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INFLUENCE OF HEAT BALANCE ALGORITMS TO ENERGYPLUS PREDICTION OF NET ZERO ENERGY BUILDING BEHAVIOUR

Abstract: *This paper analyzes use of EnergyPlus software to analyze energy consumption of the net zero energy building in a specific period. The problem can be represented as a difference in the amount of energy needed for the zero-energy building. The observed time interval can be a full year or, more precisely, the impact of climate on the territory of the Republic of Serbia – the seasons to the need for energy. The program analyses the influence of the conduction heat transfer function, conduction finite difference, conduction finite element, etc. on the prediction results. Discrepancy of the results in the observed time interval can have both positive and negative values.*

Keywords: *Zero Energy Building, EnergyPlus, Heat Balance Algorithm, Simulation*

1. INTRODUCTION

Attractive research related to energy efficiency, energy saving, the impact of climate change and CO_2 emissions are focused on renewable energy. The essential idea is to develop a building that uses different systems in relation on alternative energy source. Like PV panels, windmills and geothermal energy. The final idea is to manufacture as much energy as the system spends.

Building system work connected to the electrical grid. During the period when building produces more energy than sending excess required in a grid, and when the deficit on the energy is withdrawn from the grid. Thus the balancing is done and the building is zero annually. It means to spend the same or less power and produce as much. If this condition is met then it is a Net Zero Energy Building – NZEB.

Robbert and Kummert investigated global warming and impact of weather files used for simulations while creating zero energy buildings [1]. They concluded that weather files for future investigations should be created not only by looking on last 50-years but by taking into account climate changes.

Srinivasan et al. proposes using "Renewable Emergy Balance" (REB) as tool for maximization of renewable energy used in modern building but also in Net Zero Energy Buildings [2].

Thiers and Peuportier studied two high energy performance residential buildings in their paper [3]. They carried out thermal simulation and life performance assessment. They also showed how renewable sources of energy can contribute to system and how the optimization of system sizing can have a good contribution to energy saving overall.

Bojic et al. investigated positive-net-energy residential buildings application in Serbian conditions [4]. Negative-net

energy building – NNEB, zero-net energy building – ZNEB and positive-net energy building are defined there, according to their relationship of energy consumption and production.

Luo et al. investigated conduction transfer function method used in EnergyPlus and modified method to calculate wall surface heat fluxex [5]. They also compared results from these methods with actual measuring and volume finite method and got the results that shows that conduction finite methods and modified method gives good results.

2. SCOPE OF RESEARCH

This paper examines the impact of Heat Balance Algorithm in EnergyPlus software to zero energy building. Software has five different types of this algorithm but will be presented three of which are interesting for us to see the results. The aim is to present the impact of the Heat Balance Algorithm zero energy consumption building and affected the functioning of the entire system.

2.1 EnergyPlus – Heat Balance Algorithm

The use of the EnergyPlus software for simulations offers the user a choice as an option module for the Heat Balance Algorithm. There are five different options that can be used for research [6]:

Conduction Transfer Function
Conduction Finite Difference
Conduction Finite Difference Simplified
Moisture Penetration Depth Conduction Transfer Function
Combined Heat and Moisture Finite Element

The Heat Balance Algorithm object provides a way to select what type of heat and moisture transfer algorithm will be used across the building construction calculations [6].

2.1.1. Conduction Transfer Function (CTF)

The Conduction Transfer Function selection is a sensible heat only solution and does not take into account moisture storage or diffusion in construction elements [6].

2.1.2. Conduction Finite Difference (CFD)

Advanced / Research usage: The Conduction Finite Difference selection is a sensible heat only solution and does not take into account moisture storage or diffusion in the construction elements. This solution technique uses a 1-D finite difference solution in the construction elements. Outputs for the surfaces are described with the material property objects [6].

2.1.3. Conduction Finite Difference Simplified (CFDS)

Advanced / Research usage: The Conduction Finite Difference Simplified selection is a sensible heat only solution and does not take into account moisture storage or diffusion in the construction elements. This solution technique uses a 1-D finite difference solution in the construction elements – representing only two nodes per construction. Outputs for the surfaces are described with the material property objects [6].

2.1.4. Moisture Penetration Depth Conduction Transfer Function (MPDCTF)

The Moisture Penetration Depth Conduction Transfer Function selection is a sensible heat diffusion and an inside surface moisture storage algorithm that also needs additional moisture material property information. Sometimes, this is

referred to as the Effective Moisture Penetration Depth or EMPD.

2.1.5. Combined Heat and Moisture Finite Element (CHMFE)

Advanced / Research usage: The Combined Heat and Moisture Finite Element is a coupled heat and moisture transfer and storage solution. The solution technique uses a one dimensional finite difference solution in the construction elements and requires further material properties described in the Heat and Moisture Transfer material properties objects. Outputs from the algorithm are described with these objects [6].

2.2. System used and simulation settings

In this case models taken into account were Conduction Transfer Function, Conduction Finite Difference and Conduction Finite Difference Simplified. Other two algorithms are not considered because of the influence of moisture.

Tests were performed on a model which has a geothermal system and solar panels. Period considered is for a full year.

System installed in house is radiant floor heating. Value of Plant Loop Volume is adjusted so that the auto-calculate varies depending on the choice of algorithm. The simulation requires adjustment of Time Step for normal operation of the algorithm.

2.3. Geometrical description of building

A model of house is created to show the repercussions of the Heat Balance Algorithm to the values of interest for consideration. Appearance of the model presented in figure 1. Total area of this model is 195.84 m^2, of which the useful space 130.56 m^2. The useful area means an area that is maintained and heated. Useful area doesn't include the attic that covers 65.28 m^2.

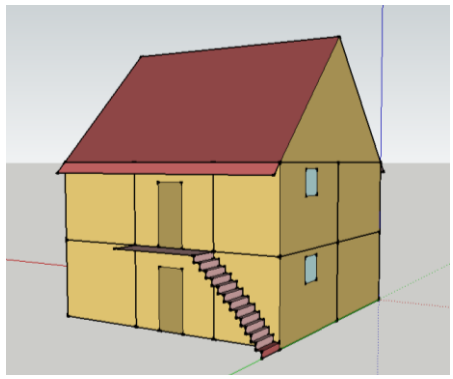

Figure 1. *Inspected house*

Floor plans are same for the first and second floor and its geometry is given on figure 2. Living room is in the middle, and the bedroom is oriented to west and it is bigger than the toilet.

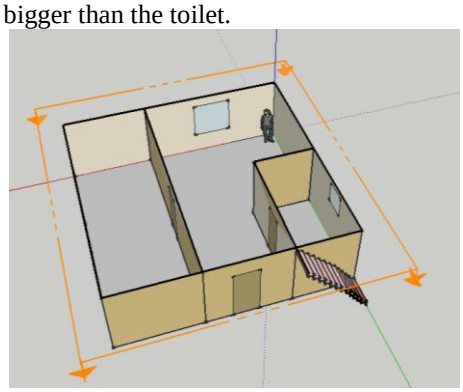

Figure 2. *Floor plan*

3. RESEARCH METHOD

3.1. About EnergyPlus software

EnergyPlus is software that enables simulation of embedded systems in the building in order to examine the actual situation. Embedded systems can be liked to energy sources and energy consumption. Analysis is performed simulations of heating, cooling, ventilation, etc. Software provides the possibility of studying the behavior of the building in a time interval that can vary. Because software has too much possibility and scope of the software

should be consulted in the course of the literature [6].

For the purposes of this paper a model house built in Google SketchUp [7] and simulations were performed at EnergyPlus. Was used OpenStudio Plug-in [8].

3.2. Mathematics used

Total consumption of electricity per year is obtained as the addition of partial consumption of heating, lighting, running pumps and interior equipment:

$$E_t = E_h + E_l + E_p + E_{ie} . \quad (1)$$

Average temperature in the rooms for one month is obtained as the mean temperature for that month.

$$t_m = \frac{\sum_{p=1}^{n} t_p}{n}, \quad (2)$$

where number *n* present total number of partial temperature for that month, t_p represents a partial temperature.

Average annual temperature is calculated as the mean value of average monthly temperature.

$$t_y = \frac{\sum_{m=1}^{12} t_m}{12}, \quad (3)$$

where t_m represent temperature of month.

4. RESULT AND DISCUSSION

4.1. Production and Consumption Energy

First results about building show clear differences in the production and consumption of electricity as shown in Figure 3. It can be seen that the CTF and CFD algorithms have results which are almost the same, and the difference between them is about 1% for consumption. They have similar production from PV panels. But when simplified model CFDS is used, results are different. Simulations are shorter when using CFDS but difference in consumption is 28.8% comparing to CTF model. When energy production from PV panel is discussed difference between CFDS and CTF is 8.5%. This gives us conclusion that

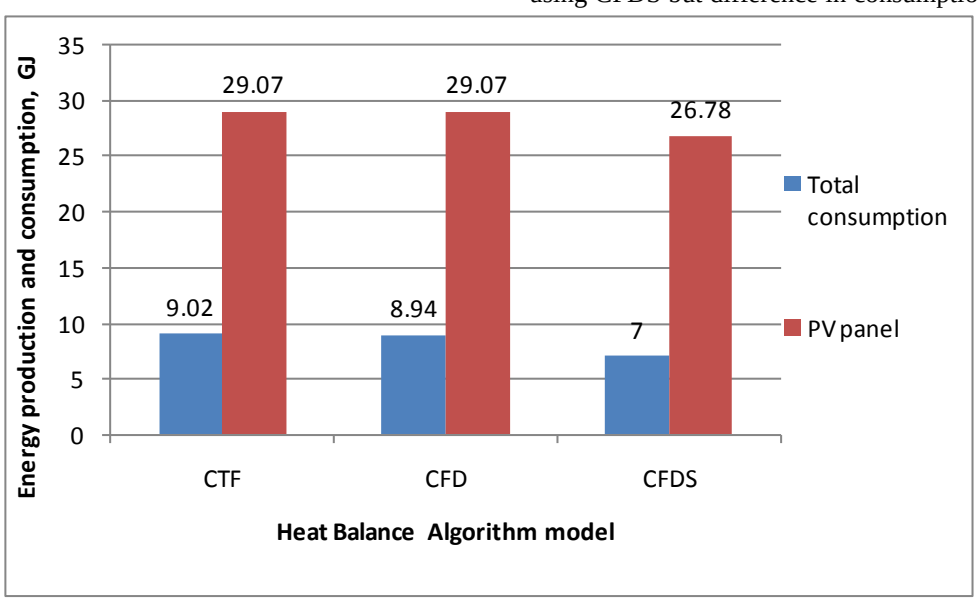

Figure 3. *Energy production and consumption by selected heat balance algorithm*

it is better to use one of the CTF and CFD model for simulation as its results are more accurate.

4.2. Plant Loop Volume

Since the Plant Loop Volume is set to auto-calculation we can see a significant difference in the required volume depending on the type of the selected algorithm (Figure 4).

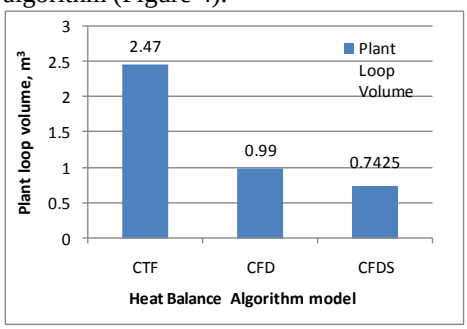

Figure 4. *Plant Loop Volume*

As those heat balance models are different so are the calculations used by them. Difference in plant loop volume between CTF and CFD is 247% and CTF and CFDS 326.5%.

4.3. Temperature

Change in temperature per month for the living room for the algorithms used is presented in Figure 5.

Average temperature shows that used models have difference in its calculations and as the CFDS is simplified it doesn't take into account all factors that influence heat balance and therefore average temperature is significantly lower during the winter months. As heating doesn't work during summer its results come closer to the results of other models.

Heating is not controlled by valves and only has design temperatures at 20°C for coldest months for living room. During these months these temperatures are achieved by more complex models like CTF and CFD, so it gives us conclusion that heating system is properly defined and designed. There is little difference between CTF and CFD model during spring and autumn months.

During the summer months average temperatures rise as there is no cooling system applied.

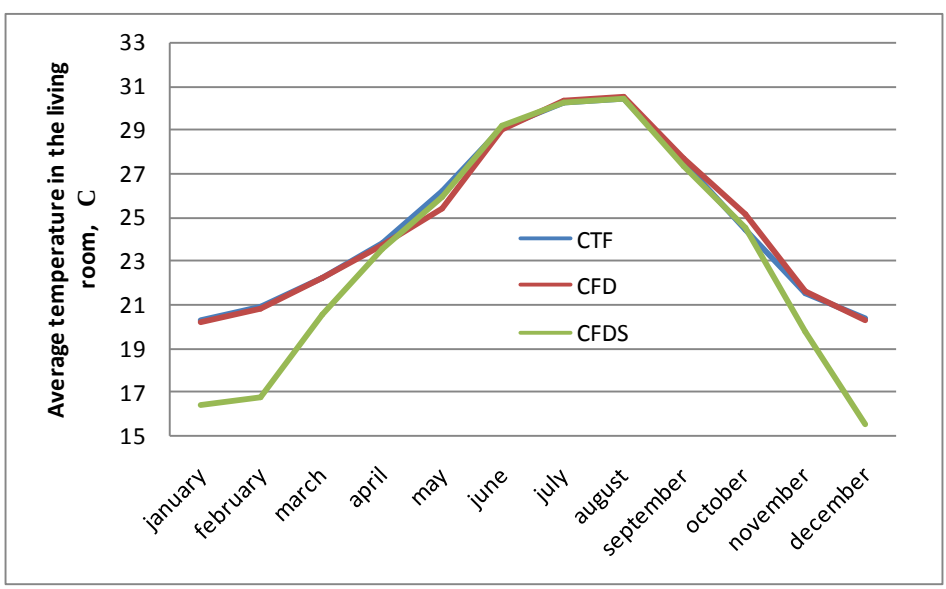

Figure 5. *Average temperature in the living room by months for different models*

5. CONCLUSION

Concerning the results given conclusions can be made. It can be seen that CFDS model is not appropriate as its results are not accurate as required, and therefore its simulation can be only used for draft. It has its good side as it is fast and by using it user can see if there are major errors in creating the geometry and EnergyPlus model definition.

Also, obviously CFDS model has different heat and energy transfer calculating model as it even gives smaller energy production from PV panels than the CFD and CTF model.

CTF and CFD models give similar results but there is difference in calculating the plant loop. CFD model takes more time to calculate and therefore it is better to use CTF model as its results are accurate and duration of time is good.

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Acknowledgment: This paper is a result of two investigations: (1) project TR33015 of Technological Development of Republic of Serbia, and (2) project III 42006 of Integral and Interdisciplinary investigations of Republic of Serbia. The first project is titled “Investigation and development of Serbian zero-net energy house”, and the second project is titled “Investigation and development of energy and ecological highly effective systems of poly-generation based on renewable energy sources. We would like to thank to the Ministry of Education and Science of Republic of Serbia for their financial support during these investigations.