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Validation of Building Energy Modeling Tools for a Residential Building in Brasov Area-Romania

Lucian Cîrstolovean, Paraschiva Mizgan

***Abstract* – A building energy model is a simulation tool which calculates the thermal loads and energy use in buildings. Building energy models provide valuable insight into energy use in buildings based on architecture, materials and thermal loads. In addition, building energy models also must account for the effects of the building's occupants in terms of energy use. In this paper we discuss building energy models and their accuracy in predicting energy use. In particular, we focus on two types of validation methods which have been used to investigate the accuracy of building energy models and on how they account for their effects on occupants. The analyzed building is P + M located in the climatic zone 4, Sânpetru / Brașov. We have carried out a detailed and exemplary energy needs analysis using two methods of analysis.**

Keywords* – *building, energy model, thermal load, occupants

1. INTRODUCTION

Buildings are a central element of EU energy efficiency policy, of the total energy consumption, buildings account for about 40% of final energy consumption and 36% of greenhouse gas emissions. Improving the energy efficiency of the European stock of buildings is essential, not only to meet the EU 2020 targets, but also to meet the longer term objectives of the climate change strategy.

A building energy model is a simulation tool which calculates the thermal loads and energy use of buildings. The models are typically used in the design of new buildings and in the renovation of existing buildings. The purpose is to predict energy use based on the building's architecture, heating system, ventilation and air conditioning systems [1]. Building energy models are used by a variety of professions ranging from architects to engineers.

In addition to the occupancy survey, Knight et al. [1], [7] use the building energy models ECOTECT, which calculate the heating and cooling loads, and BEM, which is a coarser model for predicting yearly usage, to model the building. According to Knight et al. [1], [7], neither model has been validated, but they claim that ECOTECT is 'known to give a reasonable estimate of heating loads in buildings', and from that they conclude that other programs such as Energy-Plus would provide the same results as ECOTECT [1],[7]. In our country, Romania, buildings services engineers are those who are most interested to apply these calculation models. The buildings services engineers are responsible for the buildings services equipment and for comfort assurance.

Calculation models that have been validated are usually only considered for cases under specific ranges of conditions, which exclude real life conditions such as the effects of building occupants on energy usage [2]. The behavior of a building's occupants can have a significant impact on the energy use of a building. Building occupants will affect the building energy use through the temperature set points, heating/cooling schedules of the building [2].

In this paper, we present an evaluation and a validation of building energy models under idealized and realistic conditions. The evaluation considers calculation models that discuss the validation and verification of building energy calculation models use in our country (Romania), in our conditions, which are used to predict the energy use of a building based on the heat transfer, thermodynamics, building architecture, and specific materials and buildings services equipment of a building. We present a theoretical calculus of energy consumptions for a residential building using a theoretical methodology by using a computer programme. We also present a real value of energy consumption for our building considering real measurement for gas and electricity. Articles that discuss methods for including and validating occupant effects in building energy models were also considered.

2. MATERIALS AND METHODS

The building that we evaluated in terms of energy consumption is located in Brasov, Romania:

Type: Family house (4 persons)
Year of building: 2010
Dimensions: width l = 10.10 m; length, L = 15.7 m; height, H = 8.7 m.
Levels:
- Ground floor: A = 146 m2; P = 15.45 m; h = 2.7 m
- Attic: A = 146 m2; P = 15.45 m; h = 2.6 m

External walls:
- interior plaster, 3 cm
- brick masonry, 30 cm
- polystyrene , 10 cm

Internal walls:
- interior plaster, 3 cm
- brick masonry 20 cm
- PVC joinery with double-glazed windows

Heat supply: 24 h, continuously.
Equipment from the boiler room:
- Gas boiler 24 kW Thermal agent, hot water 75/55ºC;
- Circulating pump
- Expansion tank
- Separation-isolation and safety fittings;

Heating system:
1. Heating units equipped with control valves, located below the windows;
2. The pipes of the internal heating system are made by polypropylene.
3. The distribution system of thermal agent is bi-tubular.

2.1 The calculus of energy consumption according to MC001 Romanian methodology [9]

The heat loss of the heated space is:

$$Q_h = Q_L - \eta \cdot Q_g = 51771 - 0{,}94 \cdot 37275{,}93 = 16637{,}31 [kWh] \qquad (1)$$

Q_h= heat loss of heated space of building, $[kWh]$

Q_L= transmission heat loss of the building, $[kWh]$
Q_g= the heat inputs of the building, $[kWh]$
η= factor of reducing heat inputs

Q_L= 51771 $[kWh]$; (2)

Q_g=37275, 95 $[kWh]$; (3)

$\eta_1 = \frac{1-\gamma^a}{1-\gamma^{a+1}}$=0,9425 (4)

The total energy consumption of the buildings is:

$$Q_{fh} = Q_h + Q_{th} - Q_{rh,h} - Q_{rwh}\ [kWh] \quad (5)$$

Q_h= heat loss of heated space of the building, $[kWh]$
Q_{th}= heat loss of heating system of the building, $[kWh]$
$Q_{rh,h}$= heat recovery from heating system of the building, $[kWh]$
Q_{rwh}=heat recovery from sanitary system of the building, $[kWh]$

$$Q_{th} = Q_{em} + Q_d\ ,\left[\frac{kWh}{an}\right] \quad (6)$$

Q_{em} =Heat loss due to the heat emission system, $[kWh]$
Q_d =Heat loss due to the heat distribution system, $[kWh]$

$$Q_{em} = Q_{em,str} + Q_{em,c} \quad (7)$$

$Q_{em,str}$ =Heat loss due to the uneven uniform distribution of temperature,$[kWh]$
$Q_{em,c}$= Heat loss due to the internal temperature control devices, $[kWh]$

$$Q_{em,str} = \frac{1-\eta_{em}}{\eta_{em}} \cdot Q_h = \frac{1-0,93}{0,93} \cdot 16637,31 = 1252,27\ kWh \quad (8)$$

η_{em} = The efficiency of the heat transmission system,

$\eta_{em} = 0,93\ from\ \ MC\ II - 1\ Anexa\ II\ 1B$

$$Q_{em,c} = \frac{1-\eta_c}{\eta_c} \cdot Q_h = \frac{1-0,94}{0,94} \cdot 16637,31 = 1061,95\ [kWh] \quad (9)$$

η_c = The efficiency of the heat control system,
η_c = 0, 94 $rom\ \ MC\ II - 1\ Anexa\ II\ 1B$

$$Q_{em} = Q_{em,str} + Q_{em,c} = 1252,27 + 1061,95 = 2314,22\ [kWh] \quad (10)$$

$$Q_d = \sum U_i \cdot (\theta_m - \theta_{ai}) \cdot L_i \cdot t_H \quad , \qquad [kWh] \tag{11}$$

Q_d = heat loss on distribution system of heating system, $[kWh]$

$$Qd = 6237{,}428 \quad [kWh] \tag{12}$$

$$\mathrm{Q_{th}} = 2314{,}22 + 6237{,}428 = 8550{,}2 \text{ kWh} \tag{13}$$

The energy consumption of building according to MC001 methodology is:

$$\mathrm{Q_{fh}} = 8550{,}2 + 16637{,}3 = 25187{,}5 \text{ kWh} \tag{14}$$

2.2. Analyzing real energy consumption based on 3-month utility consumption and comparing with the resulting MC001 calculations

Speaking about realistic validation studies, theoretical building energy models are compared to metering data from real buildings. In our realistic validation, authors have tried to validate the physics behind the models; occupants' behavior is typically included in building energy modeling by setting the heating, equipment and temperature set points based on the hours of use by the occupants and local weather conditions. The theoretical models used are often designed on the assumption that occupants will use the building in the way it is designed. According to the real data gathered from the field regarding the real consumption of the analyzed building, Table 1 presents the real energy consumption for: November, December and January 2017-2018.

Table 1. Energy consumption for November, December and January 2017-2018

	Heat Consumption kWh	Power consumption kWh	Total kWh
November	11678	704	12382
December	12651	1048	13699
January	12975	845	13820

Average outside temperatures for November, December and January 2017-2018 are shown in Table 2.

Table 2. Average outside temperatures for November, December and January 2017- 2018

	November	**December**	**January**
day	7	2	0
night	-4	-8	-9
average	2	-3	-5

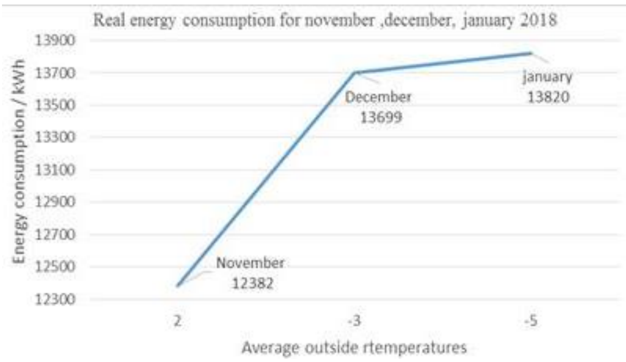

Fig. 1 Energy consumption graph for: November, December, January 2017-2018

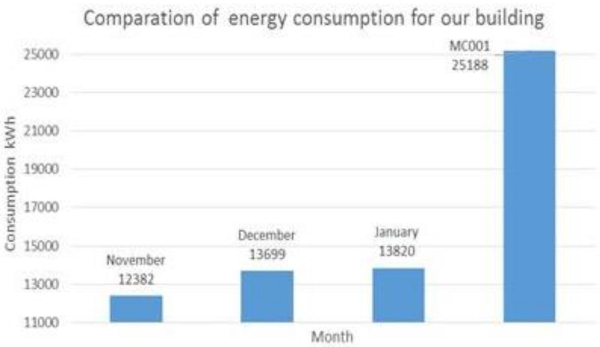

Fig. 2 Comparative chart of energy consumption for November, December and January with theoretical energy consumption calculated according to the MC001 methodology

2.3. RETScreen method to compare the predictions of building energy models[10]

The RETScreen program has calculated the energy requirement for heating, but also the electricity needed for the building under consideration [10].

Tabel 3. The result of calculating the energy consumption for the building analyzed with the RETScreen program

	Combustibil		Caz de referinţă		Caz propus		Economii ale costurilor de combustibil	
Debit combustibil	Consum de combustibil - unitate	Tarif combustibil	Consumul de combustibil	Preţ combustibil	Consumul de combustibil	Preţ combustibil	Combustibil economisit	Economii ale costurilor de combustibil
Energie electrică	MWh	$ 200.000	10.4	$ 2.089	10.4	$ 2.089	0.0	$ -
Gaz natural	kWh	$ 0.410	18.300.8	$ 7.503	18.300.8	$ 7.503	0.0	$ -
Total				$ 9.592		$ 9.592		$ -

Verificarea proiectului Debit combustibil	Consum de combustibil - unitate	Consum de combustibil - istoric	Consumul de combustibil Caz de referinţă	Consum de combustibil - variaţie
Energie electrică	MWh		10.4	
Gaz natural	kWh		18.300.8	

Necesar de energie	Încălzire MWh	Răcire MWh	Energie electrică MWh	Total MWh
Necesar de energie - caz de referinţă	18		10	29
Necesar de energie - caz propus	18		10	29
Energie economisită	0		0	0
Energie economisită - %	0.0%		0.0%	0.0%

Punct de referinţă		
Unitate de energie	kWh	
Unitate de referinţă	m²	

☑ Indică informaţia

Compararea

Ţară-regiune	România
Tipul instalaţiei	Rezidenţial
Tip	Tip
Descriere	
Consumul de combustibil	868 kWh/Persoană

☐ Afişare unit. alternative

Tabel 4. Results obtained with RETScreen programme

	Heat	Electricity	Total
Energy demand	(MWh)	(MWh)	(MWh)
Energy demand	18.3	10.4	28.7

2.4. Comparing the obtained results: MC001, real consumption and RETScreen programme

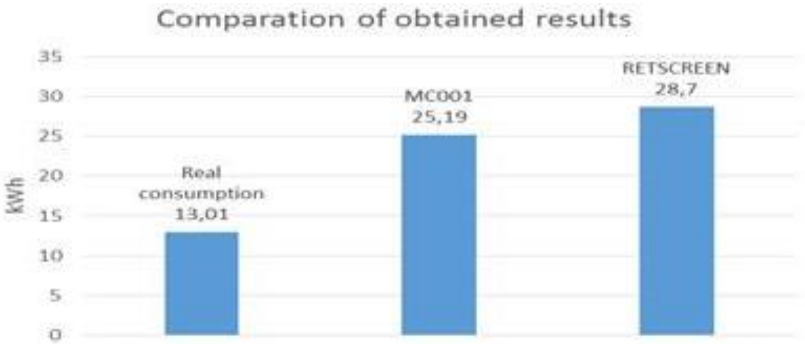

Fig 4 Comparison the results (Real consumption, MC001, RETSCREEN)

2.5. Building energy modeling and occupancy behavior

Several studies have been done on the effects of occupant behavior on building energy modeling [1], [2], [3], [4] and on advanced methods of including occupancy behavior in building energy models [2], [5].

Occupant behavior can be defined as 'the presence of people in the building' and also 'the actions users take (or not) to influence the indoor environment' [1], [2].

In most building energy models occupant behavior is modeled in a very simple form with set schedules for occupancy.

Using more complex models based on surveys and stochastic models can refine the inputs for occupant behavior and improve the accuracy of the building energy model [1], [2], [5].

Stochastic models use a set of rules to determine the probability that an event will happen. Tanimoto et al. [8] divide users into sub-categories based on age and lifestyle and use a Monte Carlo analysis to determine what activities each group is doing throughout the day and how that affects the energy use of a multi-family residence.

Clevenger and Haymaker [1], [6] investigated what effect different occupancy controlled parameters have on the predicted energy use of a school building.

They looked at the effects of eleven different building modeling parameters on the energy use of a school building.

Using a survey of building operators, they determined the range of setting used for each of the eleven parameters.

Simulations were run to study the sensitivity of the building energy model to each of the parameters.

They found that different occupancy controlled parameters can change the energy use of a school building by up to 40%.

3. CONCLUSIONS

Building energy modeling tools provide a simple method for predicting the energy use of new and existing buildings. More and more the society demands for new energy efficient construction and retrofits, thus, predicting energy use is essential to the design process of buildings and for all facilities.

Generally speaking, all models are able to predict energy use for different building and heating systems designs without any need for experimentation. As new calculus models are developed and existing building energy models are improved, the validation methodologies for building energy models also need to improve and expand to assess their validity.

All studies which have considered the effects of occupants on building energy models have shown that building energy models are very sensitive to occupants' behaviors. In all study cases, building energy models do not accurately represent the occupants' behaviors.

To improve the accuracy of building energy models it is necessary to consider the behaviors of occupants in all simulation cases, in particular for each building. In this way the accuracy of simulation is certified and the real energy consumption is determined.

Analyzing the consumption and energy requirements for the P + M building, located in the IV climate zone, Zaharia Bârsan Street, no. 13, Braşov County, we can say that the energy demand resulting from the calculations according to the MC001 methodology is 12% less than the RETScreen program, but in both cases it is considerably higher than the actual consumption of the building, following the analysis for November, December and January 2017-2018.

We consider that occupants' behaviors are those making the differences in energy consumptions of the analyzed building.

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Note:

Lucian Cirstolovean – Transilvania University Brasov, Department Buildings Services, Romania (corresponding author to provide phone: +40722294552; e-mail: luceoe@yahoo.com).

Paraschiva Mizgan - Transilvania University Brasov, Department Civil Engineering, Romania, (e-mail: paraschiva.mizgan@unitbv.ro).