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Solutions to improve the energy efficiency of non-residential buildings: Evidence from Romania

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Abstract. Energy efficiency in buildings can lead to lower costs and a smaller carbon footprint. There are now numerous standards, regulations and certifications in place to encourage the construction of sustainable buildings and the increase of energy efficiency in existing ones. One such certification platform that provides tools for analysing the sustainability and energy performance of a building is EDGE. Thus, the aim of this paper was to investigate the possibility of using this platform for analysing and testing solutions to increase energy efficiency on a storage building. The results showed that the platform allows analysing various measures for increasing energy efficiency and displays an approximate prediction as a result of these measures. By performing simulations in the platform, it is possible to check and choose the best measures leading to maximizing the energy efficiency of the building and to plan the investments. The article includes the analysis of a warehouse chosen as a case study, in which lighting was identified as an area of inefficiency and it was replaced with a more efficient system, as well as installing a photovoltaic power plant. These measures led to an increase in building energy efficiency of approximately 17%.
Keywords: *buildings, energy efficiency, solutions, platform, simulations*

Introduction

The 21st century is marked by the need to reduce pollution and protect the environment. The sector with the highest emissions is the energy production sector, and one of the main consumers is buildings, which emit one third of total polluting emissions [1]. The energy consumption in buildings in the European Union (EU-27) accounts for 26.3% of residential buildings and 13.7% of non-residential buildings, totalling about 40% of final energy [2]. Thus, constructing sustainable buildings and increasing the energy efficiency of existing buildings is key to reducing pollution. Although higher energy efficiency and the use of renewable energy sources entail high purchase costs, these investments are associated with reduced overall costs [3].

While researching the energy efficiency of non-residential buildings in Finland, Sweden, Norway, Denmark and Germany, Mihkel Kiviste et. all, found that in terms of available information and studies, the non-residential building sector has been less researched in the literature. This although the energy consumption per square meter is higher [4]. The energy consumption in the service sector (non-residential buildings) is mainly due to higher occupancy rates and building floor area. In the period 2000-2018, the final energy consumption intensity per floor area increased by 13%. Building characteristics (size, surface area) or the utilization pattern (number of employees, hours of activity in the building) have an impact on energy demand, as larger buildings have higher heating and cooling demand [5]. Non-residential buildings where services are provided include buildings used for education, office, health care, sales, warehouse, etc. Given their importance, the literature has often addressed energy efficiency in office buildings, universities or schools, shopping centres, etc.

In research on energy efficiency gains in a warehouse, Phillip Cook & Alistair Sproul found that energy efficiency gains have been studied in multiple building types, but the energy efficiency of warehouses has been less researched, although they have a high potential. In analysing a commercial warehouse in a subtropical climate, they found that affordable solutions such as skylights, automated lighting systems, building envelopes, natural ventilation and low heat transfer glazing contribute to up to 73% building efficiency [6]. D. Pamungkas et. all observed that the implementation of a photovoltaic system provides both the greatest reduction in building electricity consumption and peak consumption, reducing energy bills by 47% and having a payback period of 17 years. Adjusting the HVAC setpoints produces benefits from the first year of use, leads to a reduction in overall consumption and a reduction in peak energy consumption, but the factor reduction is 4%. Last but not least, the use of storage battery helps to decrease the peak demand of the building, contributing to an 11% reduction in bills, but it does not contribute to a reduction in overall building consumption and does not reach the break-even point [7].

The topic covered in this article is relevant because, given the size and purpose of warehouses, making them more efficient can bring benefits both to the owners, by significantly reducing energy bills, and to the environment, by reducing emissions. The main aim of the article is to study the possibility of using a platform for analysing and simulating methods or technologies used to increase the energy efficiency of a chosen building, in this case a warehouse. Such a tool allows for the analysis and selection of the most appropriate measures to help maximize energy efficiency depending on the type of building, the equipment used, the materials from which it is constructed, etc.

It is expected that the results of the research will highlight the benefits of using such a platform, such as assessing the current efficiency of the building in relation to current legislation and standards, identifying the main areas of low efficiency and the possibilities for increasing efficiency in those areas, and testing several measures and technologies so that the optimal solution can be found or a plan for efficiency improvement can be devised. The financial possibilities, the interest, but also the impact of increasing energy efficiency are generally higher than in the case of residential buildings, therefore managers, owners or even tenants of these buildings, in this case warehouse managers/owners/users should be interested in reducing the total cost of running the building by increasing energy efficiency.

This paper is structured in several stages. The first stage consists of the presentation of the main tools to promote and assess sustainability and energy efficiency in buildings and the presentation of the EDGE platform. The second stage consists of the presentation of the main results of the platform. Following the building data input, the simulation of the platform allows analysing the current status of the building's efficiency in relation to the standards in force. Also at this stage, the simulation of energy efficiency improvement proposals and the results provided by the platform were analysed. The last stage consists in highlighting the benefits of using the platform and presenting the main conclusions resulting from this research.

1. Energy efficiency of buildings and methods to evaluate it

1.1. Energy efficiency of buildings

Assessing the energy performance of buildings plays an important role in analysing and implementing different solutions for decreasing energy consumption and carbon emissions [8]. The tools used to evaluate building performance differ depending on the type of building and can analyse very detailed aspects of energy consumption up to general building consumption analyses, generally including post-occupancy evaluation, indices, standards and regulations. Standards and regulations such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), ASTM Whole Building Functionality and Serviceability Standards, Operation and Maintenance Rating System (OMRS) establish performance levels of building equipment [9].

In some European countries the energy audits required for efficiency certification led to high costs. In general, the traditional approach is based on a static methodology, and the use of thermophysical equations, technical and architectural representations and meteorological data. However, traditional approaches require a high accuracy for building modelling, and the running time of simulations is higher. Energy modelling software such as EnergyPlus, TRNSYS, DesignBuilder, and DOE-2 use this approach [8].

Nowadays in fields such as energy efficiency, energy management and building refurbishment many performance assessment systems are used. Among the most numerous are certification schemes that require the achievement of certain efficiency percentages for certain consumption categories such as LEED, BREEAM, Green Star, CASBEE, BEAM, EDGE, etc [8-10].

Regardless of the method used, engineers, designers or auditors can use sustainability analysis based on building data modelling and performance assessment methods in the planning and design stages. The main purpose of these tools is to provide simulations and data on the anticipated building performance in a very short time, instantaneously, and to identify those areas where energy efficiency improvements are needed [10].

1.2. Use EDGE platform to measure the building energy efficiency

EDGE is a free online application [11] made available by IFC (International Finance Corporation), a member of the World Bank Group. The application allows the assessment of buildings from the design stage as well as existing buildings. This is why it can be used to analyse the sustainability of a project, as well as for projects to make existing buildings more efficient, modernize or renovate them [12]. EDGE (Excellence in Design for Greater Efficiencies) is a green building certification scheme. Like other existing certification schemes, the main aim of EDGE is to promote and encourage sustainable and energy efficient design practices [13].

The EDGE platform allows analysing the efficiency of a building using a set of mathematical equations based on climate data, heat transfer and building physics as a computational approach. In order to be able to calculate the efficiency of a building, the platform uses the method of comparison with a reference model. This model is based on the European CEN and ISO 52016 standards, as well as on the building standards and practices applied in the country where the building is located. The analysis performed by the platform focuses on energy efficiency increase (equipment used and thermal insulation of the envelope), reduction of water consumption and sustainability of the materials used in the building construction [14-17].

The platform also quantifies the net carbon savings based on the information entered and the selected equipment and offers more than 33 energy efficiency measures to help the user analyse the possibilities and impact of specific measures or technologies to improve energy efficiency [18]. The application allows the analysis of various building types such as residential buildings, office buildings, educational facilities, accommodation facilities, medical facilities, light industrial, retail and warehouses. A series of studies carried out on office buildings using the EDGE platform have shown that the most widely used and effective solutions are smart lighting, increased cooling system efficiency and renewable energy production (photovoltaic panels) [19-21]. According to F. D. Kartikasari et. all these measures can be successfully addressed in university buildings as well [22].

The main steps necessary to use the EDGE platform

The platform is structured in four data entry steps. In the Design section (Figure 1) general data about the building are required such as building type (dwelling, shops, office buildings, etc.), location (country and city), project responsible data, project data (year of construction, number of buildings, etc.), exact building data (dimensions, floors, surface, etc.). Finally, it is necessary to fill in information about the fuels used and the air-conditioning systems of the building. Depending on the chosen location, the platform automatically fills in the monthly atmospheric values.

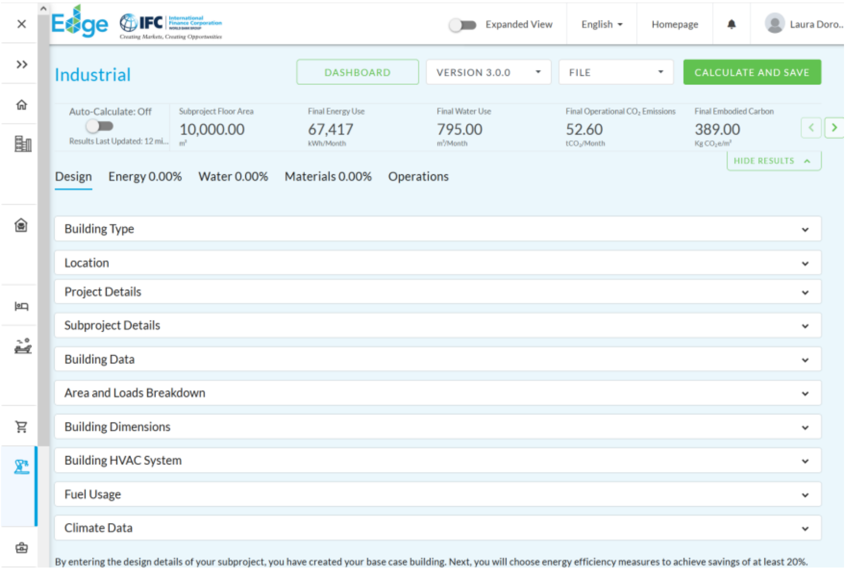

Figure 1. “Design” section of the EDGE platform.

Source: Adapted from https://app.edgebuildings.com/project/allBuildings

Next, it is necessary to complete the "Energy" section shown in Figure 2. This section requires the characteristics of the materials used (type, thickness, heat transfer coefficient, etc.), the energy performance of the ventilation systems (installed capacity, coefficient of performance, efficiency, fuel used, etc.) and of the lighting systems. The platform offers various systems to increase energy efficiency such as sensor systems for lighting, heat recovery from domestic water, installation of local or remote renewable energy systems.

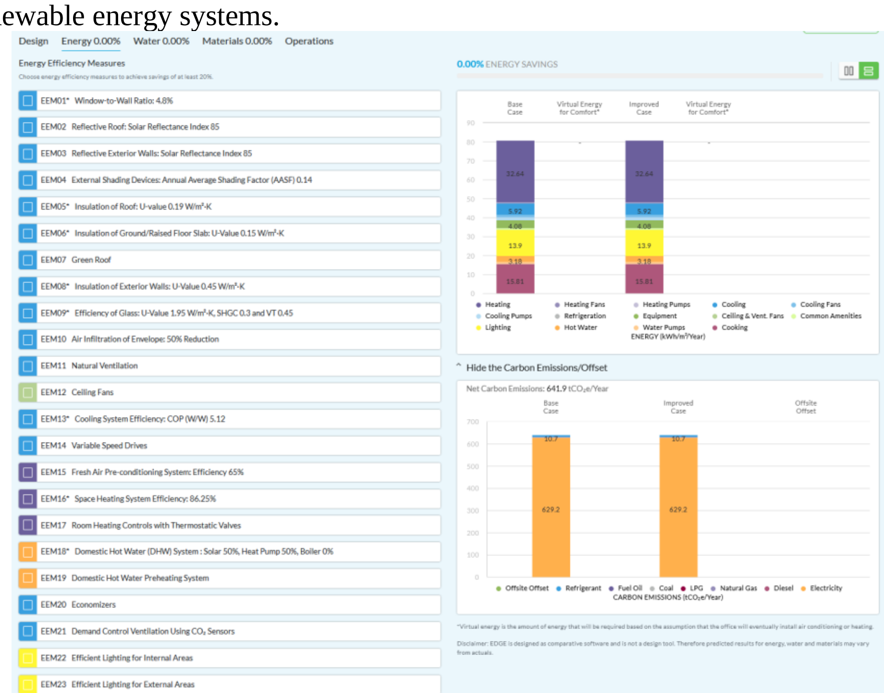

Figure 2. “Energy” section of the EDGE platform.

Source: Adapted from https://app.edgebuildings.com/project/allBuildings

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Completing the "Water" section (Figure 3) consists in filling in information on the average water flow rates of taps in bathrooms, kitchens and showers, the volume of toilet basins, the consumption of irrigation systems, etc. The platform offers possibilities to reduce consumption such as rainwater harvesting or reuse of grey (waste) water.

Figure 3. “Water” section of the EDGE platform.
Source: Adapted from [*https://app.edgebuildings.com/project/allBuildings*](https://app.edgebuildings.com/project/allBuildings)

The last section, "Materials" found in Figure 4 requires information on the types and thickness of all materials and insulation used in the construction of the building.

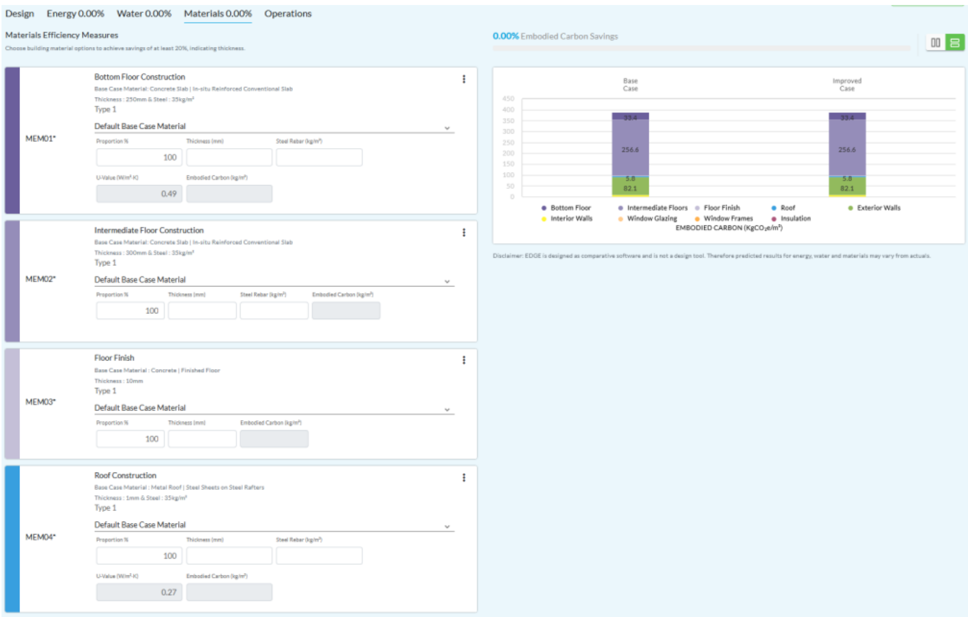

Figure 4. “Materials” section of the EDGE platform.
Source: Adapted from [*https://app.edgebuildings.com/project/allBuildings*](https://app.edgebuildings.com/project/allBuildings)

2. Solutions to improve the energy efficiency of a warehouse using the EDGE platform
In the following we will present the results obtained by entering the data of the warehouse chosen as a case study into the EDGE platform and the opportunities to increase its efficiency. In order to be able

to increase the energy efficiency of the warehouse it is necessary to analyse the current level of efficiency of the building. This analysis allows identifying the main areas of low energy efficiency.

2.1. Input data required for the simulation using EDGE platform
The chosen building has an area of approximately 15790 m^2 and consists of the main storage area and an office area for management. The structure of the building is made of reinforced concrete, with the roof and exterior walls made of steel-clad sandwich panels with mineral wool insulation with heat transfer coefficients of 0.27, 0.32 and 0.36 W/(m^2*K) respectively. The glazed area of the building is small, 0.61% percent of the external area of the building, with double glazing with a heat transfer coefficient of 1 W/(m^2*K).

The cooling system consists of several air conditioners with a total cooling coefficient of performance of 3.81 (W/W) and a cooling capacity of 48.5 kW. For heating and domestic hot water preparation, a condensing central heating plant with a rated capacity of 75 kW and an efficiency of 91% is used. The indoor lighting system is inefficient with a small number of LED lighting fixtures. LED luminaires with a luminous efficacy of 90 L/W are used for outdoor lighting. The water consumption is mainly due to the flow from the bathroom and kitchen water baths and averages 6.4 L/min.

2.2. Result analysis
The results provided by the platform show an energy efficiency of 26.39%, a water consumption efficiency of 45.74% and the use of 25% more sustainable materials than current standards, as shown in Figure 5. Also, according to the results from the platform annual energy savings are 558.9 MWh/year.

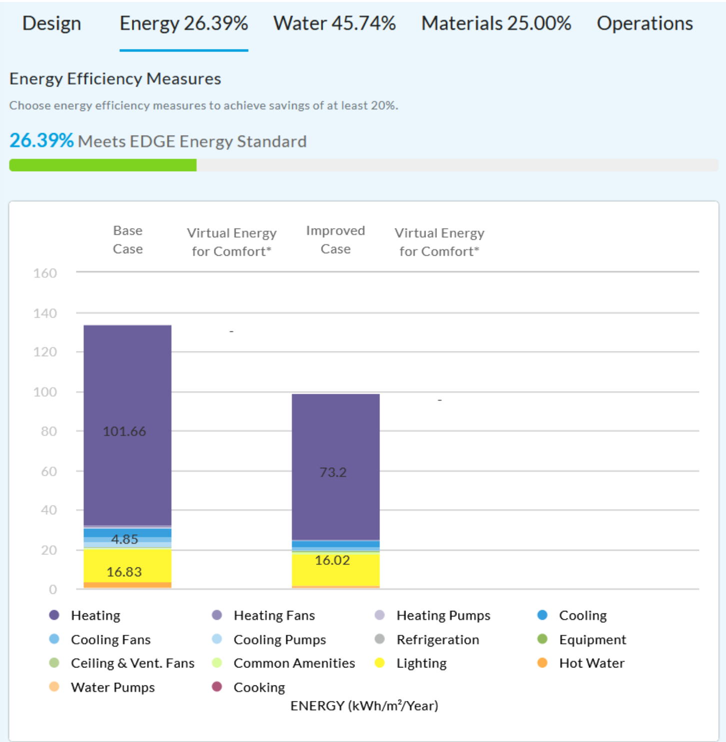

Figure 5. Simulation of warehouse energy performance in the EDGE platform

As can be seen in Figure 5, compared to the reference model simulated by the EDGE platform, the analysed building is more efficient in terms of energy consumption. At the same time, the results of the platform highlight that the main areas of inefficiency in the building are the lighting and heating systems.

2.3. Proposed measures to increase the energy efficiency of the warehouse

Measure 1 – increase the energy efficiency of the lighting system. As a first step, it was decided to study the impact of making the building's lighting system more efficient, given that the existing lighting system does not meet current efficiency standards.

Validation of the first proposal measure. Thus, the current lighting system was almost entirely replaced with LED luminaires, achieving an average luminous efficacy of 120.5 L/W. According to the results of the platform (Figure 6), this measure increased the energy efficiency of the building from 26.39% to 32.35% and annual energy savings increased to 685.2 MWh/year.

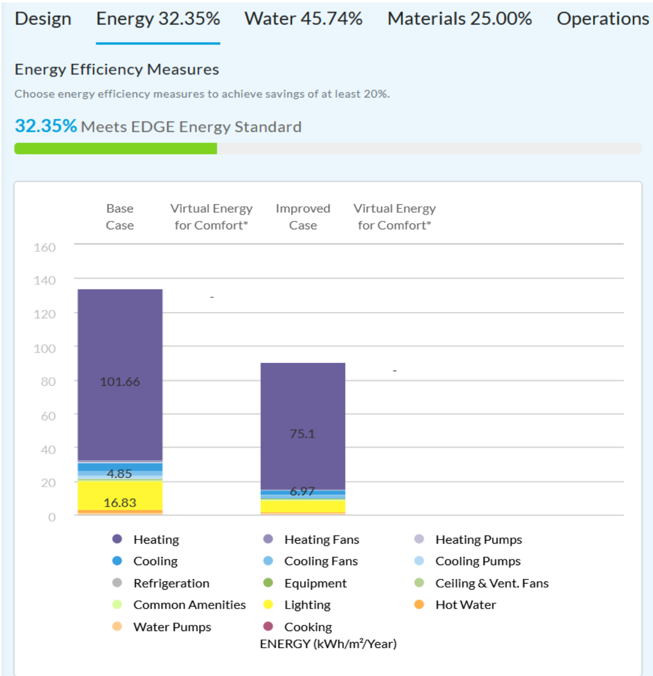

Figure 6. Simulation in the EDGE platform after increasing the efficiency of the lighting system

Measure 2 – increase the energy efficiency of the lighting system + installation of a photovoltaic system. It was decided that in the second phase the possibility of installing photovoltaic panels should be analysed. Thus, according to the platform's calculations, in order to be able to support the energy consumption of the building, it is necessary to install a photovoltaic power plant of approximately 785.7 kWp.

Validation of the second proposal measure. Thus, if the lighting system has an average efficacy of 120.5 L/W and considering the use of photovoltaic panels with an installed capacity of 550Wp, then 1430 photovoltaic panels need to be installed. The chosen panels have a size of 2216 mm x 1134 mm. The installation of 1430 such panels will occupy an area of approximately 4227.3 m^2. The roof area is over 15000 m^2, but subtract from this the areas where the panels cannot be installed, such as smoke vents, areas with outdoor equipment or free areas needed for the installation or maintenance of the panels. This gives an available area of over 5700 m^2 for panel installation.

In this case, according to the results of the platform illustrated in Figure 7, this measure increased the energy efficiency of the building from 26.39% to 43.48% and the annual energy savings increased to 922 MWh/year.

Figure 7 shows the total value as kWh/m^2/Year, including both electricity and natural gas. Given the fact that the heating and hot water preparation system remain based on natural gas, this value stays unchanged after applying energy efficiency measures. Replacing them not only entails increased costs for the purchase of equipment, but also changes to the building structure, but can be analysed as a measure to increase efficiency in the future.

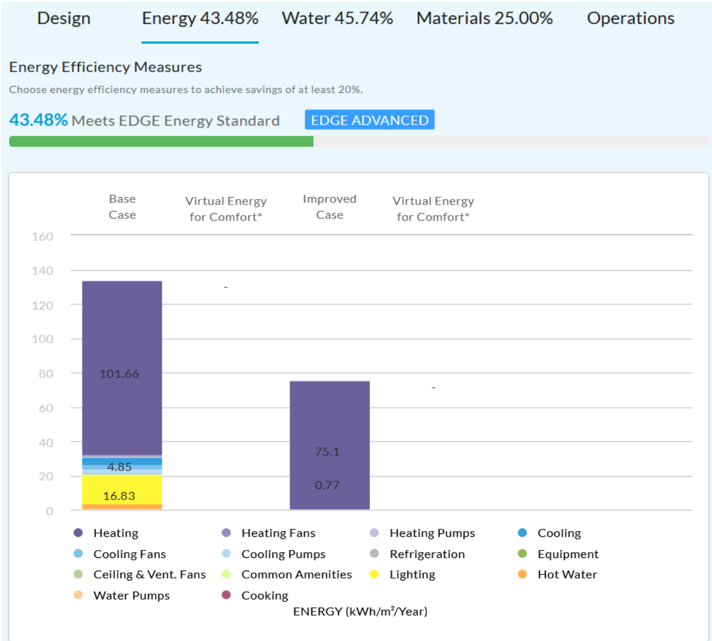

Figure 7. Simulation in the EDGE platform after increasing the efficiency of the lighting system and installation of PV panels

Table 1 summarizes all the measures analysed in the platform to increase the energy efficiency of the building such as changing the lighting fixtures and installing the photovoltaic plant. The number and approximate cost of these are also included in the table.
For the installation of the photovoltaic panels, the installation of 4 inverters, which are necessary for the functioning of the power plant, was also considered and it was assumed that the warehouse already has a smart meter to measure the energy consumption. The costs of transport, installation, assembly and costs of other additional equipment (e.g. cables) must also be added to the total cost. According to the results of the platform, the annual energy produced by the photovoltaic panels would amount to approximately 1,433,804 kWh/year.

Table 1. Energy efficiency equipment, numbers and costs

Echipaments	Number	Approximate cost [RON]
Warehouse lighting systems	230	60.950
Office lighting systems	80	12.000
PV panels	1430	850.900
Invertors	4	93.135
Total		1.016.985

Also, without changing the lighting system and installing the photovoltaic plant, and without taking into account the heating and domestic hot water system, the monthly electricity consumption of the building is approximately 34602 kWh/month. As the warehouse has a high consumption, it does not benefit from the tariffs of domestic consumers, but from those of non-household consumers. Thus, the energy price at the time of analysis (06.09.2024) varies between 0.99 and 1.3 RON/kWh. If one opts to purchase energy from a renewable energy producer, the lowest price is 1.03 RON/kWh, which means a monthly bill of about 35,725.86 RON. If it is assumed that the bill will remain constant throughout the year, then the total amount paid for one year will be 428,710.32 RON. It should be remembered that to this amount must be added the amount of the natural gas bill for the supply of gas to the power plant. Given the high value of energy bills, the proposed investments are necessary.

Both the replacement of the lighting equipment and the installation of the photovoltaic power plant, with a forecast of the equipment needs, can be realized over several years, depending on the financial possibilities of the enterprise and on the reduction in consumption brought about by the gradual implementation of these systems.

It should be recalled that financial institutions such as the EBRD, the EIB, the World Bank and various other donors, but especially the European Union, are interested in supporting and investing in such sustainable projects to increase energy efficiency. One such example is the EDGE platform itself, which is essentially a green building certification scheme. Thus, if the analysed building demonstrates that it has a minimum efficiency of 20% for each of the 3 categories analysed (energy, water and materials), the bank might be more interested in financing such projects.

Conclusions

In order to keep up with new energy efficiency standards and requirements, to reduce the environmental impact, but also to reduce the running costs of a building, it is necessary to increase the building’s energy efficiency. Many tools are now available whose main purpose is to promote and support increased sustainability, energy performance and/or user comfort. One such tool is the EDGE certification scheme platform.

The main purpose of this article was to demonstrate that this tool makes it possible to assess the energy performance of a building and to analyse the most appropriate solutions to increase efficiency. The platform allows the simulation of numerous solutions and provides information on the positive or negative impact of a solution, or its expected impact, displayed as a percentage increase or decrease of the energy efficiency, water consumption or material sustainability.

In this article, two methods of increasing energy efficiency were analysed. The first method analysed was chosen following the simulation of the energy performance of the building, from which it could be observed that the lighting system used had a high level of consumption. Therefore, it was decided to change it to a more efficient one with a luminous efficacy of 120.5 L/W. This change helped to increase the building's efficiency by almost 6% and to save 126 MWh/year.

The second method analysed consisted in maintaining the lighting system proposed in method 1 and installing a photovoltaic plant of about 786 kW. As a result of this solution, the overall building efficiency increased by 17% and energy consumption was reduced by 363 MWh/year.

The economic analysis shows that the investment in changing the lighting systems and installing the photovoltaic plant is high, this is mainly due to the large photovoltaic plant. However, given the high consumption of the building, determined by the EDGE platform, the investment is cost-effective as the approximate wear life of a PV plant is about 25-30 years (according to the manufacturers) and the payback period can be less than one third of this period.

Following the analysis of the two energy efficiency measures for the chosen case study, it turned out that the EDGE platform offers the possibility to study several measures to increase energy efficiency. The platform also allows for consumption forecasts, thus enabling the creation of a phased efficiency plan aiming at maximizing the sustainability and efficiency of the building, adapted to the proposed budget.

The limitations of this research are several. The analysis carried out was based on a single case study, but it can be extended to several storage buildings. Also, a small number of methods to increase efficiency were proposed, the platform offers many other possibilities. The study focused on the EDGE platform, but an analysis of more such platforms should be carried out in the future. Last but not least, the economic calculations should be done in more detail, including all the costs of deploying the systems and a detailed analysis of the investment and its payback, taking into account interest, discount date and financing possibilities.

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