CO2 EMISSION OF A nZEB BUSINESS FACILITY IN NIŠ AND ITS IMPACT ON THE ENVIRONMENT

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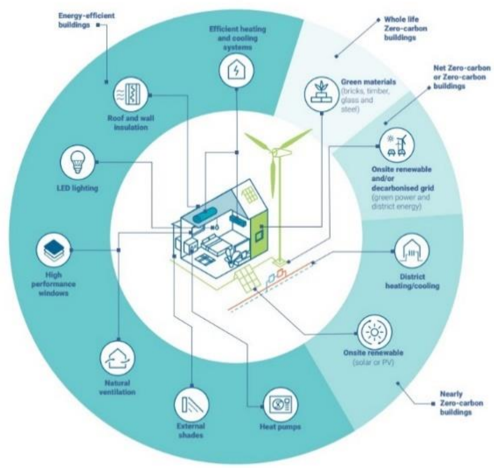
Abstract: The emission of greenhouse gases, particularly CO2, is widely recognized globally for its significant impact on the climate worldwide. These gases substantially influence the climate across the globe, thereby increasing the demand for greater energy usage and, consequently, elevating the energy requirements for HVAC (Heating, Ventilation, and Air Conditioning) systems. Additionally, the rise in atmospheric CO2 poses a serious threat to human health and ecosystems, presenting an even greater challenge for thermal comfort.
Consequently, there is a growing necessity to study buildings in order to achieve Nearly Zero Energy Buildings (nZEB). This specific study aims to demonstrate the influence of energy consumption on CO2 emission in the environment, utilizing energy sources from district heating/cooling and heat pumps, through simulations conducted using EnergyPlus software. The building subjected to these simulations is a multi-purpose structure primarily used for office purposes, located in Niš, Serbia.
Keywords: CO2, Nzeb, EnergyPlus, Buildings, HVAC, Climate change.

1. INTRODUCTION

Europe is facing a serious challenge of climate change, as the current climate shifts on our planet are reshaping the world and amplifying the risk of instability in all areas. Therefore, it is imperative to promptly and decisively take action in order to tackle this issue.
The Intergovernmental Panel on Climate Change (IPCC) released its Special Report in October 2018, focusing on the impacts of global warming at 1.5°C above pre-industrial levels and the corresponding global greenhouse gas emission pathways. Grounded in scientific evidence, this report illustrates that human-induced global warming has already reached 1°C above pre-industrial levels and is increasing by about 0.2°C per decade. If international efforts to combat climate change are not intensified, the global average temperature could approach a 2°C increase shortly after 2060, with a continued upward trend thereafter. Such unconstrained climate change carries the potential to transform Earth into a "hothouse," heightening the probability of irreversible and widespread climate effects. The IPCC report affirms that around 4% of the global land area is projected to transition from one ecosystem type to another at a 1°C global warming, a figure that rises to 13% at a 2°C temperature shift (European Commission, 2018).
Operational energy-related CO2 emissions from buildings grew by around 5 per cent in 2021 compared to 2020 to around 10 GtCO2, exceeding the previous 2019 peak of 9.6 GtCO2 by 2 per cent. This increase follows the unprecedented reduction in CO2 emissions in 2020 of around 10 per cent from 2019 levels to due to the COVID-19 pandemic. The rise in buildings sector CO2 emissions shows there has been little structural change in the overall energy efficiency of existing building. Buildings account for around 27 per cent of operational energy related CO2 emissions18, which excludes materials (IEA 2022f) (UN Environment Programme, 2022).
Considering that Serbia belongs to the continental region, the increase in greenhouse gases elevates the risk of heightened extreme heat, reduced summer rainfall, an escalating threat of river floods, an increase in the risk of forest fires, a decrease in the economic value of forests, and a rise in cooling energy demand (European Commission, 2018).
The transition towards a net-zero greenhouse gas economy positions energy at the forefront, given its current responsibility for over 75% of the EU's greenhouse gas emissions. Across all examined options, the energy system progresses towards achieving net-zero greenhouse gas emissions. This progression relies on a secure and sustainable

energy supply, supported by a market-driven and pan-European approach. The forthcoming energy system will seamlessly integrate electricity, gas, heating/cooling, and mobility systems and markets, facilitated by intelligent networks that prioritize citizens (European Commission, 2018).
However, it is insufficient to solely concentrate this type of transition on technological innovations. Instead, the focus should encompass a system that offers an array of advanced solutions, as exemplified by the circular economy approach.
In the study "Concept of Net Zero Energy Buildings (NZEB) - A Literature Review," the achievement of nZEB (net-zero energy buildings) in existing structures is depicted. This achievement is accomplished through the enhancement of energy efficiency, the optimization of user comfort, and the reduction of dependence on the electrical grid and municipal water supply via sustainable policies (Jaysawal, Chakraborty, Elangovan, & Padmanaban,2022).

Picture 1. Roadmap for Energy-Efficient Buildings and Construction in the Association of Southeast Asia. Adapted from IEA, 2021. All rights reserved

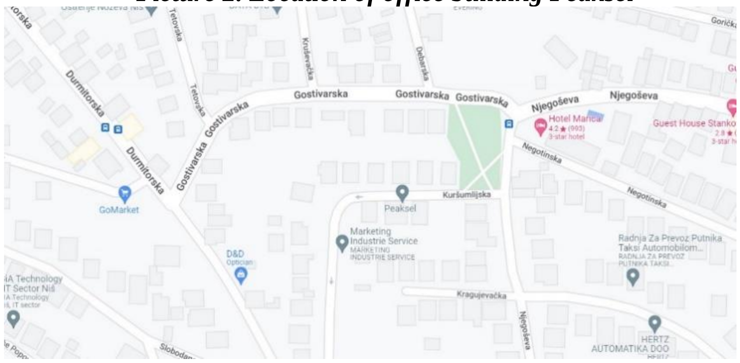


The global urban population has reached 55%, and this rate is expected to rise to 68% by 2050. However, this rate has already been surpassed in certain regions. For instance, the urban population in North America, Latin America, and the Caribbean has already exceeded 80%; in Europe, it reaches 75%, and in Oceania, it stands at 68% (Department of Economic and Social Affairs, 2019). A significant 75% of CO_2 emissions stem from cities, which also account for 60 to 80% of energy consumption (United Nations, 2019). Notably, buildings contribute to 36% of energy consumption and 40% of emissions (Ortiz-Rodriguez, Castells, & Sonnemann, 2010). CO_2 emissions in the residential sector have shown a continuous annual growth of 2% so far in this century (Zarco-Periñán, Zarco-Soto, Zarco-Soto, Martínez-Ramos, & Sánchez-Durán, 2022).
The measures that such a system will bring entail that energy efficiency should hold a central role in achieving net-zero greenhouse emissions by 2050, aiming to reduce energy consumption by up to half when compared to 2005. Advancements in energy efficiency through digitalization, home automation, labeling, and standardization have far-reaching effects beyond the European Union. As appliances and electronics are both imported into the EU and exported to international markets, foreign producers adhere to EU standards (European Commission, 2018).

2. MATERIALS AND METHODS

The office building over which simulations are conducted is located in Niš, and for the purposes of EnergyPlus, the following data are used: Latitude 48.33° and Longitude 21.9°. The total usable area of the building is 1129.2 m², while the footprint area of the building is 229.3 m².

Picture 2. Location of office building Peaksel



The building is primarily intended for office space, although there is an apartment located in the attic, making it a mixed-use structure. The exterior envelope walls of the building have a U-value of 0.205 W/m²K, the windows have a U-value of 0.8 W/m²K, while the doors have a U-value of 1.225 W/m²K. Based on simulation, the required energy per building area is 36.49 kWh/m², classifying it as a low-energy building. The annual heating energy consumption is 5046.73 kWh annually, while cooling energy is 11886.42 kWh annually. The energy needed for building lighting is 6516.29 kWh annually, and energy for devices within the building is 16891.62 kWh annually. Additional energy is utilized for ventilation, amounting to 240.89 kWh, and for pumps, totaling 618.93 kWh. Heating energy is consumed over 1755.83 hours annually, while cooling energy is used for 3578.17 hours annually.

Picture 3. Model of the office building

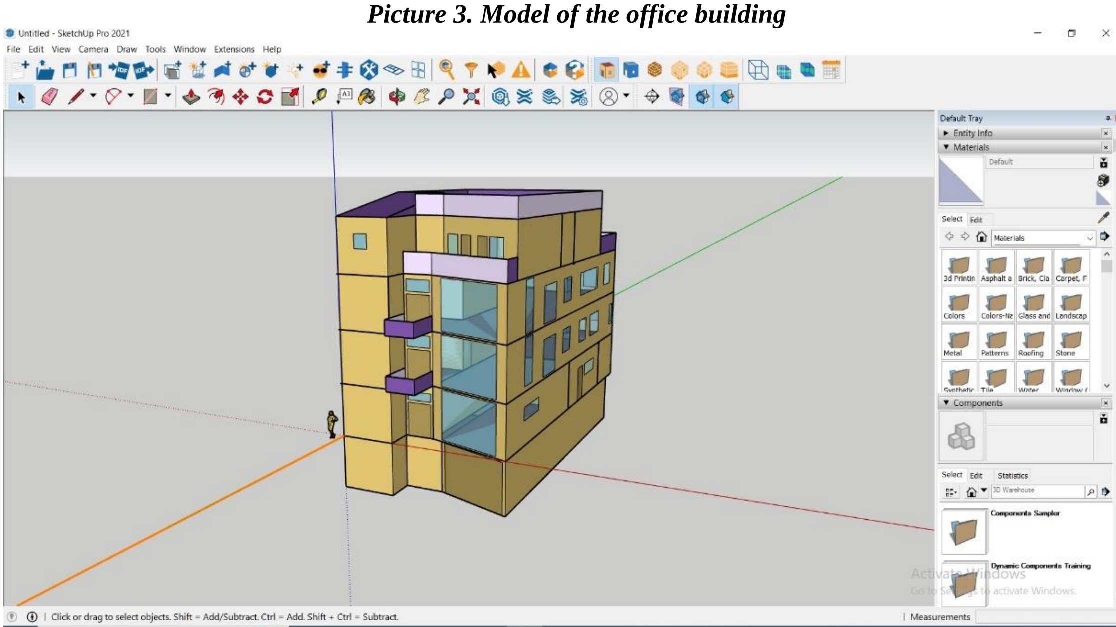


Table 1. Schedule of total energy consumption in percentages

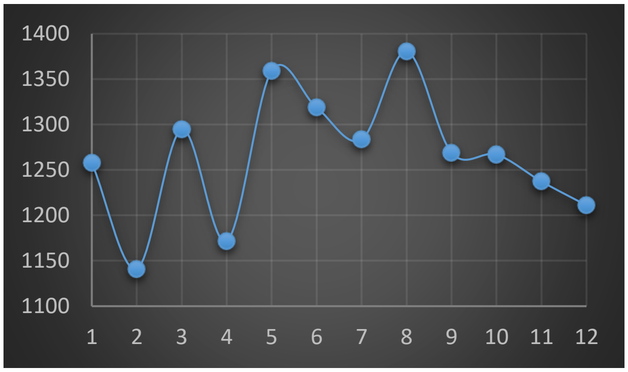
Energy consumer	**%**
Interior Lighting	15.82
Space Heating	12.25
Space Cooling	28.85
Fans	0.58
Receptacle Equipment	41.00
Miscellaneous	1.50

The actual CO_2 emissions in Serbia have been increasing year by year, as evident from the annual CO_2 emission data. In 2021, the CO_2 emission was 594 gCO_2/kWh, with a share of 35% renewable energy sources and 60.8%

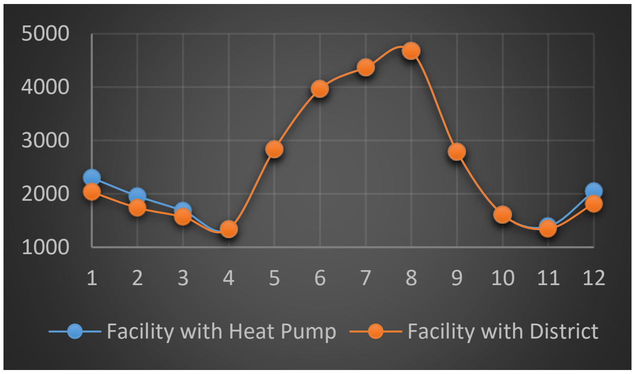
lignite. In 2022, it increased to 626 gCO_2/kWh, with 31% from renewable energy sources and 66.2% from lignite. Currently, CO_2 emission is at a record level, reaching 656 gCO_2/kWh, with a 35% share of renewable energy sources and 64.4% from lignite (Nowtricity, n.d.).
Furthermore, CO_2 emission from natural gas varies not only from country to country but also among different facilities and based on CO_2 emission policies. For direct emissions during natural gas combustion, a value of 530 gCO_2/kWh is considered (Dones, Heck, & Hirschberg, 2003.)
Given the absence of a district cooling system in Nis, the study focuses on comparing a heat pump and district heating with a heat pump during the cooling period.

3. RESULTS

This study encompasses the CO_2 emissions from all electrical consumers within the building and the energy emission required for heating/cooling. The annual CO_2 emission using a heat pump is 15.8 tons, which combined with the building's consumption amounts to 30.97 tons of CO_2 annually. Using district heating/cooling results in 14.9 tons of CO_2 emissions, which, combined with the building's consumption, totals 30.1 tons of CO_2 annually.



Graph 1. CO2 emission of electric consumer for building



Graph 2. CO2 Total emission

With a building footprint area of 229.3 m², using a heat pump results in a CO_2 emission of 135.07 $kgCO_2/year/m^2$, while using district heating yields 131.25 $kgCO_2/year/m^2$. While the CO_2 emission per square meter of total building area annually, using a heat pump, amounts to 27.43 $kgCO_2/m^2/year$, while with district heating, it is 26.65 $kgCO_2/m^2/year$.

Table 2. CO2 emission in year with heat pump and district heating/cooling

	Heat Pump (kgCO2)	kgCO2/ m²	District heating/cooling (kgCO2)	kgCO2/ m²
January	2301.67	2.04	2034.267	1.8
February	1958.737	1.73	1738.842	1.54
March	1683.294	1.49	1570.306	1.39
April	1343.891	1.19	1342.112	1.19
May	2834.479	2.51	2834.479	2.51
June	3962.497	3.51	3962.497	3.51
July	4368.728	3.87	4368.728	3.87
August	4674.63	4.14	4674.63	4.14
September	2791.231	2.47	2791.231	2.47
October	1614.39	1.43	1614.39	1.43
November	1389.157	1.23	1345.803	1.19
December	2049.267	1.81	1818.145	1.61
TOTAL	30972	27.43	30095.4	26.65

4. DISCUSSIONS

In the study itself, it can be observed that there is a very small difference in CO_2 emission between the heat pump and district heating/cooling, which is illogical. However, this is precisely because Coal (lignite) is used for electricity emission in Serbia, while very few studies focus on using data from the primary energy source. By utilizing different energy sources for electricity generation, this CO_2 emission would be significantly lower than the current use of a heat pump. Therefore, further research on this building leads to the conclusion that an alternative approach could lead to reduced CO_2 emission and a transition from a low-energy building to a passive building or nZEB.

5. CONCLUSIONS

The environmental impacts associated with construction and system usage greatly depend on the region, climate, and building type. Consequently, CO_2 emission in the construction industry is largely influenced by the utilization of modern heating/cooling systems with higher efficiency and minimal electricity consumption. In this study, utilizing an analytical method and simulations within EnergyPlus, the minimum CO_2 emissions were estimated at 26.65 $kgCO_2/m^2$ per year for the building. Therefore, further reduction requires the implementation of additional construction measures and the introduction of low electricity consumption systems. To address climate change, it is necessary to exert additional efforts and prevent further global warming.

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