing of energy performance certificates. In fact they are based on many simplifications and steady-state processes and thus incompatible with the dynamic nature of the generic model. All the better is the use of the generic model for design improvements and optimization of the building, which have to be presented to customers in the energy certification accompanying consulting. The following charts (Figs 4, 5, 6 & 7) compare the indoor comfort of two identical houses with the same mean *U*-value and the same thermal resistances of the main parts of the envelope, but with different material composition of the facades (heavy one and lightweight one). Both house variants were situated on the plane, unshaded location (mean U-value = 0.41 W/(m^2.K) each) and in the forrest/city, i.e. shaded location (mean U-value = 0.31 W/(m^2.K) each). The generic model treats the ground floor and the attic as two separate thermal zones, in order to take into account the difference in heat accumulation between more (GF - ground floor) and less (A -attic) heavy construction of their envelopes. During each calculation run also energy performance of the respective house was determined. Figs 8 and 9 show energy demand charts for both versions of building envelope in shaded location (U-value = 0.31 W/(m2.K)). All calculations were performed using Brussels climate data. On the basis of the standardized calculations required by national legislation, such a comparison would not be possible. On the contrary, the Excel controlled generic model makes it very easy.

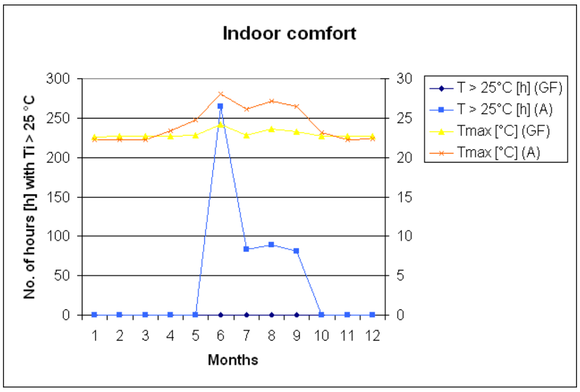

Fig. 4 Indoor comfort chart for brick-based (heavy) house having mean U-value = 0.41 W/(m^2.K) and situated on the plane (unshaded location) – secondary y-axis indicates monthly mean max. T

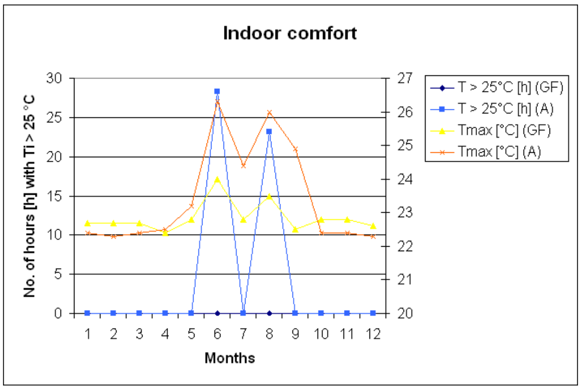

Fig. 5 Indoor comfort chart for brick-based (heavy) house having mean U-value = 0.31 W/(m^2.K) and situated in the forrest / city (shaded location) – secondary y-axis indicates monthly mean max. T

The actual results are then indicating the impact of the material composition of the facade on interior comfort even if its thermal resistance is the same. Particularly better insulated lighweight house will have problems with summer overheating even on shaded location.

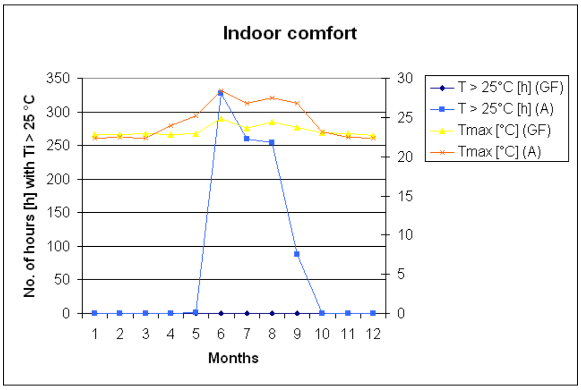

Fig. 6 Indoor comfort chart for wood-frame house (lightweight) having mean U-value = 0.41 W/(m^2.K) and situated on the plane (unshaded location) – secondary y-axis indicates monthly mean max. T

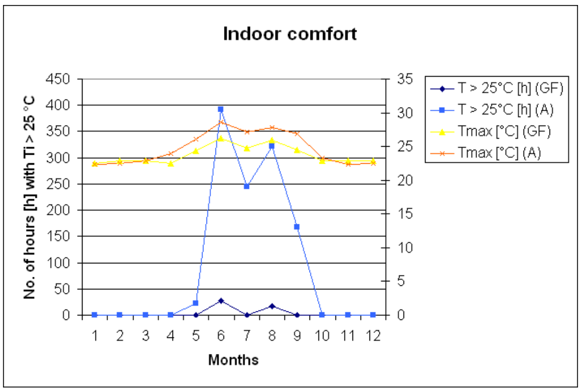

Fig. 7 Indoor comfort chart for wood-frame house (lightweight) having mean U-value = 0.31 W/(m^2.K) and situated in the forrest / city (shaded location) – secondary y-axis indicates monthly mean max. T

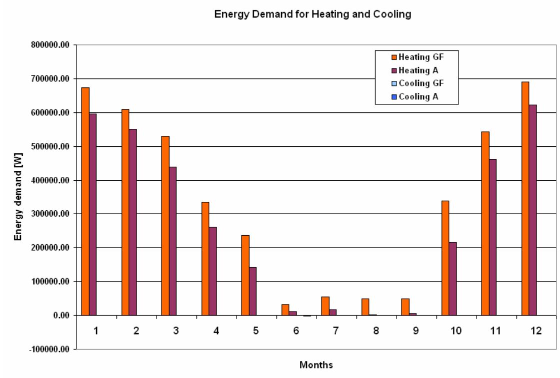

Fig. 8 Energy demand chart for heavy brick-based house – shaded location (mean U-value = 0.31 W/(m^2.K))

DISCUSSION AND FUTURE WORK

In fact the generic models represent a way to overcome the obstacles, which keep architects and designers from using computer simulation methods. In general, by developing sets of ready-made simulation models (generic models) based on the existing accurate standardized calculation methods, an easy access to these calculation methods could be provided.

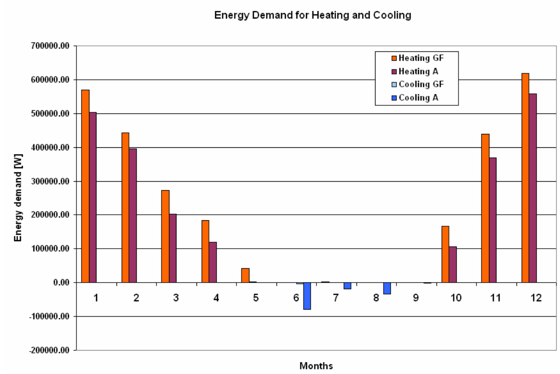

Fig. 9 Energy demand chart for lightweight house – shaded location (mean U-value = 0.31 W/(m^2.K))

The problem is that on the one hand, the existing standards provide sophisticated computational methods, but on the other hand, often overlap and are not mutually coherent. Hence, when dealing with one building physical problem, several standards have to be consulted (especially the ones related to the energy performance of buildings (Svoboda, 2009)). These standards either represent different levels of accuracy on their own or contain optional calculation methods at different levels of accuracy. From time to time they also differ in certain terms or symbols. To bring some clarity to the current situation, CEN seeks to examine or revise existing standards. The objective is to create a new generation of standards, which should be much clearer, with a uniform methodology for Member States and in particular they should motivate their use and proper designing. Part of the standards should consist of transparent calculation methods in electronic form, programmed for example in MS Excel. Hence, the ready-made simulation models (generic models) could cover, for example, typical building physical problems occurring in today's design practice. Several simulation models could be developed at differing levels of accuracy for each building physical issue. Which simulation software is selected, would depend on the nature of the building physical problem. Less complex standardized calculation methods could be incorporated directly into Excel. Actually it should be started with such simple calculations before developing comprehensive whole building models for multiple use, e.g. for the purposes of energy certification of buildings. Even though quite simple (compared to other existing applications) the described generic model belongs to the sort of more complex models (in terms of the covered aspects), whereas the limits of its application are clearly visible:

- Simulated can be only buildings that can be meaningfully divided into two thermal zones, have no basement, only the ground floor and attic with pitched saddle roof,
- Thermal insulation of walls, roof, base plate, doors and windows can be selected, but not freely defined,
- Many aspects of heating and cooling systems are set, e.g. the efficiency of heat exchanger, "hygienic" ventilation path etc.

All of the above restrictions were intended to facilitate data transfers between the interface and the generic model. Of course more advanced users can directly modify the generic model, but that goes beyond its basic purpose, the aim of which is the use in its original form. Hence, from the experience gained, it seems that the idea of a strong generic model with extensive user-friendly interface covering many aspects of the building operation is probably unrealistic in the near future. Unrealistic, because during the building operation many interrelated building physical processes are going on and, at the same time, the computational methods for describing these processes are, as already mentioned rather diversified. Promising way to implement this idea could be the development of generic models of individual partial processes. After their reliable testing they could be, perhaps, associated to higher units interconnected so that the individual generic sub-models are available within a single computational assessment of a whole building of a given type. Much more, however, they could now contribute to the development of new standards in the intentions of CEN, facilitating the use of accurate computational methods, and overall systematization of the available standardized computational procedures. An excellent application may have generic models in education. The described model has been successfully used within Bachelor (design studio) and Master's study subjects. Students of building construction are normally led to be able to assess the energy demand for heating of buildings under current legislation and standards. However, from such calculation they are usually not able to see the impact of their decisions on the quality of the indoor environment. The graphical presentation of results from the generic model makes it visible in a very easy and quick way. They clearly see the effects of accumulation capacity, building location, window quality, intermediate heating or cooling etc. without having to learn simulation software. Even though the students do not have to go too deep into building performance simulation, the generic model usually serves as a kind of motivation factor encouraging them to further studies.

CONCLUSION

The advantage of generic models is the fact that the users can operate them from outside, e.g. change calculation parameters, run the simulation and process outputs through a simplified interface designed for the particular type of building, building component or technical device, without having to learn the underlying software, within which the generic models have been developed. Of course, the generic models can be used also without the use of simplified interface. Advanced users can change or adapt them for their specific purposes. The generic models can be developed for any building type or component and, depending on their purpose, in more or less detail. Their application can reach from the early design stage up to the detailed calculations of various components and systems used in a building. Large potential represents the new generation of EPBD based standards, which creates an environment for use of transient computer simulations. Moreover, the generic models can give users a high certainty that the achieved results are, building physically, correct. They can also contribute to the improvement of the users' thermal knowledge and experience. The principles of simulation techniques described in this paper can be, in slightly modified form, applied under other building performance simulation software as well.

ACKNOWLEDGEMENT

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