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ANALYSIS OF THE POTENTIAL FOR TRANSFORMING A BUILDING INTO A NET ZERO ENERGY BUILDING

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Abstract: This paper examines the potential for transforming the Faculty of Mechanical Engineering building in Mostar into a Net Zero Energy Building (NZEB). The study assesses the building's current energy consumption and explores feasible upgrades to achieve complete energy independence and zero CO_2 emissions. The hybrid system, composed of rooftop solar panels, wind turbines, and a heat pump, has been thoroughly analyzed in this research to identify opportunities for optimization and expansion. Using software tools such as HOMER Pro and SUNNY DESIGN, the study models renewable energy capacities and simulates system performance to determine the investment potential and economic feasibility of achieving net-zero energy status. The findings offer valuable insights into practical strategies for implementing NZEB principles in public buildings across Bosnia and Herzegovina, contributing to broader sustainability goals and energy security in the region.

Keywords: Net Zero Energy Building, Energy Transformation, CO_2 emissions, Energy Efficiency, Renewable Energy

INTRODUCTION

Net-zero energy buildings (NZEB) are advanced constructions designed to produce as much energy as they consume, enabling them to achieve energy self-sufficiency. These buildings prioritize energy efficiency through advanced design principles and the incorporation of cutting-edge technologies, including efficient heating, ventilation, and air conditioning (HVAC) systems, high-quality insulation, and renewable energy sources such as solar panels, wind turbines, and geothermal systems. By utilizing smart energy management systems and sustainable materials, NZEBs aim to reduce carbon dioxide emissions significantly, mitigating the adverse effects of climate change and global warming.

The energy efficiency of NZEBs can be achieved through superior insulation that minimizes heat loss during winter and prevents overheating in summer. This includes the use of materials with excellent thermal properties for walls, roofs, and foundations. The installation of windows with low heat transfer coefficients, such as triple-glazed units, alongside well-sealed doors, significantly reduces energy losses. Advanced coatings on windows can further enhance thermal performance. The integration of high-efficiency HVAC systems, such as heat pumps and heat recovery ventilators, optimizes the energy consumption needed for heating and cooling. Furthermore, energy-efficient LED lighting and low-energy appliances contribute to overall energy savings, while smart lighting management systems adjust intensity based on occupancy and natural light availability.

Mathematically, achieving NZEB status requires maintaining a balance between energy imports and exports over a specific timeframe, ensuring that energy generated and consumed on-site, or fed back into the grid, equals or exceeds energy drawn from external sources. This necessitates implementing strategies that enhance the efficiency of existing systems within the building—such as those for heating, cooling, and water usage—while concurrently integrating renewable energy sources (RES) to minimize consumption.

The advantages of NZEBs are manifold. They reduce greenhouse gas emissions, conserve natural resources, and lessen environmental impacts. Long-term economic benefits arise from lower energy costs, improved return on investment through savings on energy bills, and potentially increased property values. Enhanced indoor air quality, improved thermal comfort, and healthier living conditions are additional health benefits for occupants. NZEBs promote greater energy independence by reducing reliance on external energy sources and increasing resilience to energy price fluctuations. This case study will focus on creating a Net Zero Energy Building (NZEB) through the integration of renewable energy sources.

The Faculty of Mechanical Engineering, part of the University of Džemal Bijedić in Mostar, encompasses a

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total area of 2,700 m² and is designed to support various academic activities and classes.

Figure 1: Faculty of Mechanical Engineering

The ground floor features three classrooms, an amphitheater, student service areas, and staff offices, while the first floor includes additional classrooms, staff offices, a library with a meeting room, and a terrace. Notably, the third floor houses a terrace accommodating a solar power plant, underscoring the faculty's commitment to integrating renewable energy sources and promoting sustainability.

The heating season at the Faculty of Mechanical Engineering is delineated from October 15 to April 15, during which specific temperature regulations are adhered to; the external winter design temperature is set at -6°C, while the internal design temperature is maintained at a comfortable 20°C. The total floor area of the building measures 1986 m², with 1131 m² designated as heated space. The overall volume of the structure is 7162 m³, of which 4019 m³ constitutes the volume of heated spaces.

1. LITERATURE REVIEW

There are multiple steps in the shift from low-energy buildings to NZEBs, with an emphasis on enhancing building energy performance. Combining developments in energy-efficient building technology with renewable energy sources like solar, wind, and geothermal systems is a crucial part of this shift. Regulations play an important role in supporting NZEBs, and effective policy frameworks are necessary to get over logistical and financial obstacles [1].

Considerable efforts have been made to improve building energy performance through integrated renewable energy solutions as low-energy buildings have evolved into Net Zero Energy Buildings (NZEBs). This includes the adoption of solar panels, wind turbines, and geothermal systems, supported by energy-efficient technologies. It is stressed that strong legislative frameworks are essential for overcoming logistical and financial challenges, and that rules promote the development and uptake of NZEBs [2].

Despite the advancements, expanding NZEBs for broader adoption continues to present difficulties. Enhancing design elements, taking into account regional climate conditions, and enhancing energy storage and management technologies are the main goals of ongoing research. Effective project evaluations emphasize the necessity of ongoing observation and verification to guarantee peak performance and increase the usability and accessibility of NZEBs [3], [4].

Significant advancements have been made in residential NZEB research, especially in the areas of design and energy-sharing techniques. These structures generate energy in addition to consuming less. The efficiency of residential NZEBs has been significantly improved by the use of energy storage devices and cutting-edge building management technologies. These developments contribute to energy security and sustainability by enabling residential buildings to become essential components of the energy grid [5].

Schools have also successfully adopted NZEBs, which have greatly decreased operating expenses while teaching students the value of energy sustainability. The scalability of NZEB concepts to larger structures and communities is demonstrated by these initiatives, which serve as models for wider applications in many sectors [6].

2. DESIGN OF A NET ZERO-ENERGY BUILDING IN THE MEDITERRANEAN CLIMATE

2.1. Climatic analysis

This case study focuses on the location Sjeverni logor b.b., 88 000 Mostar, Herzegovina-Neretva Canton, positioned at coordinates 43°21'16"N, 17°48'33"E, with an elevation of 63.8 meters. Mostar, situated in the southwestern part of Bosnia and Herzegovina, lies within the Neretva River valley and experiences a Mediterranean climate with significant continental influences. These climatic conditions lead to a diverse range of seasonal variations throughout the year.

Historically, Mostar was characterized by an extremely dry climate; however, recent changes have resulted in increased humidity levels, contributing to noticeably uncomfortable summer heat. The summers in Mostar are particularly intense, with temperatures frequently exceeding 30°C. During the peak months of July and August, temperatures can soar above 40°C, making Mostar the hottest city in Bosnia and Herzegovina, where the highest recorded temperature has reached an astonishing 46.2°C. In contrast, winters in Mostar are generally mild, with average temperatures ranging from

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5°C to 10°C. While freezing conditions are rare, nighttime temperatures can occasionally drop below zero. Snowfall, although infrequent, does occur from time to time during the winter months.

The climatic characteristics of Mostar play a pivotal role in the design and energy performance of buildings, particularly concerning the development of net-zero energy buildings (NZEBs). A comprehensive understanding of the seasonal temperature variations and their implications for energy consumption and thermal comfort is fundamental for optimizing building design and energy systems.

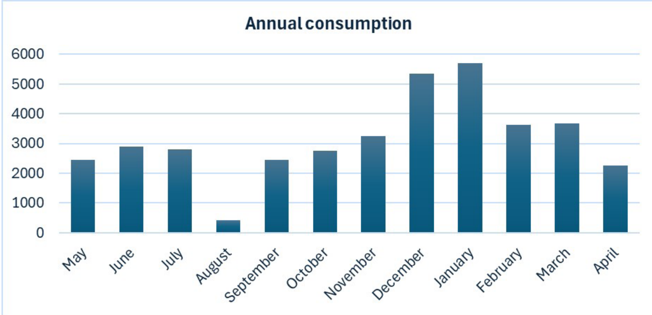
Figure 2: Location of the Faculty building

2.2. Electrical consumption

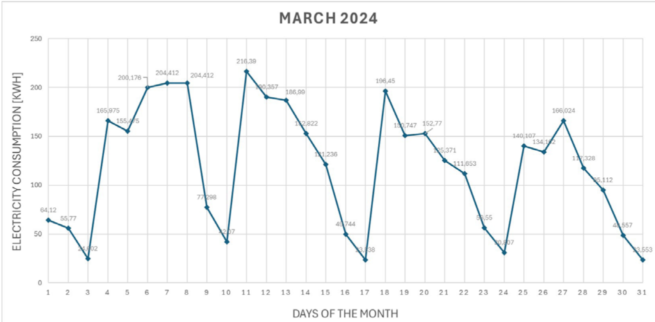
In analyzing the electrical consumption of the Faculty of Mechanical Engineering, comprehensive data was collected over a one-year period, spanning from May 2023 to April 2024. This data was instrumental in understanding the energy usage patterns and identifying the primary consumers within the building. The consumption metrics include annual, monthly (specifically for March 2024), and daily (for March 11, 2024) data, illustrated through corresponding graphs that depict the varying levels of electricity usage throughout the specified time frames.

The initial phase of data collection utilized a standard electrical meter until February 7, 2024, after which a digital meter was installed. The digital meter significantly enhanced data accuracy by providing readings every 15 minutes, allowing for a more granular analysis of electricity consumption trends. Among all electrical consumers within the faculty, the heat pump emerged as the predominant electricity consumer, highlighting the importance of this system in the building's energy profile.

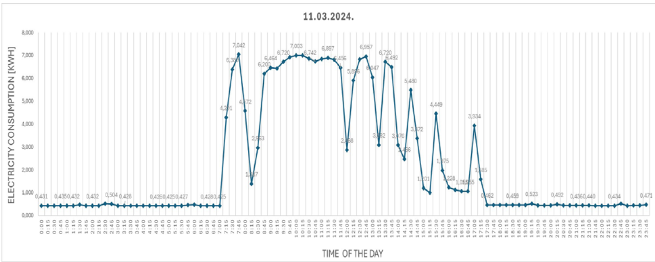
Graph 1 illustrates the annual consumption patterns, while Graph 2 focuses specifically on electricity usage during March 2024, and Graph 3 presents a detailed breakdown of daily consumption for March 11, 2024 which recorded the highest consumption.



Graph 1: Annual consumption



Graph 2: Consumption for March 2024.



Graph 3: Daily consumption for March 11, 2024

The building's overall energy footprint is influenced by a wide range of tiny users, such as different lighting and equipment. The internal lighting system comprises 493 LED bulbs and 118 fluorescent lights, each with specific capacities and an operational period averaging 18 hours per week. The external lighting system utilizes only two LED spotlights, which operate for approximately 2 hours per week, minimizing unnecessary energy expenditure. A variety of devices are employed within the faculty, including computers, copiers, printers, fan coil units, quartz heaters, and coffee makers. Notably, computers represent the largest category of devices, with a total of 45 units contributing significantly to the electricity demand. Copiers and printers, while fewer in number, collectively add a meaningful amount to the overall energy consumption. Fan coil units, characterized by their intensive operational period of 50 hours per week, emerge as one of the larger energy consumers within the facility, further accentuating the need for effective energy management strategies.

2.3. Energy Resources

The Faculty of Mechanical Engineering at the University of Džemal Bijedić in Mostar is equipped with several advanced systems for electricity generation and HVAC applications. The key components include 250W and 375W solar panels, a 30kW inverter, a vacuum tube thermal collector, a 600W wind turbine, and a water-to-water heat pump with a capacity of 86 kW.

2.3.1. Solar Panels

At the Faculty of Mechanical Engineering, solar panels with a cumulative capacity of approximately 20 kWp have been installed on both the northern and southern sections of the roof. The southern array comprises panels rated at 250W (Figure 3) while the northern array features solar panels rated at 375W.

Figure 3: Solar panels on the south side of the roof

2.3.2. Wind turbine

They range in power from small turbines that can produce around 50 W to large wind farms with turbines capable of up to 5 MW. Although wind can be an intermittent energy source, storage technologies enable efficient use of energy even when the wind is not blowing. A 600W wind turbine manufactured by Artas is installed at the Faculty of Mechanical Engineering and is shown below.

Figure 4: The wind turbine on the roof

2.3.3. Solar Collectors

Solar collectors are economically viable as they reduce energy costs over their long lifespan, while simultaneously contributing to reducing CO_2 emissions and decreasing dependence on fossil fuels. A vacuum tube collector is located on the roof of the Faculty of Mechanical Engineering in Mostar, as shown in Figure 5.

Figure 5: Solar collectors on the roof

2.3.4. Heat pump

At the Faculty of Mechanical Engineering, a water-water heat pump manufactured by Systemair “WQH.75” is installed. It uses the refrigerant R410A, with a nominal heating capacity of 86 kW and a nominal cooling capacity of 86.1 kW. The maximum electrical power consumption for heating is 21.2 kW, while for cooling, it is 17.4 kW. The system operates with a maximum AC current of 66 A and a voltage of 400 V / 3 / 50 Hz, respectively.The heat pump efficiency is expressed by a COP value of 3.92, which utilizes two Scroll compressors. The project originally planned the installation of two identical heat pumps to meet the building’s heating and cooling energy needs, but currently, only one unit is installed. Alongside the heat pump, a water storage tank with a capacity of 2 m^3 is installed. Water circulation in the system is achieved through two circulation pumps with maximum powers of 1150W and 750W, and a submersible pump in the well transports groundwater to the heat exchanger with a power of 5 kW.

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Figure 6: Systemair heat pump at the Faculty

3. MODELING OF THE SYSTEM TO MEET ELECTRICITY DEMAND

Given that the current solar power plant is insufficient to fulfill the electricity needs of the specified public institution, it is necessary to develop an additional, complementary system. For this study, Sunny Design software was utilized to model and optimize the proposed solution, ensuring alignment with existing infrastructure and enhancing energy efficiency. This modeling approach allows for a precise evaluation of the system's potential to reduce reliance on conventional energy sources while meeting the institution's specific power demands.

3.1. Sunny Design Software

On the southern side of the roof, there are already 40 solar panels with a capacity of 250W each, resulting in a total capacity of 10 kW. The northern side hosts an additional 26 panels rated at 375W, achieving a cumulative output of 9.28 kW. The northern side was examined for further installation potential; however, due to shading concerns illustrated in Figure 7, only half of this area was deemed suitable (Building 2 and Area 5). This led to the installation of 18 chosen panels, each rated at 580W, providing a combined output of 10.44 kW.

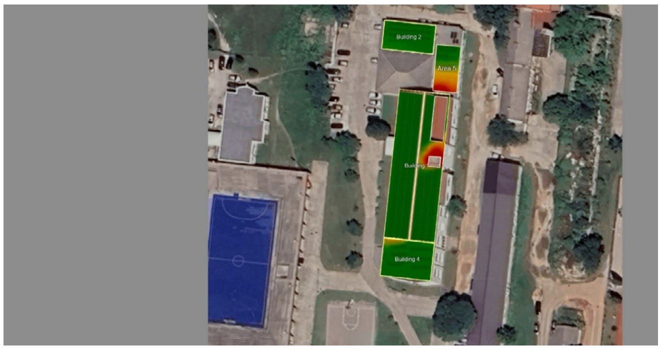


Figure 7: Predicted shading on the roof

The main roof area, oriented east-west, showed the highest potential for additional panel installation, estimated to accommodate 205 modules with a total capacity of 118.9 kW. To maximize solar exposure, careful attention was given to panel orientation and tilt, with shading impacts also assessed and noted.

Due to space limitations, 480W panels were selected instead of the initially preferred 580W modules. It was determined that 29 panels could be installed here, producing a total output of 13.92 kW, with shading effects considered in this configuration. The completed model demonstrates the feasibility of installing 318 solar panels across all available roof surfaces, achieving a total capacity of 162.54 kW.

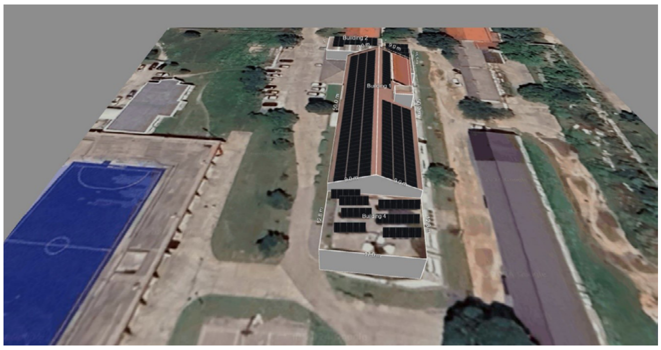


Figure 8: Modeling of the new system

3.2. HOMER PRO Software

In this study, priority is given to photovoltaic (PV) systems due to their cost-effectiveness and efficiency. The schematic layout of the included components is illustrated in Figure 9. The existing solar system on the southern part of the roof consists of 250W panels, labeled as PSE-1, while the northern part features 375W panels, labeled as PSE-2. A new solar power plant (NSE) is proposed for installation on the main roof, the roof of the associated institute, and the unused space on the northern roof. To ensure a backup energy supply during periods of insufficient production, a battery "CAT – TimeShift" with a capacity of 130Ah is used. The converter is crucial for transforming the direct current (DC) produced by the panels into alternating current (AC), making it suitable for use in standard electrical systems. The system also includes a connection to the grid, allowing excess generated electricity to be fed back into the distribution network.

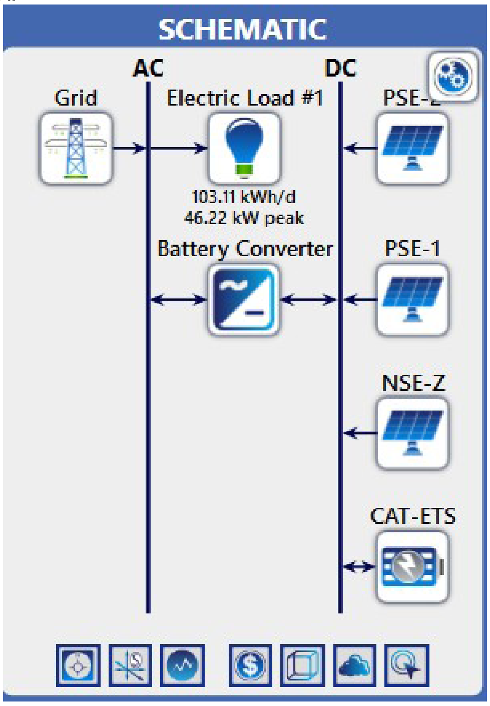


Figure 9: Included components in the system

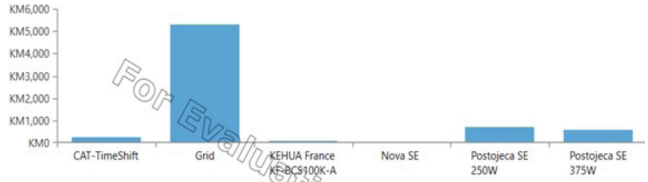
Within the HOMER Pro software, three scenarios are analyzed to assess different energy configurations.

3.2.1. Scenario 1

This scenario includes a grid connection. However, it is important to note that due to specific algorithms in HOMER Pro, the grid is not utilized optimally for releasing excess production; instead, electricity is occasionally drawn from the grid. Although this approach is incompatible with the principles of a Net Zero Energy Building (NZEB), it is included to compare investment costs. After running the simulation, it was found that the most optimal solution relies on energy from the grid.

The annual cost summary for this scenario shows a reduction in electricity expenses from over 10,000 KM to 6,953.82 KM (Figure 10). The reliance on the grid is evident in the analysis of electrical performance (Figure 11), which reveals that the solar systems are not fully utilized, with the grid supplying approximately 50% of the needed energy. Individual contributions of each power plant to the total renewable energy production are also shown in the Figure. The renewable penetration metric indicates that total renewable production accounts for 62% of the load and 51.7% of generation, suggesting that renewable resources are underutilized.

Battery performance highlights the need for energy storage during winter months and nighttime. Figure 12 presents data on CO_2 emissions, revealing a significant emission of 14.5 kg for one year, highlighting the environmental implications of this scenario.



Component	Capital (KM)	Replacement (KM)	O&M (KM)	Fuel (KM)	Salvage (KM)	Total (KM)
CAT-TimeShift	KM264.72	KM0.00	KM0.00	KM0.00	KM0.00	KM264.72
Grid	KM0.00	KM0.00	KM5,295.38	KM0.00	KM0.00	KM5,295.38
KEHUA France KF-BCS100K-A	KM36.77	KM80.99	KM0.00	KM0.00	-KM21.57	KM96.18
Nova SE	KM25.36	KM0.00	KM17.24	KM0.00	KM0.00	KM42.60
Postojeca SE 250W	KM294.13	KM0.00	KM400.00	KM0.00	KM0.00	KM694.13
Postojeca SE 375W	KM294.13	KM0.00	KM266.67	KM0.00	KM0.00	KM560.80
System	KM915.11	KM80.99	KM5,979.29	KM0.00	-KM21.57	KM6,953.82

Figure 10: Cost summary for scenario 1

Production	kWh/yr	%
Postojeca SE 375W	12,548	24.4
Postojeca SE 250W	12,748	24.8
Nova SE	1,275	2.48
Grid Purchases	24,804	48.3
Total	51,375	100

Consumption	kWh/yr	%
AC Primary Load	37,603	87.7
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	5,283	12.3
Total	42,886	100

Quantity	kWh/yr	%
Excess Electricity	7,407	14.4
Unmet Electric Load	32.0	0.0851
Capacity Shortage	36.3	0.0965

Quantity	Value	Units
Renewable Fraction	42.2	%
Max. Renew. Penetration	1,568	%

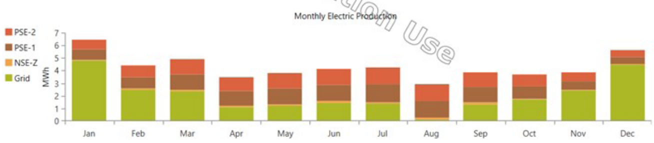


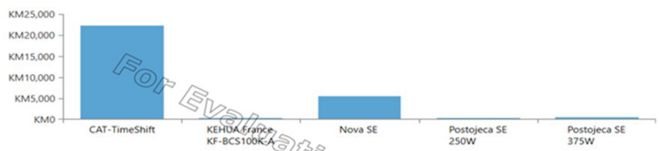
Figure 11: Electrical aspect for scenario 1

Quantity	Value	Units
Carbon Dioxide	14.5	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	53.5	kg/yr
Nitrogen Oxides	26.2	kg/yr

Figure 12: Emissions for scenario 1

3.2.2. Scenario 2

This scenario exclusively combines the PV system and batteries, resulting in a significant annual investment of 29,006.95 KM (Figure 13).



Component	Capital (KM)	Replacement (KM)	O&M (KM)	Fuel (KM)	Salvage (KM)	Total (KM)
CAT-TimeShift	KM22,236.58	KM0.00	KM0.00	KM0.00	KM0.00	KM22,236.58
KEHUA France KF-BCS100K-A	KM141.56	KM311.82	KM0.00	KM0.00	-KM83.07	KM370.32
Nova SE	KM3,296.34	KM0.00	KM2,241.38	KM0.00	KM0.00	KM5,537.72
Postojeca SE 250W	KM151.54	KM0.00	KM206.08	KM0.00	KM0.00	KM357.62
Postojeca SE 375W	KM264.72	KM0.00	KM240.00	KM0.00	KM0.00	KM504.72
System	KM26,090.74	KM311.82	KM2,687.46	KM0.00	-KM83.07	KM29,006.95

Figure 13: Cost summary for scenario 2

The analysis of electrical performance and renewable penetration demonstrates that all solar plants operate at full capacity, achieving 100% utilization of renewable sources (Figures 14-15).

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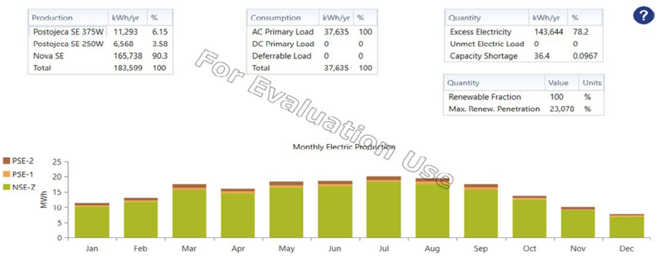


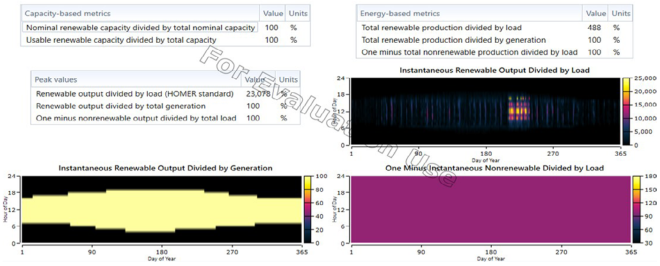
Production	kWh/yr	%
Postojeca SE 375W	11,293	6.15
Postojeca SE 250W	6,568	3.58
Nova SE	165,738	90.3
Total	183,599	100

Consumption	kWh/yr	%
AC Primary Load	37,635	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	37,635	100

Quantity	kWh/yr	%
Excess Electricity	143,644	78.2
Unmet Electric Load	0	0
Capacity Shortage	36.4	0.0967

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	23,078	%

Figure 14: Electrical aspect for scenario 2



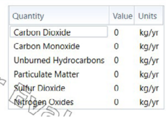
Capacity-based metrics	Value	Units
Nominal renewable capacity divided by total nominal capacity	100	%
Usable renewable capacity divided by total capacity	100	%

Energy-based metrics	Value	Units
Total renewable production divided by load	488	%
Total renewable production divided by generation	100	%
One minus total nonrenewable production divided by load	100	%

Peak values	Value	Units
Renewable output divided by load (HOMER standard)	23,078	%
Renewable output divided by total generation	100	%
One minus nonrenewable output divided by total load	100	%

Figure 15: Renewable penetration for scenario 2

Energy storage is enhanced by utilizing 84 high-capacity batteries, which ensure a reliable energy supply during periods of reduced solar production. This configuration successfully meets the goals of the NZEB concept, achieving zero emissions (Figure 16) and demonstrating the efficiency of the installed photovoltaic systems.

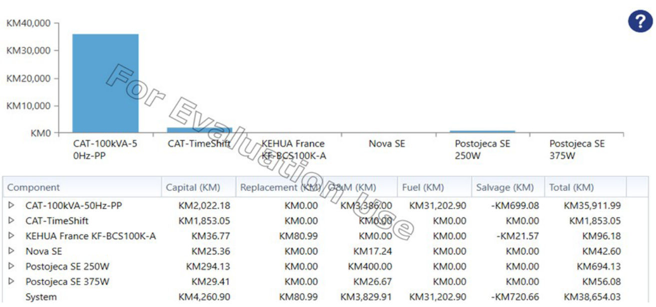


Quantity	Value	Units
Carbon Dioxide	0	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	0	kg/yr
Nitrogen Oxides	0	kg/yr

Figure 16: Emissions for scenario 2

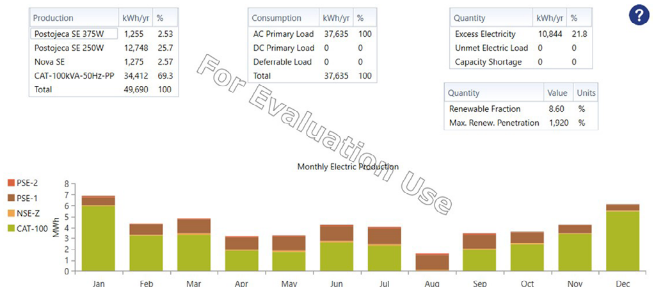
3.2.3. Scenario 3

This scenario is enriched by the inclusion of a diesel generator, which is necessary to enhance stability within the off-grid system, ensuring consistent energy supply during fluctuations in solar production. This investment, costing 38,654.03 KM, is the most expensive, primarily due to the chosen CAT-100kVA-50Hz-PP diesel generator (shown in Figure 17). Notably, as seen in Figure 18, this generator provides most of the building's electrical energy, except in August (Figure 19). However, since it is not a renewable energy source, it emits significant CO_2 emissions (29,485 kg/year). This scenario is considered only for comparing investment costs and finding the optimal solution.



Component	Capital (KM)	Replacement (KM)	O&M (KM)	Fuel (KM)	Salvage (KM)	Total (KM)
CAT-100kVA-50Hz-PP	KM2,022.18	KM0.00	KM3,386.00	KM31,202.90	-KM699.08	KM35,911.99
CAT-TimeShift	KM1,853.05	KM0.00	KM0.00	KM0.00	KM0.00	KM1,853.05
KEHUA France KF-BCS100K-A	KM36.77	KM80.99	KM0.00	KM0.00	-KM21.57	KM96.18
Nova SE	KM25.36	KM0.00	KM17.24	KM0.00	KM0.00	KM42.60
Postojeca SE 250W	KM294.13	KM0.00	KM400.00	KM0.00	KM0.00	KM694.13
Postojeca SE 375W	KM29.41	KM0.00	KM26.67	KM0.00	KM0.00	KM56.08
System	KM4,260.90	KM80.99	KM3,829.91	KM31,202.90	-KM720.66	KM38,654.03

Figure 17: Cost summary for scenario 3



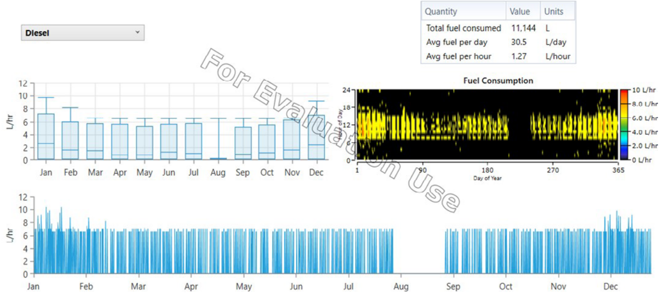
Production	kWh/yr	%
Postojeca SE 375W	1,255	2.53
Postojeca SE 250W	12,748	25.7
Nova SE	1,275	2.57
CAT-100kVA-50Hz-PP	34,412	69.3
Total	49,690	100

Consumption	kWh/yr	%
AC Primary Load	37,635	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	37,635	100

Quantity	kWh/yr	%
Excess Electricity	10,844	21.8
Unmet Electric Load	0	0
Capacity Shortage	0	0

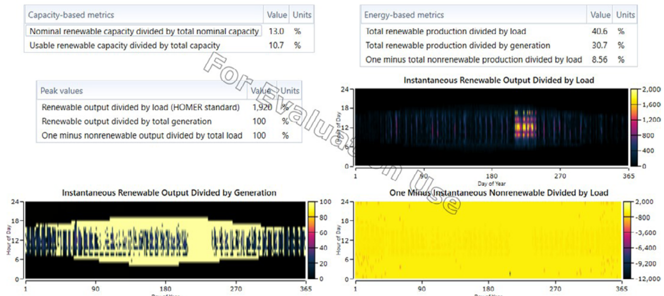
Quantity	Value	Units
Renewable Fraction	8.60	%
Max. Renew. Penetration	1,920	%

Figure 18: Electrical aspect for scenario 3



Quantity	Value	Units
Total fuel consumed	11,144	L
Avg fuel per day	30.5	L/day
Avg fuel per hour	1.27	L/hour

Figure 19: Fuel summary for scenario 3

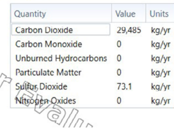


Capacity-based metrics	Value	Units
Nominal renewable capacity divided by total nominal capacity	13.0	%
Usable renewable capacity divided by total capacity	10.7	%

Energy-based metrics	Value	Units
Total renewable production divided by load	40.6	%
Total renewable production divided by generation	30.7	%
One minus total nonrenewable production divided by load	8.56	%

Peak values	Value	Units
Renewable output divided by load (HOMER standard)	1,920	%
Renewable output divided by total generation	100	%
One minus nonrenewable output divided by total load	100	%

Figure 20: Renewable penetration for scenario 3



Quantity	Value	Units
Carbon Dioxide	29,485	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	73.1	kg/yr
Nitrogen Oxides	0	kg/yr

Figure 21: Emissions for scenario 3

4. CONCLUSION

The modeling of a net zero energy building (NZEB) for the Faculty of Mechanical Engineering in Mostar signifies a pivotal advancement in the realm of energy sustainability, yielding benefits for both the institution and society. This initiative plays a critical role in reducing CO_2 emissions, thereby addressing the pressing challenges of climate change and global warming.

The integration of renewable energy sources, including solar panels, wind turbines, and geothermal systems, emerges as a foundational aspect of offsetting energy consumption and achieving net zero targets. This integration not only represents a transformative approach to energy management but also sets a precedent for other institutions to adopt similar sustainable practices. Using advanced simulation and modeling software enriches the understanding of the interactions between various systems, while a meticulous economic assessment evaluates the feasibility of investment. An analysis of multiple scenarios underscores the financial challenges of transitioning to NZEBs. Notably, Scenario 2 achieves complete zero emissions, yet necessitates an annual investment that significantly surpasses current electricity expenditures, highlighting the economic obstacles associated with such transitions.

Several factors additionally contribute to achieving net-zero emissions. The building's orientation, principles of natural ventilation, strategic selection of high-performance materials and advanced insulation techniques reduce heat losses, ensuring a stable internal temperature with minimal energy consumption. Together, these elements create a comprehensive approach to sustainability and energy efficiency.

Despite these challenges, the long-term benefits of investing in NZEBs extend beyond immediate financial considerations. They encompass enhanced energy independence, a reduced environmental impact, and an increased commitment to sustainability. The study suggests that further advancements can be made by investigating passive design strategies and minimizing heat losses.

This modeling approach for the Faculty of Mechanical Engineering in Mostar serves as a vital blueprint for analogous projects, contributing to a broader movement towards sustainable development and environmental stewardship. The findings underscore the potential of NZEBs to lead the way in fostering resilient, energy-efficient buildings that align with global sustainability objectives. This analysis highlights the significant potential for on-site solar energy generation at the Faculty of Mechanical Engineering and supports the institution's commitment to sustainable energy practices.

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