Revista Română de Inginerie Civilă, Volumul 14 (2023), Numărul 3

Comparative study of two heating/cooling systems for an office building using Design Builder software

Studiu comparativ a două sisteme de încălzire/răcire pentru o clădire de birouri utilizând software-ul Design Builder

Mirela Țoropoc [1], Adriana Tokar [2], Dănuț Tokar [2], Mihai Cinca [2], Marius Florin Oprea[1]

[1] Technical University of Civil Engineering Bucharest
Bd. Lacul Tei No. 122 - 124, 020396, Sector 2, Bucharest
E-mail: mirela.toropoc@utcb.ro

[2] Politehnica University Timisoara
Square Victoriei No. 2, 300006 Timisoara, Timis county, Romania
E-mail: adriana.tokar@upt.ro, danut.tokar@upt.ro, mihai.cinca@upt.ro

DOI: 10.37789/rjce.2023.14.3.12

Abstract. *The buildings sector is responsible for the largest percentage of total energy consumption, especially for heating and cooling. For this reason, the paper compares two heating/cooling systems (multisplit VRF and respectively chiller, central heating and fan coil units) for an office building. Energy consumption for heating/cooling, domestic hot water preparation and lighting, expressed in MWh/year, was analyzed. Following the simulation, the VRF air-conditioning system, which registers a global consumption of 70.23 MWh/year, compared to the system with a chiller, thermal plant and fan coil units, which registers a global consumption of 81.25 MWh/year, was found more advatageous.*

Key words: global energy consumption, heating, cooling, building

1. Introduction

Energy consumption has become a global issue in recent years. Of the total energy consumption of the European Union member states, approximately 40-45% is used in residential and commercial buildings, which means that the building sector is responsible for approximately 36% of total carbon dioxide emissions [1], [2], [3], [4], [5], [6], [7].

The Kyoto Protocol emphasizes improving energy efficiency and also solving major problems that can affect the environment, mainly through efficient management of resources and costs and reduction of carbon dioxide (CO2) emissions [8].

The existing building stock in Europe represents approximately 35,000,000 square meters of built-up area, i.e. a large part of this area (more than 80%) was built before 1975. In addition, 18% of the existing building stock was built after the 1990s. This fact explains the very high consumption of European buildings, 60% of these buildings being residential characterized by an energy consumption of primary energy around 190 kWh/(m^2an year).

Taking into account the current context of sustainable development and the most efficient use of energy worldwide, it was proposed to construct buildings in which energy consumption is as low as possible or almost equal to zero, a requirement in the course of mandatory implementation starting from December 31, 2018 for public buildings and 31 December 2020 for all types of buildings.

Thus, by reducing consumption in buildings, a nation can reduce its dependence on imported energy and strengthen its strategic position at an international level. The "energy efficiency" criterion is understood by the European Union to be a good way of establishing long-term energy security.

2. The description of the analyzed building

The studied building was constructed in 2014, and falls into the category of open space office buildings, with a S + GF + 4F height regime and a total area of each floor of 229 sqm (Fig.1).

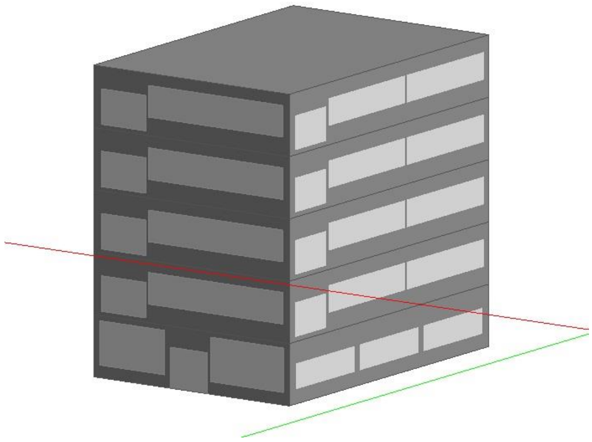


Fig.1. Analyzed building

The constructive structure is of the reinforced concrete frames type, the masonry is made of brick plastered with lime and cement mortar, thermally insulated. The terrace is passable with gravel, thermally insulated and waterproofed with bitumen cardboard. The interior walls and floors are made of reinforced concrete. The exterior carpentry is made of PVC, wood and metal.

3. Simulation of air conditioning systems with the help of Design Builder

Solution 1 – VRF air conditioning system

For indoor spaces that require air conditioning, a multisplit VRF system will be provided, operating with ecological refrigerants. The indoor units are non-encased and will be mounted buried in the false ceiling, for all areas of the building. The outdoor units will be mounted on the terrace of the building. The air conditioning system will work both in the cooling system (up to outside temperatures of +43ºC) and in the heating system (up to minimum temperatures of -25ºC). The connections between the indoor units and the outdoor units are made of Cu pipe and insulated with Armaflex.

Solution 2 - Water-based air-conditioning system, air-cooled chiller and unheated 4-pipe fan-coil indoor units

The air conditioning system designed is of the heating/cooling type with ceiling fan coil units with reversible battery, with condensate pump with supply pipes with thermal agent cooling and heating. The thermal heating agent hot water with temperature parameters 75°C -55°C will be provided from the boiler through the heating installation and as a cooling agent cold water with temperature parameters 7°C -12°C, provided by coolers external water chiller type, through supply pipes that will be connected to the level distributors.

The box type fan coil units will be mounted in the decorative ceiling, and are without fresh air intake, considering the fact that a ventilation installation with fresh air intake has been provided (in both solutions). The supply of thermal heating and cooling agent to the fan convectors will be done with an internal distribution installation with polyethylene pipes joined with cold-pressed fittings, insulated and mounted in the decorative ceiling. The distribution of the heating/cooling agent will be made from level distributors, mounted in the decorative ceiling. Adjustment/separation valves and a three-way valve are mounted on the connection pipes from the fan coil units.

For the comparative study of the two systems, the simulation program Design Builder [9] was used. After choosing the air conditioning solution, the model created with the help of Design Builder software was simulated and the output data was analyzed. The program automatically generates the heating requirement related to the created model and allows the creation of graphs between the parameters of interest (temperatures, heat inputs, energy consumption, etc.).

Thus, the two systems proposed for analysis were simulated:

- *Solution 1 - Air conditioning installation in direct expansion with VRF type equipment - centralized, having uncased DUCT type indoor units*

The first step of the simulation involves the creation of the model (Fig.1) [9] based on which the software automatically generates the heat requirement for heating (Fig.2) and cooling (Fig.3) [9].

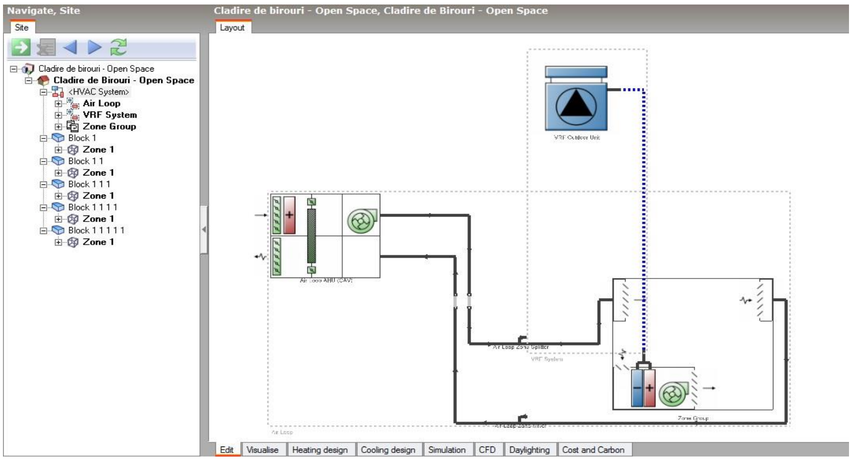
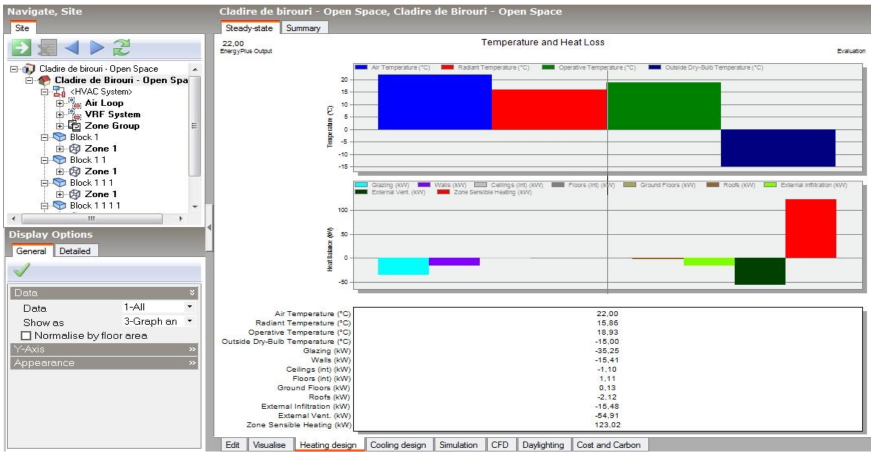
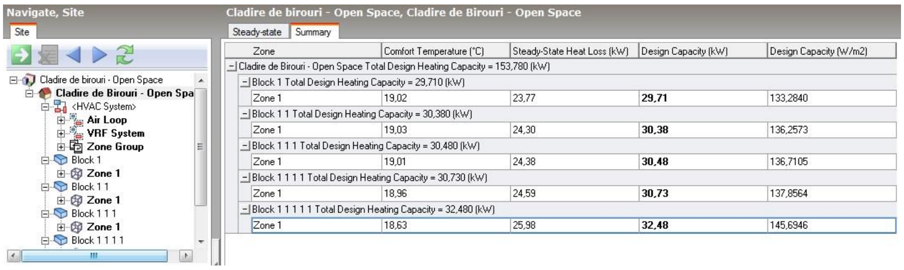


Fig.1. The creation of the model – Solution 1



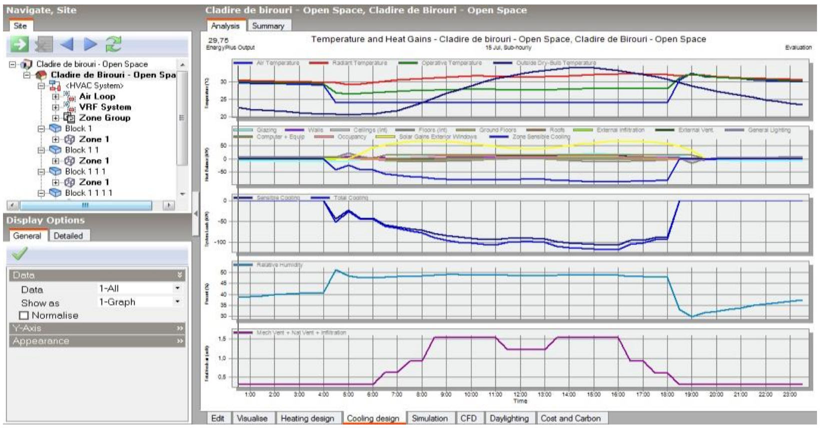
a)



b)

Fig.2. Generating the energy requirement for heating – Solution 1

a) Entry data, b) Generation of the heat requirement



a)

b)

Fig.3. Generating the energy requirement for cooling – Solution 1
a) Temperature and Heat Gains, b) The cold requirement for cooling

Following the simulation, a heat demand for heating of 153.78 kW and a cold demand for heating of 134.13 kW respectively resulted for the air conditioning system with VRF.

- *Solution 2 - Water-based air-conditioning installation, with an air-cooled chiller for the production of chilled water, a thermal power plant (TPP) for the production of hot water and a non-cased indoor unit of the fan coil type*

The creation of the model is shown in Fig.4 [9], the heat demand for heating in Fig.5 and the cold demand for cooling in Fig.6 [9].

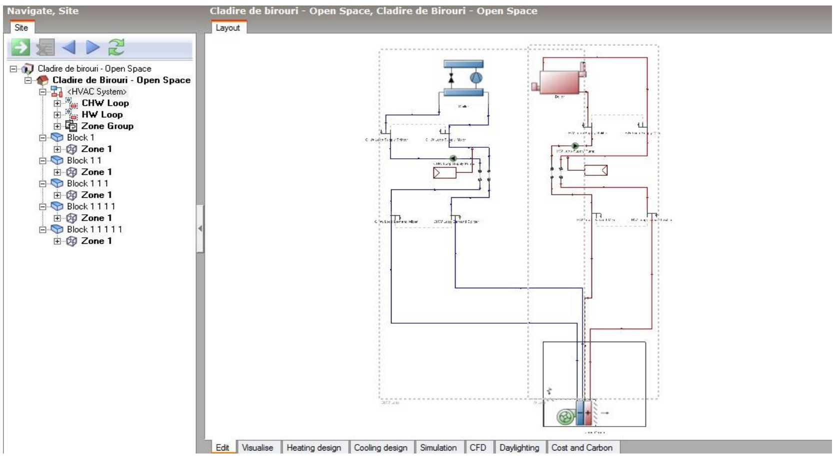
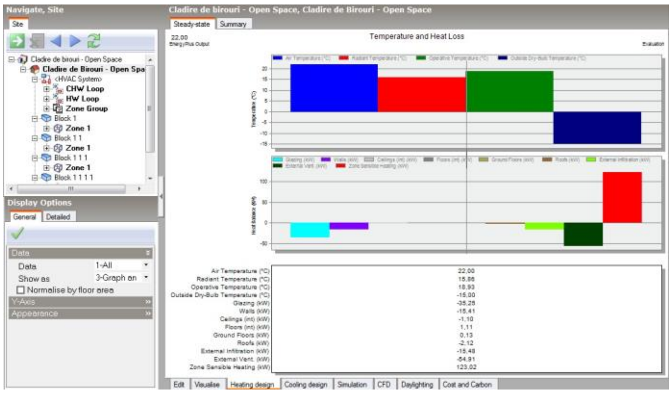
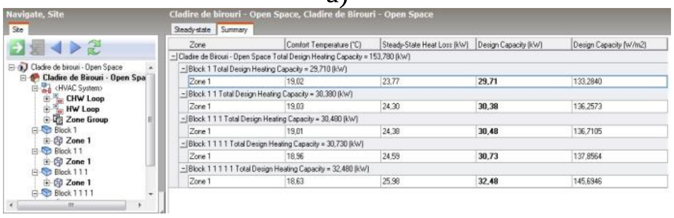


Fig.4. The creation of the model – Solution 2



a)

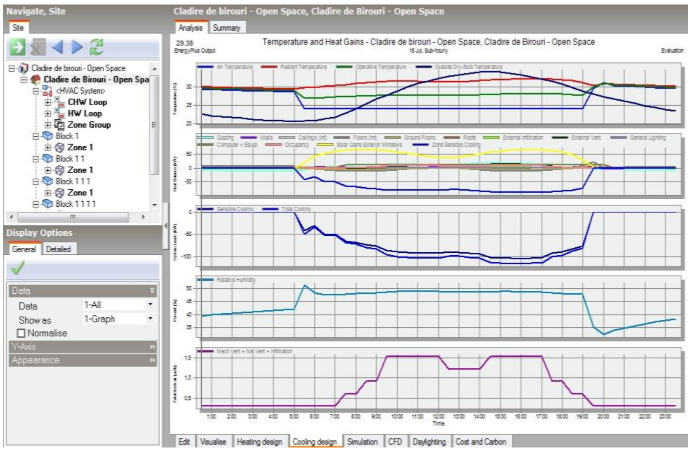


b)

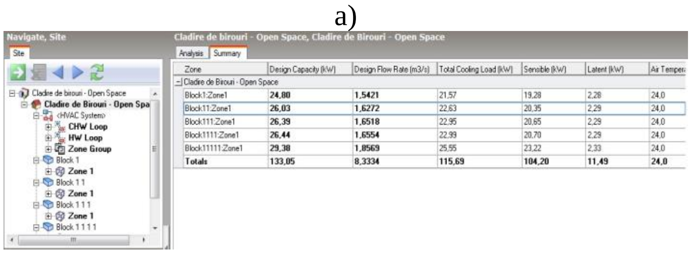
Fig.5.

Generating the energy requirement for heating – Solution 2

b) Entry data, b) Generation of the heat requirement



a)



b)

Fig.6. Generating the energy requirement for cooling – Solution 2

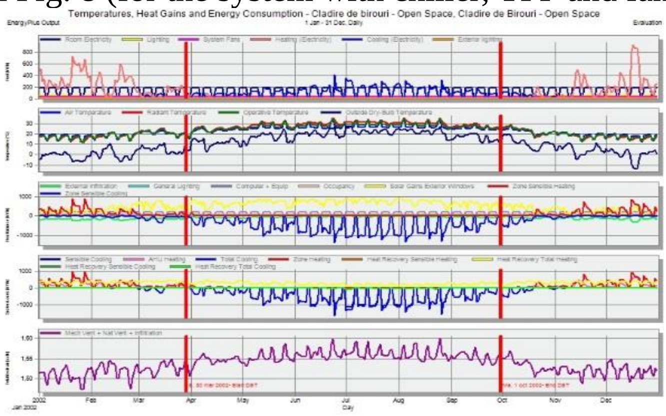
a) Temperature and Heat Gains, b) The cold requirement for cooling

Following the simulation for the air conditioning system with chiller, heating plant and fan coils, a heat requirement for heating of 153.78 kW and a cold requirement for heating of 133.05 kW respectively resulted.

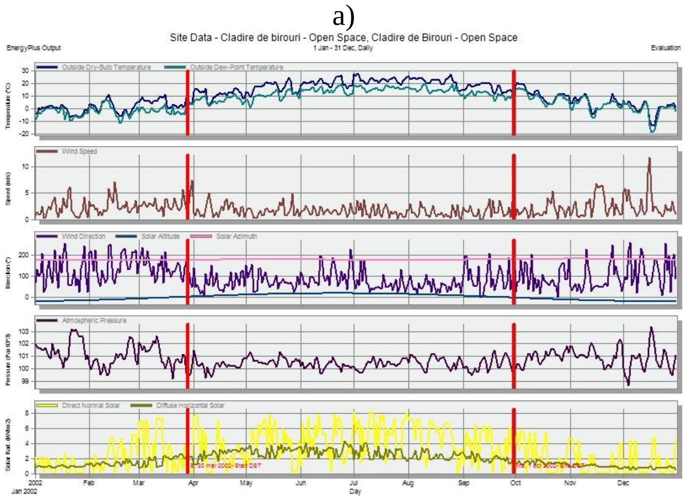
4. Results and discussions

After entering the selection parameters and choosing the air conditioning system, the Design Builder program generates a data analysis over a determined period of time, staged where we find the cooling and heating periods.

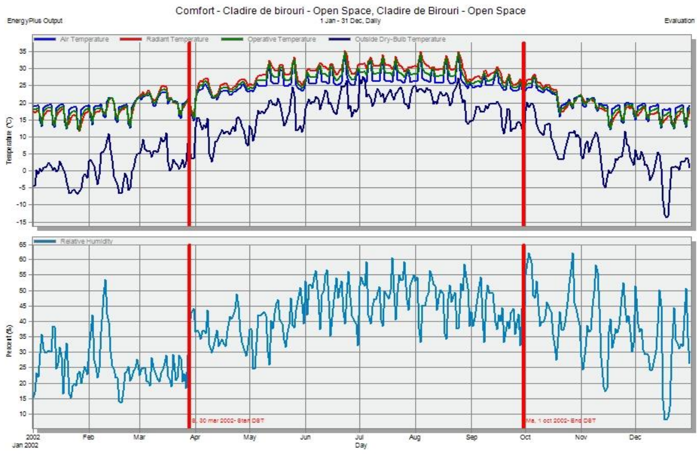
The obtained data are present for the two types of systems in Fig. 7 (for the VRF system) and in Fig. 8 (for the system with chiller, TPP and fan coils).



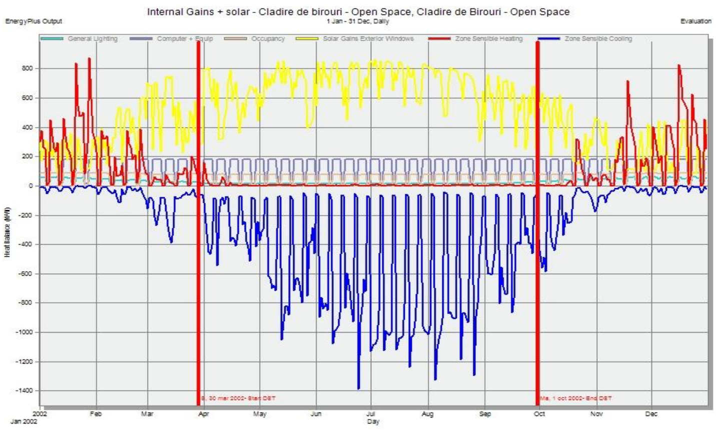
a)



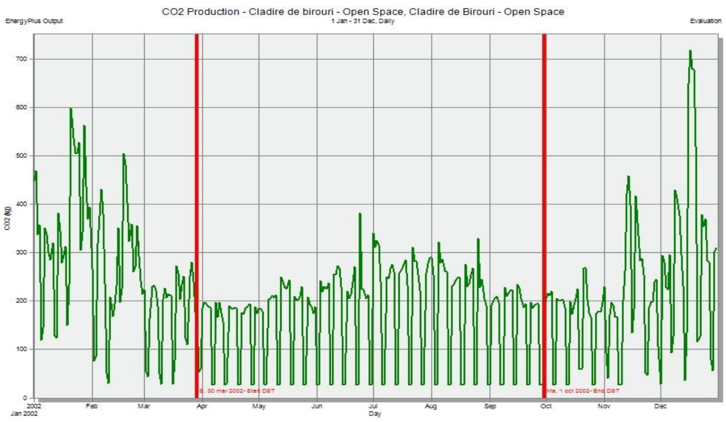
b)



c)



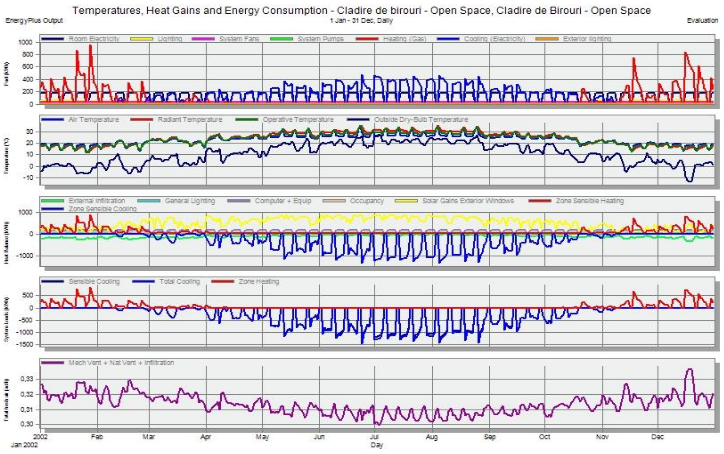
d)



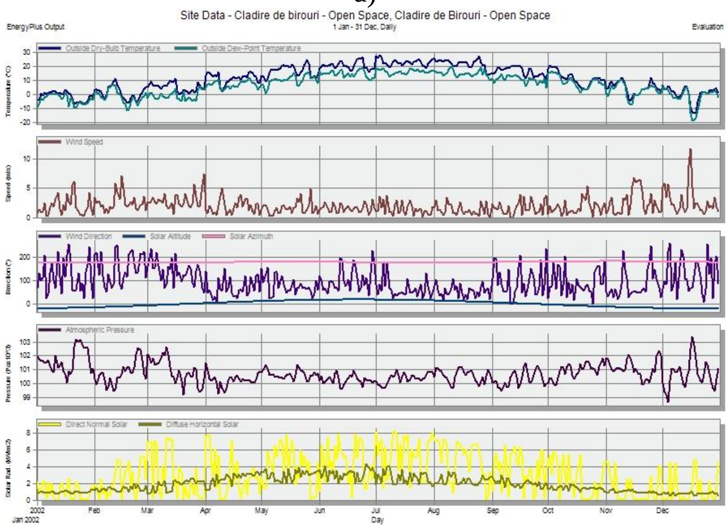
e)

Fig. 7. Simulation results for Solution 1 [9]
a) Temperature, heat gains and energy consumption, b) Site data, c) Comfort parameters, d) internal gains+solar, e) CO2 production

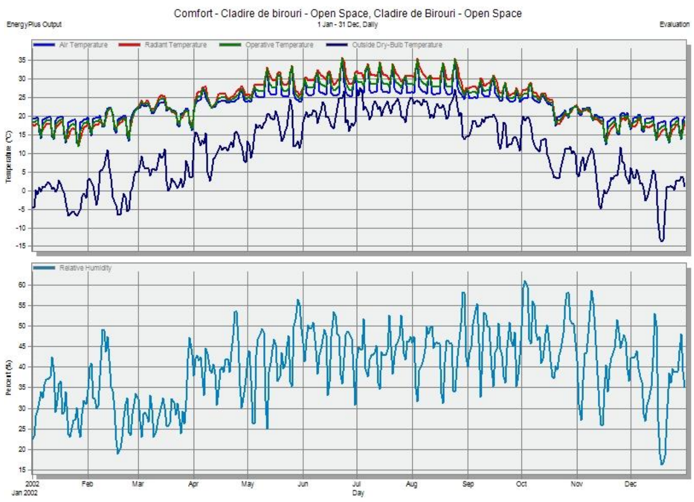
As in the case of Solution 1, the second variant was also simulated for the air conditioning system with chiller, TPP and fan coils for which the data is shown in Fig. 8 [9].



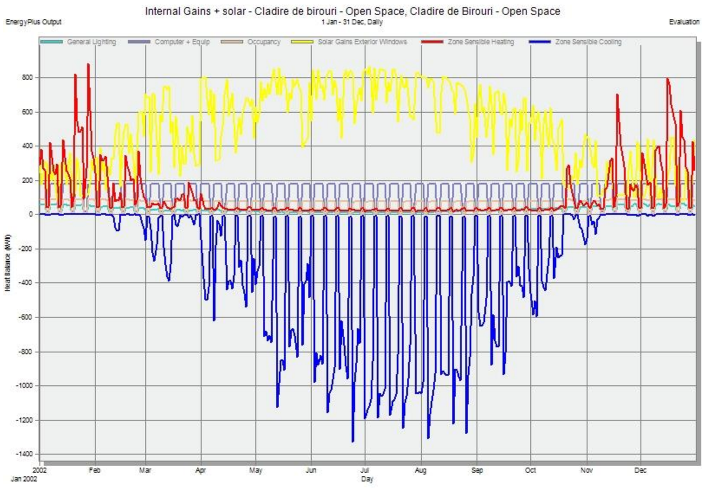
a)



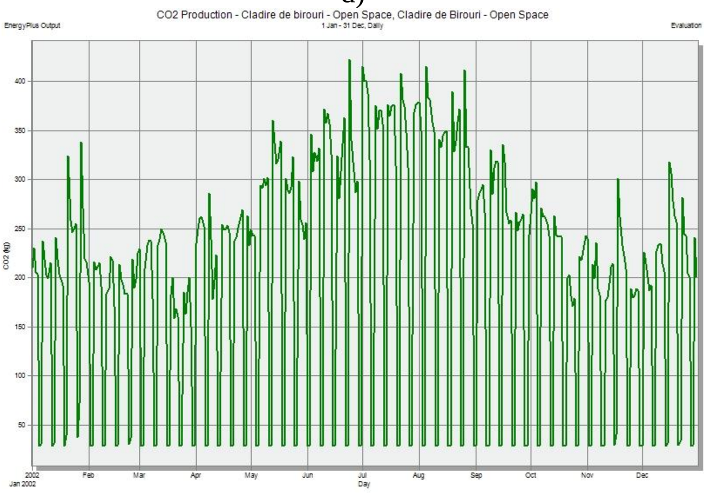
b)



c)



d)



e)

Fig. 8. Simulation results for Solution 2 [9]
a) Temperature, heat gains and energy consumption, b) Site data, c) Comfort parameters, d) internal gains+solar, e) CO2 production

Analysis of energy consumption for the two analyzed system solutions

With the help of the report generated by the Design Builder program, the electricity consumption was compared in the case of the two variants.

A comparative analysis between the two analyzed systems, in terms of energy consumption for heating and cooling, is presented in Fig. 9 and respectively Fig. 10 [9].

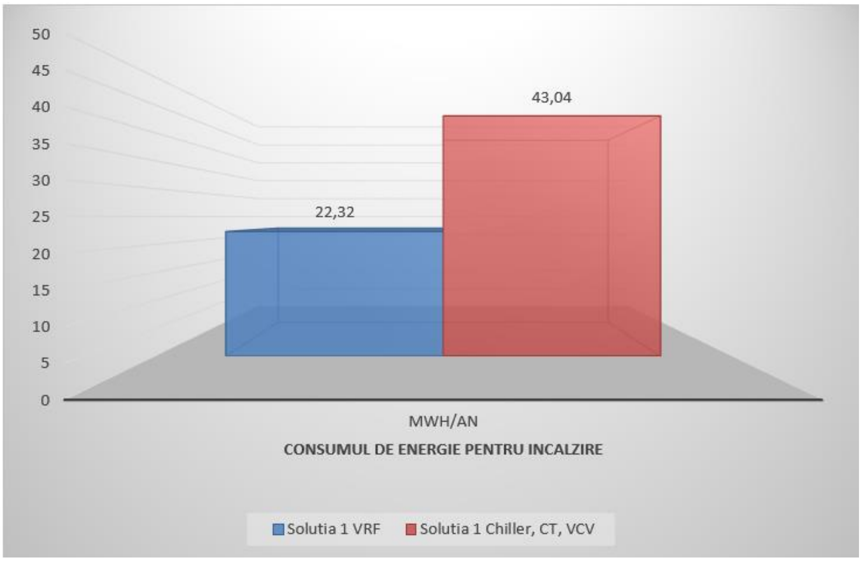


Fig. 9. Comparative analysis of energy consumption for office building heating. Solution 1 vs. Solution 2 [9]

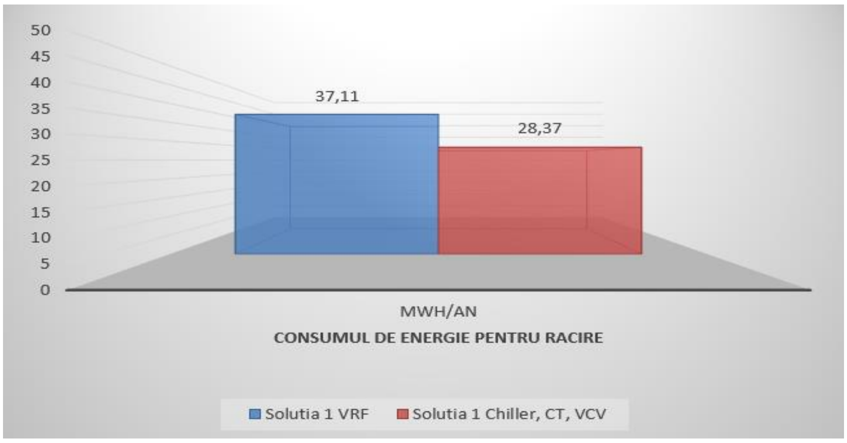


Fig. 10. Comparative analysis of energy consumption for office building cooling. Solution 1 vs. Solution 2 [9]

Also, the energy consumption for the preparation of domestic hot water was determined (Fig. 11) and the electricity consumption for lighting, which does not undergo changes depending on the chosen solution, recording a consume of 8.28 MWh/year. For domestic hot water, a consumption of 2.52 MWh/year was determined in the case of installing the system proposed in Solution 1 and 1.56 MWh/year for the system proposed in Solution 2, consumptions that do not differ between the two variants.

At the same time, the global energy consumption for the two systems, obtained after the simulation, is presented comparatively in Fig. 12.

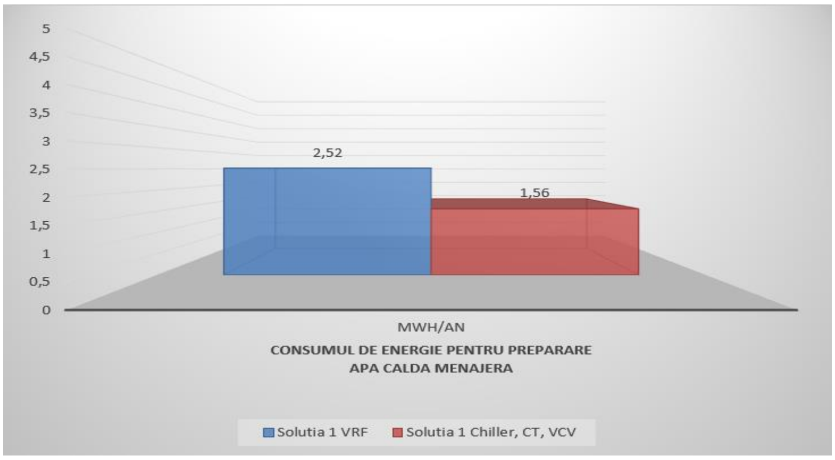


Fig. 11. Comparative analysis between the energy consumption for the preparation of domestic hot water related to the office building.
Solution 1 vs. Solution 2 [9]

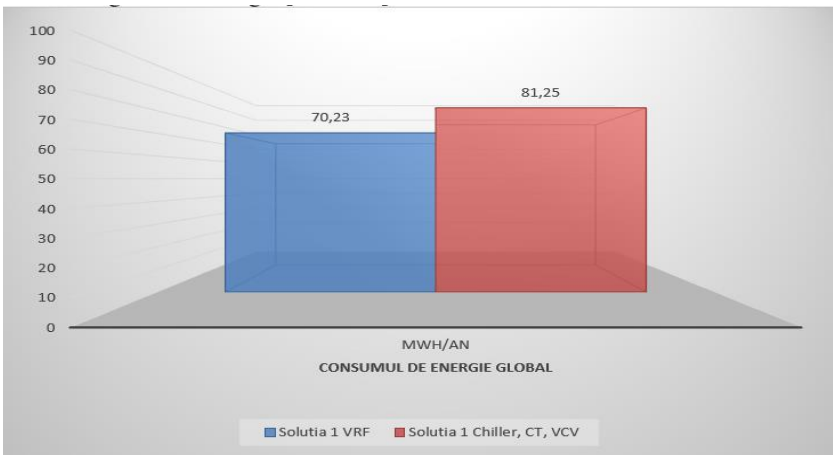


Fig. 12. Comparative analysis of global office building energy consumption.
Solution 1 vs. Solution 2 [9]

5. Conclusions

For the comparative analysis of the consumptions generated by the two types of analyzed systems (Solution 1 and respectively Solution 2) taking into account the same input data, different global consumptions were obtained. As the energy consumption for lighting is not influenced by the type of system, and the consumption for the preparation of domestic hot water shows small differences between the two systems (0.96MWh/year), it is obvious that the difference in consumption is determined by the heating/cooling of the building offices. Thus, it was found that there is a difference of 11.02MWh/year, a difference which in the current climatic conditions can be considered problematic. On the other hand, it is found that for cooling the most advantageous system is Solution 2, and for heating the advantageous system is Solution 1, but from the point of view of global consumption it is found that Solution 1 is the most advantageous system for the considered building and under the conditions imposed by the input data.

References

[1] A. Loy, „Eurostat: Gazele cu efect de seră generate de activitățile economice din UE sunt încă sub nivelurile pre-pandemie", August 16, https://www.caleaeuropeana.ro/, 2022.
[2] MDLPA, „Strategia națională de renovare pe termen lung. Pentru sprijinirea renovării parcului național de clădiri rezidențiale și nerezidențiale, atât publice cât și private și transformarea treptată într-un parc imobiliar cu un nivel ridicat de eficiență energetică și decarbonat până în 2050", Monitorul Oficial al României, Partea I, Nr. 1247 bis, decembrie 2020.
[3] D. Oancea, "Câte clădiri necesită reabilitare energetică? Rata de renovare rămâne scăzută." Mediafax.ro, 16Decembrie, 2021.
[4] N.E. Kaba , A. Retezan , A. Tokar, „Thermal Rehabilitation of an Educational Building in the Context of the Adaptation of Buildings to the Effects of Climate Change. Case Study", in Hidraulica, No. 3, pp. 66-74, 2022.
[5] D. Muntean A. Tokar, „Reducing operating costs in district heating systems by optimizing functional parameters. Comparative studies", 14^{th} International Conference on Hydroinformatics, IOP Conf. Series: Earth and Environmental Science, vol. 1136, Article ID 012060, 2023.
[6] B.P. Koirala, E. Koliou, J. Friege, R.A. Hakvoort, P.M. Herder, „Energetic communities for community energy: a review of key issues and trends shaping integrated community energy systems", in Renewable and Sustainable Energy Reviews, vol. 56, pp. 722-744, 2016.
[7] J. Fouladvand, A. Ghorbani, N. Mouter, P. Herber, „Analysing community-based initiatives for heating and cooling: A systematic and critical review", in Energy Research & Social Science, vol. 88, Article ID 102507, 2022.
[8] United Nations Climate Change, „1/CP.3-Adoption of the Kyoto Protocol to the United Nations Framework Convention on Climate Change", Conference of the Parties (COP), December 1997.
[9] ***, Design Builder, Software dezvoltat de Design Builder Software Lld, Londra.