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INFLUENCE OF SURFACE CONVECTION ALGORITHM 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 surface convection algorithms such as TARP, simple, adaptive convection, 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, Surface Convection Algorithm, Simulation*

1. INTRODUCTION

Building zero energy buildings presents modern way to reduce energy consumption, improve energy efficiency and reduce CO_2 emission from energy usage in residential building.

Those building have their renewable sources of energy built on-site from which they take electricity and energy. In most cases it is PV panels, but there are also installations which gets energy from geothermal or wind.

When building is producing more energy then it consumes it is positive net energy building, and if it is same then it is net zero energy building.

Bojic et al. investigated positive-net-energy residential buildings application in Serbian conditions [1]. 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.

Thiers and Peuportier studied two high energy performance residential buildings in their paper [2]. They did thermal simulation and assessed life performance. 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.

Robbert and Kummert investigated global warming and impact of weather files used for simulations while creating zero energy buildings [3]. 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 [4].

Praene et al. investigated usage of

renewable energy sources in zero net energy systems on Reunion Island [5]. Marszal et al. have defined the life cycle cost analysis for zero net energy building in Denmark and they have discussed if it is better to have on-site or off-site renewable energy supply options [6].

2. SCOPE OF RESEARCH

Aim of the research is to investigate influence of surface convection algorithms used in EnergyPlus on prediction results. For inside algorithms used are TARP, Simple, Ceiling Diffuser, Adaptive Convection Algorithm. For outside algorithms used are Simple, TARP, DOE-2 and MoWiTT and Adaptive Convection algorithm.

2.1. EnergyPlus – Surface Convection Algorithm: Inside

This input object is used control the choice of models used for surface convection at the inside face of all the heat transfer surfaces in the model. This object sets the selection for convection correlations in a global way. The Zone Inside Convection Algorithm input field in the Zone object may be used to selectively override this value on a zone-by-zone basis. The model specified in this field is the default algorithm for the inside face all the surfaces. The key choices are Simple, TARP, Ceiling Diffuser, and Adaptive Convection Algorithm [7].

2.1.1. TARP

The TARP model correlates the heat transfer coefficient to the temperature difference for various orientations. This model is based on flat plate experiments.

2.1.2. Simple

The Simple model applies constant heat transfer coefficients depending on the surface orientation.

2.1.3. Ceiling Diffuser

The CeilingDiffuser model is a mixed and forced convection model for ceiling diffuser configurations. The model correlates the heat transfer coefficient to the air change rate for ceilings, walls and floors. These correlations are based on experiments performed in an isothermal room with a cold ceiling jet. To avoid discontinuities in surface heat transfer rate calculations, all of correlations have been extrapolated beyond the lower limit of the data set (3 ACH) to a natural convection limit that is applied during the hours when the system is off.

2.1.4. Adaptive Convection Algorithm

The Adaptive Convection Algorithm model is a dynamic algorithm that organizes a large number of different convection models and automatically selects the one that best applies.

The adaptive convection algorithm can also be customized using the Surface Convection Algorithm: Inside: Adaptive Model Selections input object. These models are explained in detail in the EnergyPlus Engineering Reference Document. The default is Adaptive Convection Algorithm.

2.2. EnergyPlus – Surface Convection Algorithm: Outside

Various exterior convection models may be selected for global use. The optional Zone Outside Convection Algorithm input field in the Zone object may be used to selectively override this value on a zone-by-zone basis. Further, individual surfaces can refine the choice by each surface or surface lists.

The available key choices are Simple Combined, TARP, MoWiTT, DOE-2, and Adaptive Convection Algorithm [7].

2.1.1. Simple

The Simple convection model applies heat transfer coefficients depending on the roughness and wind-speed. This is a combined heat transfer coefficient that includes radiation to sky, ground, and air. The correlation is based on Figure 1, Page 25.1 (Thermal and Water Vapor Transmission Data), 2001. ASHRAE Handbook of Fundamentals.

2.2.2. TARP

The TARP algorithm was developed for the TARP software and combines natural and wind driven convection correlations from laboratory measurements on flat plates.

2.2.3. DOE-2 and MoWiTT

The DOE-2 and MoWiTT were derived from field measurements. DOE-2 uses a correlation from measurements by Klems and Yazdanian for rough surfaces [8]. MoWiTT uses a correlation from measurements by Klems and Yazdanian for smooth surfaces and, therefore, is most appropriate for windows [8].

2.2.4. Adaptive Convection Algorithm

The Adaptive Convection Algorithm model is an dynamic algorithm that organizes a large number of different convection models and automatically selects the one that best applies.

The adaptive convection algorithm can also be customized using the Surface Convection Algorithm: Outside: Adaptive Model Selections input object. All algorithms are described more fully in the Engineering Reference of EnergyPlus [9].

2.3. Thermal and geometrical building description

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

System used for heating 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 and Time Step required for normal operation of the algorithm.

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.

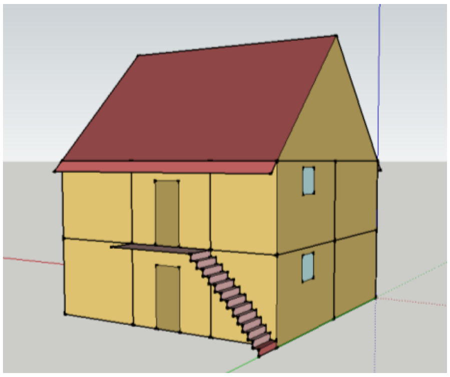

Figure 1. *Inspected house*

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.

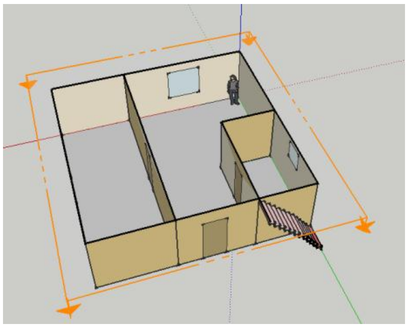

Figure 2. *Floor plan*

3. RESEARCH METHOD

3.1. About EnergyPlus software

EnergyPlus is a whole building energy simulation program that engineers, architects, and researchers use to model energy and water use in buildings. Modeling the performance of a building with EnergyPlus enables building professionals to optimize the building design to use less energy and water. Each version of EnergyPlus is tested extensively before release.

EnergyPlus models heating, cooling, lighting, ventilation, other energy flows, and water use. EnergyPlus includes many innovative simulation capabilities: time-steps less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems.

EnergyPlus runs on the Windows, Macintosh, and Linux platforms [10].

For the purpose of the simulations house models are created in Google SketchUp and then implemented in EnergyPlus by using OpenStudio plugin [11, 12].

3.2. Mathematics used

An average temperature for whole year in each room is calculated during a year for each month by following equation:

$$t_{r,m,ave} = \frac{\sum_{d=1}^{n} t_{h,r,m,d}}{d}, \qquad (2)$$

where $T_{r,m,ave}$ presents average temperature in each room type – r, for selected month – m. Average temperature is calculated for all days – d in selected month during simulation. Number of days in selected month is given by n.

The total heat consumption of the house presents an annual heat consumption of the heaters in the house to sustain the desired air temperature, as shown in the following equation:

$$E_u = \sum_{d=1}^{365} \sum_{h=1}^{24} E_{uhd}, \qquad (3)$$

where E_{uhd} for heat consumption in hour – h on day – d.

4. RESULT AND DISCUSSION

4.1. Production and Consumption Energy

Results show that difference in results between inside models of surface convection investigated there is no big difference for energy production from PV panels as expected. But considering consumption, ceiling diffuser is different from the rest of the three models for 2.2%. These results are given in figure 3.

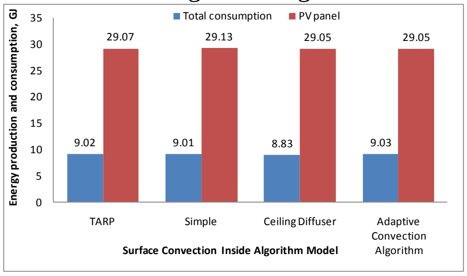

Figure 3. *Energy Production and Consumption for Inside algorithms*

As for the outside surface convection models the biggest production is when adaptive convection algorithm is used and the smallest is for simple combined algorithm (Fig. 4). Difference between those two is 1.2%. As for consumption same as in case of production adaptive algorithm has the biggest consumption and the simple combined algorithm has smallest consumption just like MoWiTT algorithm. Difference between them two is around 3%.

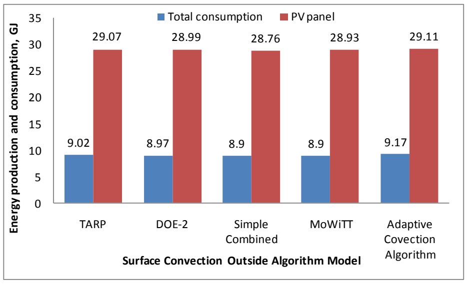

Figure 4. *Energy Production and Consumption for Outside algorithms*

4.2. Duration of the simulation

Values obtained by simulation plays an important role and the duration of the simulation is also important. Simulation for TARP inside algorithm lasts for minute more than other inside convection algorithm or about 22%-25% more time (Fig. 5).

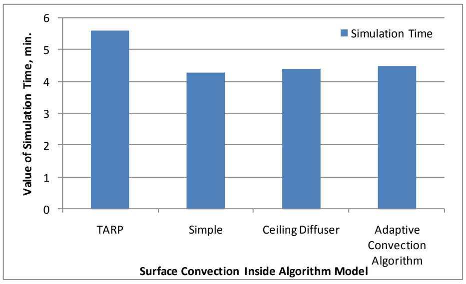

Figure 5. *Duration of simulation for different Inside algorithms*

For outside convection algorithm used, fastest time was for adaptive convection algorithm (Fig. 6). Simple Combined time was almost the same. But, times for DOE-2 and MoWiTT was about 20% longer and for TARP even 25% longer.

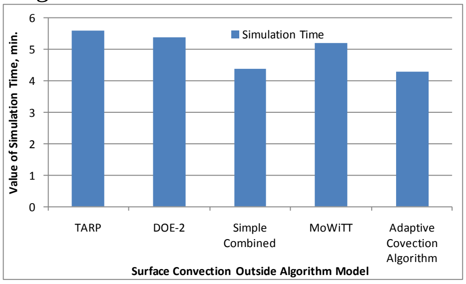

Figure 6. *Duration of simulation for different Outside algorithms*

4.3. Temperature

When inside algorithms were changed

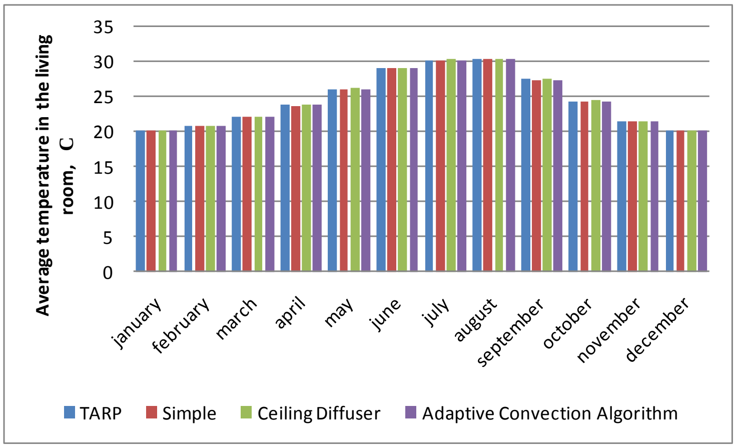

Figure 7. *Average temperature in the living room by months for different models for Consumption for different Surface Convection Algorithm Inside*

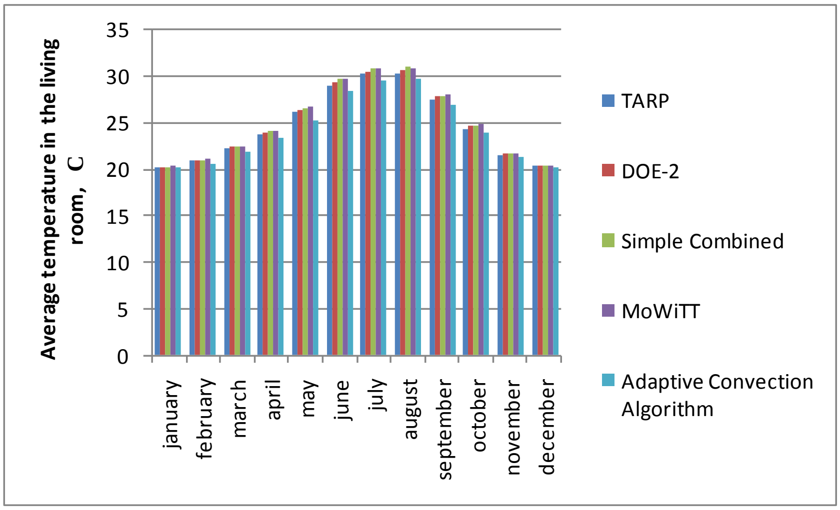

Figure 8. *Average temperature in the living room by months for different models for Consumption for different Surface Convection Algorithm Outside*

average temperature in living room was almost the same for all algorithms (Fig. 7).

But when outside algorithms were changed it can be seen that average during summer months can be different up to 1°C for different algorithms and up to 0.5°C during winter days. Summer days are not conditioned and therefore this can happen during them (Fig. 8).

5. CONCLUSIONS

By all results given, it can be said that best performance are achieved by using adaptive convection algorithms for both inside and outside surfaces convection.

By using the adaptive convection algorithm software decides which algorithm is the best for the given problem and uses it.

For this model it had the shortest time of simulation and results were almost the same as for the other algorithms. Results were within the 0.5% to 3% for energy production and consumption, and for the average temperature.

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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.