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OPTIMIZATION OF LOW-RISE BUILDING GEOMETRICAL FORMS IN DESIGN BUILDER

Abstract:*This paper is oriented on maximizing the beneficial, and minimizing the negative effects in creating energy efficient buildings. Optimization is performed in Design Builder software based on various criteria. A building was modeled for the needs of this research using standard materials and systems built into the software. For the created object which hill be the subject of the experiment a minimization of* CO_2*emissions, minimization of building and installation costs, while energy efficiency has been maximized. System variables are chosen to be only the ones with the most influence on the optimization process. Using the Pareto optimum specific values are suggested for the most desirable final model. This is a perspective approach for analyzing and predicting the behavior of energy efficient buildings, in order to have their exploitation benefit from an overall life comfort.*
Keywords:*Design Builder, energy efficiency, building form, optimization.*

1.INTRODUCTION

The problem of building an energy efficient building is of great importance for energy savings and a decrease of pollution. Today, a large number of scientists is working on these problems from various aspects. In the paper [1] authors have simulated how the use of solar panels could make a building closer to a zero-net energy use. Authors of paper [2] have worked on researching typical family houses in Lithuania and how the number of occupants influences energy efficiency. In Teheran [3] research on how window area and glass type, as well as overhang influence energy efficiency in heating a house. Research on the subject of achieving a zero-net energy consumption, using solar photovoltaic panels conducted in Serbia [4]. In paper [5] authors have investigated energy efficiency and achieving zero-net energy consumption, in COMIS software from an aspect of ventilating a house. The decrease of energy use can also be completed using various isolation materials [6]. For houses and other buildings which are heated CO_2 emissions are also taken into consideration. The reduction of CO_2 emissions can be achieved through the use of various heating systems depending on the house structure, [7]. In order to decrease CO2 emissions a lot of attention is given to renewable energy sources, for example solar fields, [8].

One of the practically applicable approaches to and improvement in energy efficiency is definitely multi-criterion optimization. In paper [9], authors have completed a multi-criterion optimization in Design Builder software.

This paper also covers a multi-criterion optimization in Design Builder software. As a goal function a Pareto optimum of CO2 emission minimization and number of discomfort hours per year has been determined with the following variables: type of heating system, shading coefficient and window type. Optimization is performed for two types of house base with the same base area. The paper concludes with a discussion of results, reached conclusions and gives directions for further research.

2. PROBLEM STATEMENT

At the start of this research a question was asked of weather houses with the same base areas, and different base shapes are equal in energy efficiency. This is where the base motivation for developing this paper came from. The research is based on real house projects, so it can have a great use in real world application.

2.1 Basic assumptions on the geometrical shape of the house

This research is conducted on two types of houses. The first house is of a rectangular base, while the other house is with an L shaped base. Both houses have a pitched roof. The orientation of both houses is the same. Both houses have the same surface area of outward facing windows and doors.

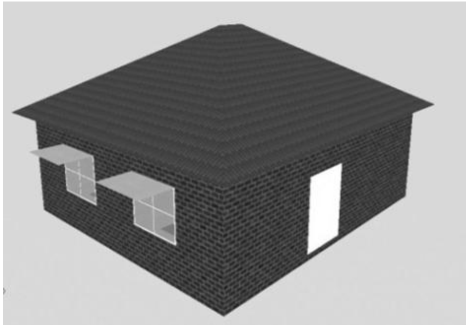
2.2Basic assumptions on the house energy system

Energy characteristics are equally input for both houses:

- same heating systems are installed,
- the same lighting use is input,
- the same kitchen appliance heat influence is input,
- the same heating influence of other electrical appliances is input.

3. MODELS OF ANALYZED HOUSES

Models of the houses are designed and analyzed in Design Builder. The model and house with the square base and the L based house are shown in figure 1. The base are of the square and L house is 60 m^2 each.



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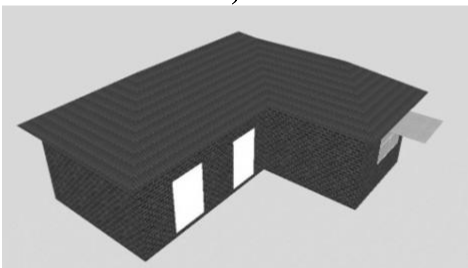

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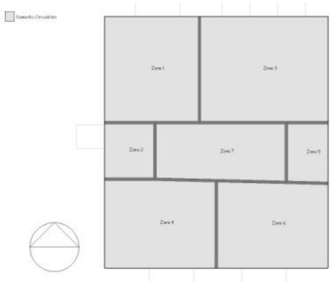
Figure 1 -House models a) square base house; b) L base house

On both house models initially basic heating system analysis were performed as well as basic simulations for the entire year for the area of Belgrade, Serbia. After this an optimization of both models has been performed.

Both houses are adapted, according to the layout of the rooms for a four member family. Both house layouts contain following: hallway, bathroom, living room with dining room and kitchen, and two bed rooms. The floor plan layouts are as shown in figure 2.



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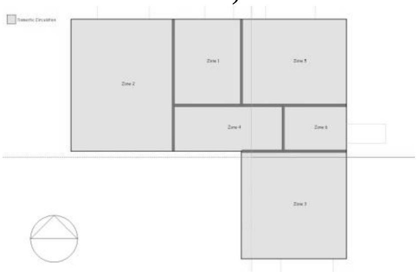

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Figure 2 -Floor plan a) square based; b) L base house

For all rooms in both houses have outward facing windows with overhangs which prevent excessive heating of the house through windowed areas.

4. RESULTS

All calculation and simulation results are derived from Design Builder software. All calculations and simulations in Design Builder are done in Energy Plus. For this optimization with various variables, which influence building and exploitation quality of the house, in Design builder software a module which optimizes using the genetic algorithm has been developed.

4.1 Previous calculation of energy consumption

While modeling the houses as well as the basic systems on both houses a thermo-accumulative heater system has been put in place. Heating with thermo-accumulative heaters uses electric energy for generating heat. The results of the previous heating calculations are shown in table 1.

Table 1 - Previous calculation of heating for both houses

	Square House			L House		
Room name	Comfort temperature [C^0]	Steady state heat loss [kW]	Design capacity [kW]	Comfort temperature [C^0]	Steady state heat loss [kW]	Design capacity [kW]
Hallway	19,60	1,84	2,30	19,22	1,06	1,32
Bathroom	19.68	0.48	0.60	19,59	0,58	0,73
Sleeping r. 1	19.29	1.69	2.11	18,49	2,48	3,10
Sleeping r. 2	19.28	1.65	2.06	19,03	1,88	2,35
Living room	19.29	2.33	2.92	18,49	2,97	3,71
Kitchen	19.29	1.72	2.15	19,54	1,16	1,46
	∑	9.71	12.14	∑	10,13	12,67

4.2Optimization of heating and window tinting parameters

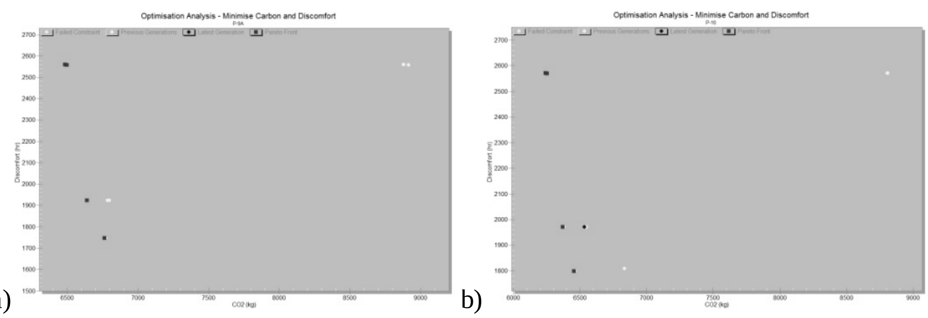
In order to make a choice between these two types of houses, an optimization of both types must first be performed. The optimization of both house types is performed in order to determine their maximal energy efficiency according to the choice of the following parameters which are closely related:

- heating system,
- type of installed windows,
- tinting coefficientand

- area which windows take up on the outside walls.

Before optimizing with initial CO_2emission parameters for the house with a square base was 8880 kg per year, while the number of discomfort hours was 2559, also on a yearly level. for the L based house CO_2emission before optimization was8806 kg yearly, while the number of discomfort hours was 2571.

Optimization in Design Builder software is done using the Genetic algorithm method. The completed optimization gives a Pareto optimum. In the placement of changeable heating systems eight systems based on radiator systems based on floor heating, air heating and others. For window type variables five types were adopted: aluminum windows, aluminum windows with a thermal break, wooden windows, lacquered wooden windows and PVC windows.tinting coefficient is set from 0 to 1.5, while the area of external windows is set from 20 to 80% of the outer walls. The goal function is set to minimize CO_2 emissions and to minimize the number of discomfort hours in the house during the year. The number of discomfort hours in the house per year represents the number of hours when the conditions in the house vary over 10% from the ideal values. Graphs of the completed optimization are shown in figure 3.



a) b)

Figure 3 - Pareto optimum a) square based house; b) L based house

In the Pareto optimization of the house with a square base CO_2 emissions range from 6483kg to 8915kg yearly. The number of discomfort hours ranges from 1747 to 2559 hours yearly. As a Pareto optimum according to the lowest CO_2 emissions the following parameters were obtained: 42% window coverage on external walls, floor heating with natural ventilation, tinting coefficient of 0.240 and the choice of laquered wodden windows with a CO_2 emmision of 6483 kg per year and a number of discomfort hours of 2559 hours per year.

In the Pareto optimization of the house with a L base CO_2 emissions range from 6242kg to 8808kg yearly. The number of discomfort hours ranges from 1799 to 2571 hours yearly. As a Pareto optimum according to the lowest CO_2 emissions the following parameters were obtained: 59% window coverage on external walls, radiator heating with natural ventilation, tinting coefficient of 0.242 and the choice of PVC windows with a CO_2 emmision of 6242 kg per year and a number of discomfort hours of 2571 hours per year.

4.3 Final calculation of heating consumption

Upon the completed optimization a final calculation was performed of the heating system consumption. The optimal solution of window coverage for the external walls is different for both house. The L based house needs a larger window area on external walls. The square based house was optimized for a floor heating system which is different from the initially selected heating system using radiators. The L based house kept the same heating system. With the optimal choice of windows there is an obvious difference. The square based house has an optimal use of lacquered wooden windows, while the L based house has an optimal solution which involves PVC windows. Tinting coefficients do not differ much for both housing types. Results of the completed calculation are shown in table2.

Table 2-Final calculation for heating of both houses

	Square House			L House		
Room name	Comfort temperature [C^0]	Steady state heat loss [kW]	Design capacity [kW]	Comfort temperature [C^0]	Steady state heat loss [kW]	Design capacity [kW]
Hallway	19,29	1,86	2,34	19,25	1,05	1,31
Bathroom	19,58	0,49	0,61	19,69	0,57	0,71
Sleeping r. 1	18,94	1,80	2,25	18,79	2,34	2,92
Sleeping r. 2	18,93	1,76	2,20	19,23	1,8	2,25
Living room	18,92	2,48	3,10	18,66	2,87	3,59
Kitchen	18,85	1,87	2,34	19,63	1,14	1,42
	∑	10,26	12,84	∑	9,77	12,2

5. CONCLUSION

Comparing initial parameters to CO_2 emissions for houses with a square base and L based houseit can be seen that pollution for the L based house is less by approximately 0.83%, in the initial conditions before optimization. The number of discomfort hours is almost equal for both houses. After optimization for the house with a square base CO_2 emissions are lowered by 27%, while with the L based house the decrease is 29%. The number of discomfort hours stays almost equal for both houses. Comparing CO_2 emissions between both houses after optimization.the house with the L base has an approximately 4% mower CO_2 emission compared to the square base house.

Comparing necessary power for heating systems before and after optimization for the house with a square base, after optimization 6% more power is necessary for heating. Comparing necessary power for heating systems after optimization for the L based house 4% less heating power is necessary.

The completed optimization according to these criterion concludes that from an aspect of minimizing CO_2 emissions it is better to build an L based house. A large benefit of this house with an L base would be in the lower heating consumption. Comparing necessary power values, the L based house, after optimization has a 6% lower consumption than the square based house.

Further research in this field would be based on using other geometric shapes for the house base.

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