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Energy Performance Analysis using EnergyPlus for an Office Building

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SUMMARY

In the last couple of years, people noticed a breakdown of energy resources. Therefore many stakeholders have realised the importance of energy efficiency and came up with ideas on how we should use the resources more efficiently. The building sector is one of the energy consumers around the world, according to IEA (International Energy Agency) with 32% of total energy consumption. In the case of lighting systems, energy consumption can be determined precisely because it does not resonate with other consumers. Organizations invested a lot of money in solutions that will help improve environmental aspects, considering economic factors. Pollution and energy consumption became an essential issue in the recent years. Therefore people needed to come up with ideas to remove all the negative aspects of the current environmental situation. There are numerous sources of uncertainty about the building which need to be addressed. Deterministic simulations are used to estimate the potential performance of a building. For a more accurate determination of energy consumption, considering weather conditions, cooling systems or lighting systems, the solution is EnergyPlus. EnergyPlus is the next generation of the modeling programs, supported and maintained by a team founded by USDOE (U.S. Department of Education), used by engineers, architects and researchers which gathers multiple modules which work together in order to analyze and simulate the energy consumption, like heating, cooling, ventilation, lighting, connection and processing tasks, and heat load inside buildings. Based on the user-entered sketch of the building, EnergyPlus calculates the heating and cooling loads needed to maintain the temperature control, the conditions in a secondary HVAC (Heating, Ventilation and Air Conditioning) system and the coil loads. In the paper, we present a case study on an office building using the simulation manager module which describes the heat balance process, air loop/plant loop and other processes. The simulation model involves a complex set of data such as general information on the building, the number of users or the energy consumed by the utilities. Location and necessary information of the structure such as details on the lighting system must be introduced at the beginning to start de analyse. Since the EnergyPlus is an integrated simulation, we demonstrate how all three of the significant parts must be solved at the same time to obtain a simulation which is physically realistic. EnergyPlus has the benefit that it makes easy for both developer and user, because of its graphical interface, to add new features and modules. The data described performance characteristics are intended to be used in the simulation and the developers can include different comments, types of throughout their input data files. The primary purpose of this article is to use the open-source simulation tool, Energy Plus, and try to quantify the energy performance in office buildings. In terms of building's retrofit, non-residential buildings clearly represent a challenging category. An office building, as a type of non-residential building, requires simultaneous production of chilled and hot water. The results show that the usage of more detailed simulation routines improves the building's design for energy optimisation.

KEYWORDS

Energy consumption, Energy simulation, EnergyPlus, HVAC

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1. INTRODUCTION

EnergyPlus is a simulation program that allows the user to understand the energy consumption better. As nowadays buildings tend to occupy an essential place in each city life, the economic and the environmental aspects must be taken into consideration to reduce costs and to improve the quality of people's lives. According to recent studies, around 20-40% of the total energy consumed by users in advanced countries comes from buildings [1]. The same research shows that the energy which is consumed in buildings can reach even 40% of the total power, exceeding in some cases sectors such as the transportation one. This percentage comes from lighting, equipment or HVAC systems.

Moreover, Brunei Darussalam, which is a buildings sector, reported in 2012 that its industry occupied 39% of the National energy use [2]. Due to recent changes in the environment, problems such as pollution or heating of the atmosphere became frequent.

The first step of the process is to understand the energy consumption to predict and improve it later. Later, future upgrade approaches must be taken into account.
The study focuses on the integrated control of electric lighting and its impact on building energy consumption using building simulation models. We have limited it to a single type of building and climate zone because we want to show a concrete example of how EnergyPlus works.
Fig. 1 shows the overall software structure. The simulation manager, which includes the heat and mass balance and the building system simulation module, controls the entire simulation process.

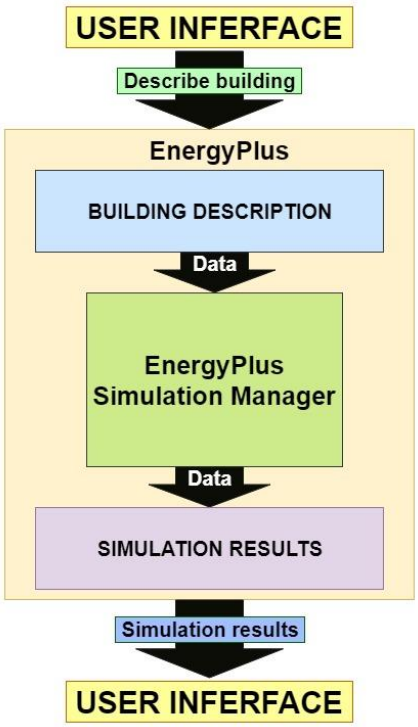

Fig. 1 - The overall of EnergyPlus software

The main advantage of EnergyPlus is that it has new, structured, modular code which is easy to use for developers which can add new modules and algorithms. Also, EnergyPlus allows the use of Phase Change Materials (PCM) in different applications/methods.

This paper is divided as it follows. Section 2 presents some background regarding energy simulation programs. Section 3 presents the EnergyPlus software and our simulations and results. The conclusions are presented in Section 4.

2. RELATED WORK

Most of the popular building energy simulation programs are no longer supported/used because of the current requirements. Some of them use methods and code that originated in the 1960s.

According to [3] by 2020 “positive energy” building will become the norm. In addition to this, energy-plus buildings will make extensive use of renewable energy.
There are two main simulation programs which are similar to EnergyPlus, DOE-2 and BLAST which have been used throughout the world. The difference between these programs is the load calculation method, DOE-2 uses a room weighting factor approach and BLAST uses a heat balance approach.

Each program comprises hundreds of subroutines which can simulate heat and mass-energy flows throughout a building. Even if both software programs have subroutines which are accurate, they became expensive to maintain, modify and enhance.

EnergyPlus is based on system algorithms from DOE-2 and the load algorithms from BLAST and several other modules reengineered for the inclusion on EnergyPlus. Also, new features were added to create well-organised modular structures [4], [5].

A system [6] that measures durability in several buildings has been developed. This involves a study of how several resources such as energy or water are consumed in a building. For this purpose, was used BRE Environmental Assessment Method (BREEAM) which will help managers improve environmental aspects of their office buildings. Another project involved 20 countries in developing a standard which will improve the way we are using resources. Therefore, they used a spreadsheet tool called GBTool where they stated performance criteria such as the energy consumption to highlight common problems in buildings. They also considered the economic aspects and how the implementations of the presented solutions will affect the company’s budget [6].

In [7] for a rural residential model situated in Shenyang it is established the simulation of the buildings using DesignBuilder [8] which is a software based on EnergyPlus [9], but with a user-friendly interface. It was used only for a rural pilot experiment. EnergyPlus [9] is used for engineers because of its integrated set of high-productivity tools used to assist suitable building design.

3. ENERGYPLUS. SIMULATION AND RESULTS

EnergyPlus [9] is software that engineers, architects and researchers use to analyze and simulate energy consumption and heat load inside buildings. Files are introduced by the user considering the map of the building and the weather conditions. EnergyPlus [9] will evaluate the resources needed to maintain a constant temperature in the building.

EnergyPlus [9] disposes of some utilities, including IDF-Editor to create input folders using a simple interface with spreadsheets. Moreover, they use EP to managing the input and the output files and EP-Compare to analyse the graphical results of two or more simulations.
EnergyPlus [9] is a free, open-source program which runs on Windows [10], Mac OS X [11] and Linux [12]. The installation of EP-Launch Windows is mandatory (it is not available for Linux [12] and Mac [11]). EP-Launch offers a simple way to select and run the files coming from Energy Plus [9]. EP-Launch is localised in the main folder. By accessing it on the screen, there will be shown the EP-Launch graphical interface to run a single input file (**Fig. 2**).

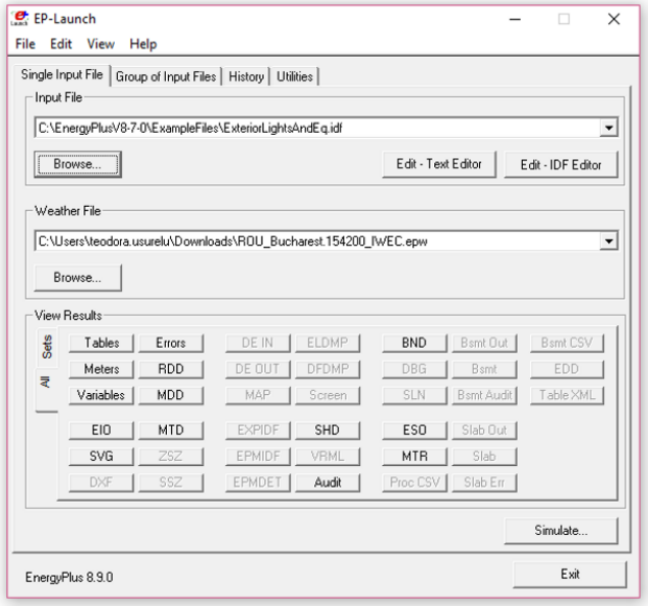

Fig. 2 - Graphical interface of EnergyPlus software

There has been used in the scheme of Beia Consult International [13] building as “Input File” to test the EnergyPlus [9] software, The weather file was selected after accessing Weather File->Browse and then “ROU_Bucharest.154200_IWEC.epw”. After selecting the files, in the “Single Input File” tab, one will push the button “Simulate…” that will start the process of simulating the consumed energy within the building. A DOS window (**Fig. 3**), which shows the progress of the simulation, will be displayed on the screen. The simulation is complete when the window closes.

Fig. 3 - DOS Window

Once the simulation has ended a status message (**Fig. 4**) will be displayed on the screen which will offer an insight into an error that occurred during the execution. Moreover, the time of the performance will be shown.

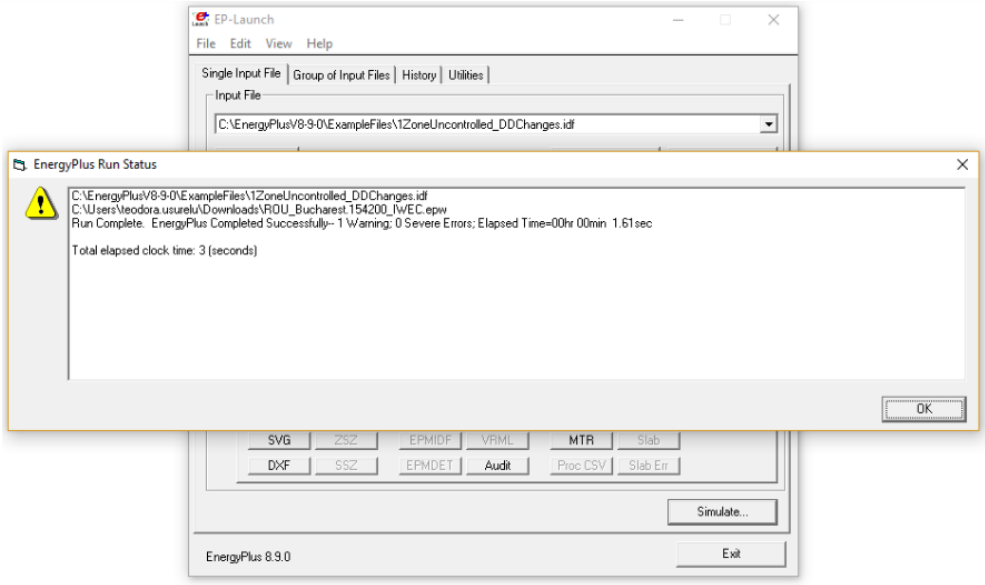

Fig. 4 - Status message

After pressing OK, the option "ERR / EIO / BND Output Files Only" will be selected from the View menu. ERR, EIO (**Fig. 5**) files contain details about the simulation process and about errors that occurred during the installation.

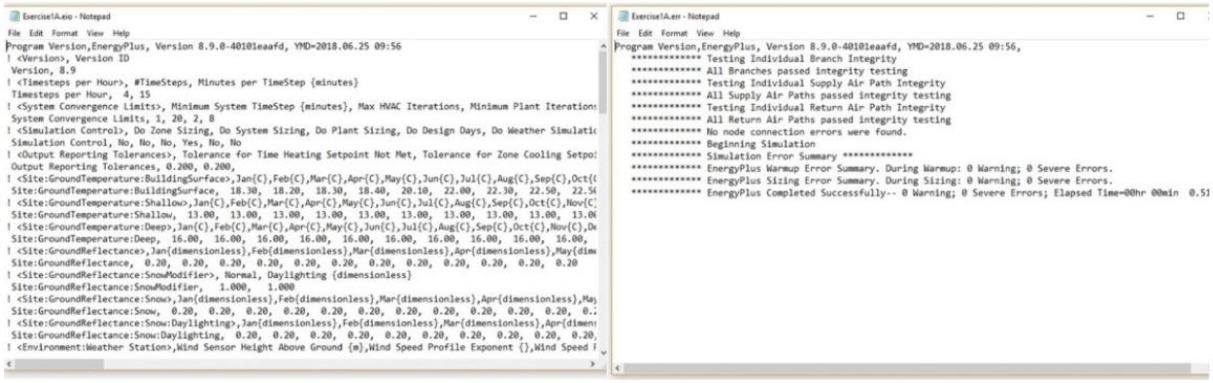

Fig. 5 - .eio and .err files

The input file, called IDF, can be edited by choosing one of the two buttons in the "Input File" menu. The "Edit - Text Editor" button will start a text editor and "Edit - IDF Editor" will open the program called IDF Editor. Any changes made to the editor must be saved before running the simulation.
The sketch of the building (**Fig. 6**) can be viewed directly from the "View Results" field by pressing the "Drawing File" button, having already installed one of the following software Voloview Express [14] or DWG True View [15].

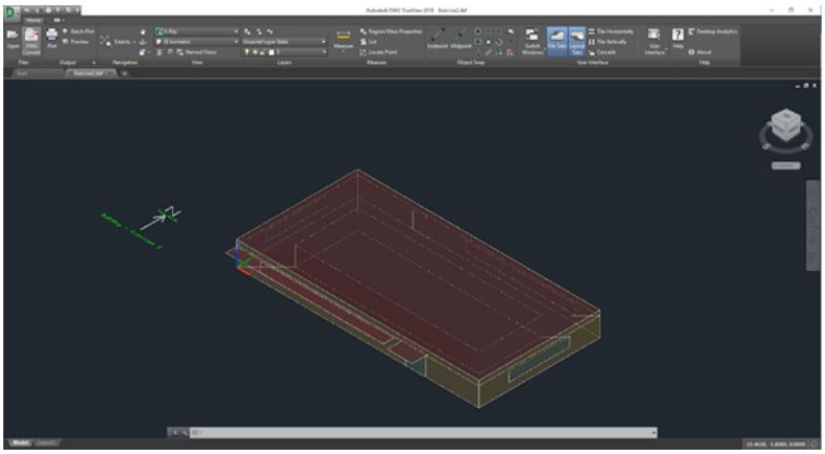

Fig. 6 - Outline of the building

The "Spreadsheets" button opens the files with csv extension which contain numeric data related to the outside and inside conditions of the building and data of the heating and cooling system. The displayed results are generated for a summer day (July 21) and for a winter day (January 21) hour by hour, so that the temperature difference between outside and inside the building can be as high as possible (**Fig. 7**).
On the left side of **Fig. 7**, are the outside air temperature (Zone Air Temperature) for two days, one of the warm season (21 July) and the other during the cold season (January 21), for better data comparison. In the warm season, the temperature difference between outside and inside the building varies between 1 and 8 °C. In the cold season, the outside temperature of the building is -21 °C, and the temperature inside the building is 20 °C.
On the right side of **Fig. 7**, in the warm season, an intense use of the cooling system is observed from 9:00 a.m-8:00 p.m. During the cold season the heating system was used without interruption.
The measurements on the consumption of the cooling system and the heating system are shown in **Fig. 7**.

	Date/Time	Environment:Site Outdoor Air Drybulb Temperature [C](Hourly)	ZONE ONE:Zone Air Temperature [C](Hourly)
2	07/21 01:00:00	23.453249999999998	22.083927484519806
3	07/21 02:00:00	22.935499999999999	21.926930809516049
4	07/21 03:00:00	22.567625	21.805778314966479
5	07/21 04:00:00	22.240624999999999	21.712902214611299
6	07/21 05:00:00	21.981749999999999	21.6357305355238
7	07/21 06:00:00	22.036249999999997	21.70864743762628
8	07/21 07:00:00	22.594875	22.430803096463536
9	07/21 08:00:00	24.039124999999996	23.413280113343819
10	07/21 09:00:00	26.028374999999998	23.986248441545765
11	07/21 10:00:00	27.963124999999999	23.999999996612855
12	07/21 11:00:00	29.679874999999997	23.999999999999969
13	07/21 12:00:00	30.974249999999999	23.999999999999987
14	07/21 13:00:00	31.927999999999999	24.000000000000001
15	07/21 14:00:00	32.595625	24.000000000000055
16	07/21 15:00:00	32.8	24.0
17	07/21 16:00:00	32.39125	24.000000000000005
18	07/21 17:00:00	31.601	24.000000000000001
19	07/21 18:00:00	30.592749999999996	24.0
20	07/21 19:00:00	29.162124999999997	23.999999999999998
21	07/21 20:00:00	27.799624999999997	23.948265252591466
22	07/21 21:00:00	26.736874999999999	23.442120624484319
23	07/21 22:00:00	25.755874999999997	22.940706756969976
24	07/21 23:00:00	24.911125	22.576679001787773
25	07/21 24:00:00	24.148124999999998	22.29410432901790
26	01/21 01:00:00	-21.2	20.0
27	01/21 02:00:00	-21.2	20.0
28	01/21 03:00:00	-21.2	20.0
29	01/21 04:00:00	-21.2	20.0
30	01/21 05:00:00	-21.2	20.0
31	01/21 06:00:00	-21.2	20.0
32	01/21 07:00:00	-21.2	20.0
33	01/21 08:00:00	-21.2	20.0
34	01/21 09:00:00	-21.2	20.0
35	01/21 10:00:00	-21.2	20.0
36	01/21 11:00:00	-21.2	20.0
37	01/21 12:00:00	-21.2	20.0
38	01/21 13:00:00	-21.2	20.0
39	01/21 14:00:00	-21.2	20.0
40	01/21 15:00:00	-21.2	20.0
41	01/21 16:00:00	-21.2	20.0
42	01/21 17:00:00	-21.2	20.0
43	01/21 18:00:00	-21.2	20.0
44	01/21 19:00:00	-21.2	20.0
45	01/21 20:00:00	-21.2	20.0
46	01/21 21:00:00	-21.2	20.0
47	01/21 22:00:00	-21.2	20.0
48	01/21 23:00:00	-21.2	20.0
49	01/21 24:00:00	-21.2	20.0

	Date/Time	DistrictHeating:Facility [J](Hourly)	DistrictCooling:Facility [J](Hourly)
2	07/21 01:00:00	0.0	0.0
3	07/21 02:00:00	0.0	0.0
4	07/21 03:00:00	0.0	0.0
5	07/21 04:00:00	0.0	0.0
6	07/21 05:00:00	0.0	0.0
7	07/21 06:00:00	0.0	0.0
8	07/21 07:00:00	0.0	0.0
9	07/21 08:00:00	0.0	0.0
10	07/21 09:00:00	2.4581936486356427e-8	279155.2517023405
11	07/21 10:00:00	3.2562752494413387e-8	907227.4324245912
12	07/21 11:00:00	3.8573944038944324e-8	1371022.5195170374
13	07/21 12:00:00	0.0	1626344.4728549787
14	07/21 13:00:00	5.7195848057745027e-8	1750387.9732436639
15	07/21 14:00:00	7.7864115155534826e-8	1921664.5605778192
16	07/21 15:00:00	1.5245404938466711e-8	2009492.1096181067
17	07/21 16:00:00	0.0	1918168.5829742705
18	07/21 17:00:00	5.586571205640212e-8	1635419.6642467334
19	07/21 18:00:00	3.2281377757105287e-8	1286232.4854689094
20	07/21 19:00:00	1.2047962627548259e-8	750213.9569790105
21	07/21 20:00:00	5.051958851254312e-10	76911.31018807335
22	07/21 21:00:00	0.0	0.0
23	07/21 22:00:00	0.0	0.0
24	07/21 23:00:00	0.0	0.0
25	07/21 24:00:00	0.0	0.0
26	01/21 01:00:00	5884000.995536374	1.6350441001122818e-7
27	01/21 02:00:00	5884000.995536374	1.6350441001122818e-7
28	01/21 03:00:00	5884000.995536376	1.6370904631912709e-7
29	01/21 04:00:00	5884000.995536372	1.6329977370332927e-7
30	01/21 05:00:00	5884000.995536376	1.6370904631912709e-7
31	01/21 06:00:00	5884000.995536372	1.6329977370332927e-7
32	01/21 07:00:00	5884000.995536376	1.6370904631912709e-7
33	01/21 08:00:00	5884000.995536374	1.6350441001122818e-7
34	01/21 09:00:00	5884000.995536374	1.6350441001122818e-7
35	01/21 10:00:00	5884000.995536374	1.6350441001122818e-7
36	01/21 11:00:00	5884000.995536374	1.6350441001122818e-7
37	01/21 12:00:00	5884000.995536376	1.6370904631912709e-7
38	01/21 13:00:00	5884000.995536372	1.6329977370332927e-7
39	01/21 14:00:00	5884000.995536376	1.6370904631912709e-7
40	01/21 15:00:00	5884000.995536372	1.6329977370332927e-7
41	01/21 16:00:00	5884000.995536376	1.6370904631912709e-7
42	01/21 17:00:00	5884000.995536374	1.6350441001122818e-7
43	01/21 18:00:00	5884000.995536374	1.6350441001122818e-7
44	01/21 19:00:00	5884000.995536374	1.6350441001122818e-7
45	01/21 20:00:00	5884000.995536374	1.6350441001122818e-7
46	01/21 21:00:00	5884000.995536376	1.6370904631912709e-7
47	01/21 22:00:00	5884000.995536372	1.6329977370332927e-7
48	01/21 23:00:00	5884000.995536376	1.6370904631912709e-7
49	01/21 24:00:00	5884000.995536372	1.6329977370332927e-7

Fig. 7 - Temperature from inside and outside the building (on the left) Usage of the cooling and heating system from the building (on the right)

4. CONCLUSION

Efficiently using the resources has never been such an important issue until now. Therefore, managers are trying to come up with ideas that might solve the resources issues that occured in the last years.
In this paper, we presented how EnergyPlus, an open source program, can help one understand the how the consumption of the energy works and what investments should be made in order improve the management of the energy in office buildings. EnergyPlus is a powerful energy consumption simulation analysis software which combines the best features of BLAST and DOE-2 programs and represents a significant step forward for computational techniques and program structures.
For this paper were taken several sets of data in order to evaluate the diagnostic power of the building, in different seasons for the demonstration of the practicability of using EnergyPlus to identify energy wastage of an office building, but more sets of daily consumption data are needed for a more detailed analysis. As future work, we will try to develop a methodology in order to reduce EnergyPlus simulation runtime.

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BIBLIOGRAPHY

[1] Yi-kai, J.; Peng G. and Jie W. "A hybrid decision support system for sustainable office building renovation and energy performance improvement". (Energy and Buildings, Vol. 42, 2010, pages 290-297)

[2] Shabunko V.; Lim C. M. and Mathew S. "EnergyPlus models for the benchmarking of residential buildings in Brunei Darussalam" (Energy and Buildings, Vol. 169, 2018, pages 507-516)

[3] Energy-Plus buidlings soon the norm. Available on: https://atelier.bnpparibas/en/prospective/article/energy-plus-buildings-norm

[4] Zhu D.; Tianzhen H.; Yan D. and Wang C. "Z. A detailed loads comparison of three building energy modeling programs: EnergyPlus, DeST and DOE-2.1E". (Building Simulation, Vol. 6, 2013, pages 323-335)

[5] Simulation Research Group. "DOE-2. Modeling Tips".(Building Energy Simulation User News, Vol. 23, 2002, pages 60-65)

[6] Juan Y. K.; Gao P. and Wang J. "A hybrid decision support system for sustainable office building renovation and energy performance improvement". (Energy and Buildings, Vol. 42, 2010, pages 290-297)

[7] Shui Y.; Yumeng C.; Xiaolong X. and Guohui F. "Impact of Civil Envelope on Energy Consumption based on EnergyPlus". (Procedia Engineering, Vol. 121, 2015, pages 1528-1534)

[8] Design Builder software. Available on: https://www.designbuilder.co.uk.

[9] EnergyPlus software. Available on: https://energyplus.net/downloads

[10] Windows Operation System. Available on: https://www.microsoft.com/en-us/windows

[11] MAC Operation System X. Available on: https://support.apple.com/downloads

[12] Linux Operation System. Available on: https://www.ubuntu.com/download/desktop

[13] BEIA Consult International. Available on: http://www.agile.ro/beia/en/index.html

[14] Voloview Express software. Available on: https://volo-view.en.softonic.com/

[15] DWG True View. Available on: https://www.autodesk.com/products/dwg/viewers