APPLICATION OF THE DOUBLE SKIN FAÇADE IN REHABILITATION OF THE INDUSTRIAL BUILDINGS IN SERBIA

by

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This study aims to check the various possibilities of application of the double layer of the façade in the rehabilitation of industrial facilities in Serbia, with the aim of improving the energy performance of buildings and energy savings for heating and cooling. Industrial facility of Raska textile factory in city of Novi Pazar, Serbia, was taken as a model for this study. This facility needs to be adapted into the building for administrative purposes. Using the existing structural system of the building, the existing shell and infrastructure of the building, the scheme of future business functional areas of the building have been proposed, which defines the thermal zones in the building. The paper examined various modalities of double layer on the east and west façades of the building, adding a curtain wall with single glass as the outer membrane. The results of the energy characteristics of the proposed rehabilitation of the building were obtained using a computer simulation program EnergyPlus and software DesignBuilder, based on climatic parameters of Serbia and the parameters of necessary thermal comfort defined by the Regulations on energy efficiency in buildings and in accordance with standard EN 15251. The criteria on the basis of which the valorization of improving the energy efficiency of the building would be performed are the thermal comfort, the required amount of energy for heating and cooling the facility and reduction of CO_2 emission.

Key words: *industrial building, double skin façade, energy performance, simulation, EnergyPlus, DesignBuilder, adaptive reuse, thermal comfort*

Introduction

Buildings consume about 40% of the total energy in the European Union [1]. Our building sector is expanding, which further increases power consumption. Energy efficiency and use of energy from renewable sources represents important measures needed to reduce energy consumption in buildings and environmental pollution [2]. Therefore, the primary parameters that mostly affect the energy performance commercial buildings are heating and cooling requirements during the working hours [3]. All new buildings in the EU by the end of 2020 must be nearly zero energy consumption [1].

Analysis of the energy performance of buildings is a topic that has investigated numerous important scientific papers through simplified and detailed models based on the window properties, building design, and climate conditions [4]. Influence of glazing type and type of blinds on the energy performance of the building was also largely investigated topic [5-7].

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Simulations of heat gains to the application of passive solar system in terms of energy are sufficiently investigated in current research [8].

Analysis and evaluation of buildings based on thermal comfort according to EN 15251 standard is the actual theme of the approach which determines the level of comfort in buildings [9]. Numerical simulation of thermal comfort for buildings with natural ventilation is significantly represented approach in determining the quantitative value of thermal comfort [10].

Numerous proposals have been applied in order to reduce the annual heating and cooling energy demand, as for example double skin façades which represent an additional skin on the outside wall of the building [11].

There is a small number of researches about the application of the double skin façade during the reconstruction of the façade of industrial buildings, which until now was investigated in aspect of air comfort [12]. Optimization of model an industrial building to improve energy performance of a building for the climate conditions of the Republic of Serbia in case of adaptive reuse has not investigated theme. Adaptation and redevelopment of existing industrial buildings into buildings for different purposes a justified approach in contemporary practice of architectural design around the world. The application of passive solar systems in the process of the rehabilitation of industrial buildings is so far unresearched topic, and with this paper is expected, in this regard, a certain scientific contribution. Analog by implementation of elements of passive solar architecture on existing industrial buildings in the Republic of Serbia, a similar approach is applicable to all buildings that have similar design features tread, volumetry, and orientation of the building.

This paper presents the potential ways of application of double skin façade in the process of reconstruction, as an element of passive solar architecture, re-purposing and energy rehabilitation of the existing building. The existing industrial structure needs to be adapted into the building for administrative purposes. A renovation of the existing building is necessary to provide required thermal comfort in the building. Accordingly, this paper examines the different modalities of application of the double skin façade on the east and west façades in addition to reconstruction of windows and doors and reconstruction of non-transparent parts of the façade by adding insulating layers. The application of a double skin façade includes a corridor type double skin façade [13]. This reconstruction proposal undertakes the approach in accordance with the European standards EN 13947 [14] and EN 15251 [15], and Regulations on energy efficiency in buildings [16], the maximum allowable heat transfer coefficients for certain structural elements, calculation of the reduction of thermal losses, and reduction of CO_2 emissions.

Selected type of industrial facility is industrial hall with a two-sloped roof. Orientation that the hall takes is the north-south direction. This type of industrial facility is a typical building of industrial halls built in the sixties in ex-Yugoslavia during this period. By repurposing of industrial building into administrative building, functional zones in the building are proposed on the base of which the zoning of thermal loads functional units was performed. Model of the newly designed building has been a subject to numerical simulation by use of *EnergyPlus* software [17], and *DesignBuilder* software [18], and with those results the values of the energy needed for heating and cooling of the building, CO_2 emission, internal gains in the house, the amount of solar gain have been obtained. Thermal comfort and the impact of the facility on the environment as well as reduction of CO_2 emissions as criteria of improvement of energy efficiency of the building have been discussed in the paper. Based on the obtained results of necessary energy and CO_2 emissions in buildings that have a double skin façade as a cover, optimization of the obtained solutions has been discussed the in terms of energy. The paper does not discuss the design of the facility, but leaves the possibility for further research, the use of different materials in the rehabilitation of the building cover and quality of architectural expression and design.

Methodology

Selected type of industrial facility has been created in a computer program and is subject to numerical simulations in order to gain insight into its energy performance. Numerical simulation is carried out in accordance with applicable regulations in the field of energy efficiency of buildings, based on climate characteristics of locations, data on building materials, components and systems, data on electrical equipment, apparatus, and purpose of use of the building. By use of computer simulations of the energy performance of buildings a great advantage when designing new or rehabilitation of already built facilities is provided. In the first phase of the design already the different alternatives in the design and meeting the expected aesthetic and energy requirements of buildings can be tested.

Simulation of different rehabilitation of the chosen model is derived using *EnergyPlus* simulation platforms, with the help of graphic software *DesignBuilder*. This software combination was chosen primarily because of the reliability of *EnergyPlus* program, which is one of the most efficient tools which most other commercial software rely on [19]. Because of the reliability of software DesignBuilder which obtained simulation data significantly coincide with the real data in the functioning of the building [20]. In tab. 1 are specified five different scenarios of rehabilitation of the facility, of which four involve the application of a double skin façade while one sanitation scenario is a classic tread.

The methodological approach to the development of scenarios that are used for improving the energy performance of the building is guided by the desire to preserve the identity of the existing building, improving the design of the building by use of passive solar principles of architecture, preservation of geometry and ways of opening windows and doors, replacement of inadequate and environmentally unjustified roof cladding with new material.

Software *DesignBuilder* defined by a physical model of the building with a concrete geographical location and use of materials, layers of façade envelope. The software include the scheme of thermal zones, their internal design temperature, time intervals of use and occupancy, a load of electrical appliances and lighting. Working hours of functioning of the building are defined based on the 40 hour working time per week, respectively, 8 hour per day in the period 8:00 a. m. to 4:00 p. m from Monday to Friday. Interior design temperatures are defined by the Regulation on Energy Performance of Buildings (2011) [16], wherein said design temperature out of the working hours is adjusted by ±4 °C depending on the mode of heating or cooling facility, tab. 2. The presence of people, heat output per person, occupancy are also defined according to the Regulations, while the value of the heat output of the electrical equipment and lighting are taken over from the software *DesignBuilder* depending on the heat zone. Considering that the subject occupies only moderately sheltered location where more than one façade is exposed to the wind, the reported values of the facility ventilation by use of natural ventilation depending on the state of tightness of the building are defined with 0.9 air changes per hour (ac/h) for existing state and 0.5 ac/h for the state after rehabilitation. Those parameters are shown in tab. 2.

Once the concept of general thermal comfort is defined, it is the moment to define its two main indices: predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD).

Table 1. Proposed measures of rehabilitation of selected industrial building

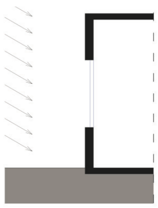
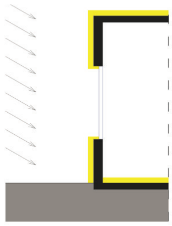
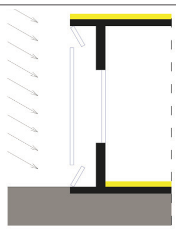
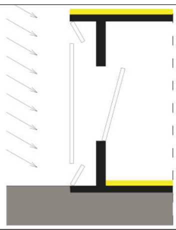
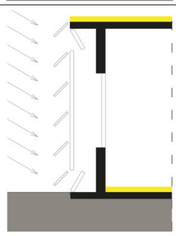
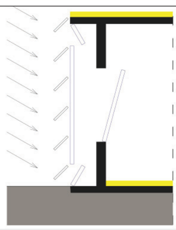
	Diagram of rehabilitation	Description of rehabilitation
Current situation		Current situation – Current situation of the building includes the current condition of the structural elements of the building envelope with constructive assembly building. Observing the selected types of industrial buildings is evident in the lack of insulating layer in the roof, façade walls and floor on ground of the building, resulting in a very high coefficient of heat transfer. The windows in the façade wall consisting of a single glass thickness of 6 mm and the coefficient of heat transfer U = 5.8 W/m^{2}K with metal frame without thermal break. Doors in the façade wall are metal structures with coefficient of heat transfer U = 3.124 W/m^{2}K.
Scenario 1		Scenario 1 – Rehabilitation of the building cover by adding insulating layers of 15 cm rock wool in façade wall and panel on the ground, while on the roof there is a need to add rock wool in the layer of 20 cm. Reconstruction of the windows is followed by replacing the existing metal frames with PVC profiles with the overall heat transfer coefficient U = 1.4 W/m^{2}K and replacing the existing single glass with double low-e glass 4+12+4 (Kr) with a coefficient of heat transfer U = 1.1 W/m^{2}K. Entrance metal doors were also replaced with a new with overall heat transfer coefficient U = 1.25 W/m^{2}K.
Scenario 2		Scenario 2 – This type of rehabilitation includes rehabilitation of the facility as in scenario 1 except for the eastern and western façade wall. On the east and west walls there is no planned rehabilitation of non-transparent parts of the façade but only the reconstruction of the windows as in scenario 1. On the east and west façades a double skin façade was formed whose outer membrane makes the curtain wall at a distance of 60 cm from the existing façade wall with a single glass with thickness of 6 mm and the overall heat transfer coefficient U = 5.8 W/m^{2}K
Scenario 2a		Scenario 2(a) – Is a rehabilitation scenario 2 advanced by the introduction of night ventilation in order to reduce the energy needed to cool the building in summer. Night ventilation means ventilation of the building, by controlled opening in the lower and upper zone of the double skin façade, opening of the windows and openings of internal openings /skylights of interior doors which would make a constant aeration of 0.5 ac/h between 6 p. m. and 6 a. m. increased to a maximum of 1.2 ac/h in the period April 1st to October 1st.
Scenario 3		Scenario 3 – Represents an improved rehabilitation scenario 2 with introduction of blinds on the east and west façades within the double skin fa 1st façade, which would reduce the energy needed to cool the building in summer. Blinds include fixed horizontal Sun breakers along the double façade, with a width of 50 cm are positioned at an angle of 45° in a vertical distance of 80 cm.
Scenario 3a		Scenario 3(a) - Is improved rehabilitation scenario 3 with additional introduction of night ventilation in order to reduce the energy needed to cool the building in summer. Night ventilation means ventilation by control of facility openings in the lower and upper zone of double skin façades, the internal control aperture and shutter windows /skylights of interior doors which would provide a constant aeration of 0.5 ac/h between 6 p. m. and 6 a. m. increased to a maximum of 1.2 ac/h in the period April 1st to October 1st.

Table 2. Loads of heat zones of people activity, occupancy, timetables, interior design temperature, heat load zone of lighting and electrical devices, ventilation

Data	Office	Corridor	Caffe	Conference room	Dressing room	Storage	WC	Unit
The internal projected temperature for winter conditions	20 / 16	16 / 16	20 / 16	20 / 16	20 / 16	18 / 14	18 / 14	°C
The internal projected temperature for summer conditions	26 / 30	30 / 30	26 / 30	26 / 30	26 / 30	26 / 30	26 / 30	°C
Occupancy per person	0.05	0.10	0.20	0.20	0.05	0.001	0.05	per m^2
People	80	100	100	80	100	100	100	W per person
Occupancy	08.00 a. m. 4.00 p. m.	08.00 a. m. 4.00 p. m.	08.00 a. m. 4.00 p. m.	08.00 a. m. 12.00 p. m.	08.00 a. m. 4.00 p. m.	08.00 a. m. 4.00 p. m.	08.00 a. m. 4.00 p. m.	h
Light energy	5							W/m^2 -100 lux
Natural ventilation	0.7							ac/h
Electricity equipment	11.77	1.85	14.72	5	/	/	5.48	W/m^2
External infitration existing / reconstructed	0.9 / 0.5	0.9 / 0.5	0.9 / 0.5	0.9 / 0.5	0.9 / 0.5	0.9 / 0.5	0.9 / 0.5	ac/h

The PMV provides information about the thermal sensation of occupants in an indoor environment, experienced on a scale of seven points. This scale goes from minus three to plus three, passing through zero, which represents the neutral thermal sensation.

The PPD is related to the PMV model, owing to the fact that there are differences in the perception of thermal comfort between persons. At the same time, it is related to individual habits, such as food, different clothes and styles and, in general, all the differences between individuals in their daily lives [9]. In accordance with indices PMV and PPD and European standard EN 15251, the categories of thermal comfort are defined, tab. 3.

Table 3. Predicted percentage of dissatisfied based on the predicted mean vote

Comfort category	PPD [%]	PMV
I	<6	$-0.2 < \text{PMV} < 0.2$
II	<10	$-0.5 < \text{PMV} < 0.5$
III	<15	$-0.7 < \text{PMV} < 0.7$

To define general thermal comfort, one needs to estimate metabolic rate and clothes' insulation. The metabolic rate (met) is defined as the amount of energy released as a function of the level of muscular activity. It is defined as 58.15 W/m^2 of body surface, in accordance with the values reflected in the ISO standard. In this research for office work, metabolic rate is specified to be 1.2 met, and clothing level 0.5 clo for summer regime and 1.0 clo in winter regime. Indoor air speed is defined 0.1 m/s in winter and 0.9 m/s in summer, according internal operative temperature and relative humidity of interior space [21].

Model for the analysis

Selected industrial facility is an apparel hall that belonged to the complex of textile plant *Raska* in Novi Pazar [22]. This building is the work of architects and D. Djukic and R.

Avramovic, was built in 1965 and represents the typical industrial building with a two-sloped roof, built in ex-Yugoslavia in that period. The building is freestanding industrial building that houses manufacturing facility, toilets and warehouses for the needs of workers. The building is rectangular in shape, orientation north-south with deviation of the north-south direction by 13 °, G + 0, fig. 1.

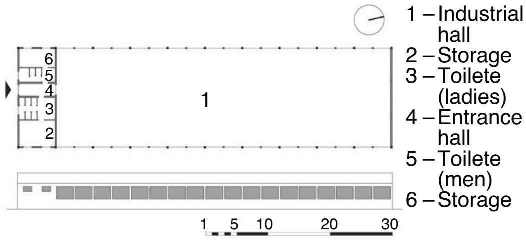


Figure 1. Ground floor (up) and east façade (down) of textile factory *Raska* – current conditions

In the immediate surroundings of the object, there are buildings that used to represent the ancillary facilities of the textile plant *Raska*. Based on the position of objects in the tighter location, the number of floors of surrounding buildings has been stated. The observed objects have a smaller number of floors and the lower overall height compared to the subject building, and they are far enough in order not to affect building's exposion to the Sun, not by its location, height or shade.

The production plant is located in the northern part of the building, while the entrance to the building with toilets and utility rooms is located in the southern part of the building. The building has smaller openings for the toilets on the south façade and a larger number of openings on the east and west façades with a uniform scheme followed by a constructive grid.

The constructive structure of industrial hall is made of the reinforced concrete structure of concrete columns with steel beam grid as a carrier. The exterior walls are made of bricks 25 cm thick plastered on both sides of the longitudinal mortar layer of 2 cm. The roof of the building is two-sloped roof with asbestos boards as a final layer. The panel on the ground consists of reinforced concrete layer 10 cm thick on gravel pad layer 10 cm thick, with parquet on the asphalt as a final layer.

The windows of the industrial building are single with a single layer glass 6 mm thick with heat transfer coefficient U = 5.8 W/m^{2}K and metal frame without thermal disconnection with coefficient of heat transfer U = 6.0 W/m^{2}K.

Table 4 presents basic information about the building, the surface of the thermal cover of the building, volume of heated space, building shape factor and the percentage of transparent surfaces in the building cover.

Table 4. Information about the building

Information about the building	Existing condition
Area of the thermal building envelope, A [m^2]	2207.277
The volume of the heated part of the building, V [m^3]	3951.3
Building shape factor, [m^{-1}]	0.559
The share of transparent surfaces, [%]	16.901

Renovation and adaptation of the building anticipates repurposing the building for administrative purposes. In the renovation, the attention was paid to the utilization of the existing structure of the building and the existing infrastructure. In fact, when changing the purpose of the space, the existing physical structure and purpose of the existing additional space of the industrial building have been used, while the space reserved for industrial production has been transformed into office space, with conference room and horizontal communication, fig. 2. In the aim of better utilization of the space two-tracts with the corridor and administrative units that are positioned on the east and west façades of the building have been formed. Achieved surfaces and volumes of the rooms are given in tab. 5.

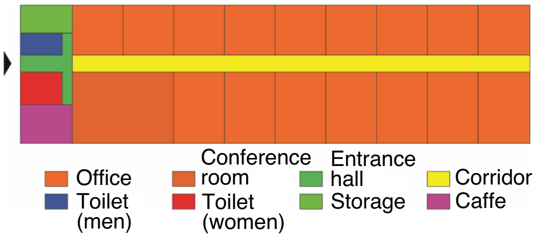


Figure 2. One implementation of the functional areas of adaptive reuse the office building
(*for color image see journal web site*)

Results and discussion

In this part, the paper presents the results of building's energy demand for heating and cooling, results in CO_2 emissions and the value of internal heat gains from solar gains obtained by computer simulation using software *EnergyPlus* and *DesignBuilder*.

Table 5. Area and volume are in the building – adaptive reuse

Zone	Area, [m^2]	Volume, [m^3]
Storage (west)	17	63.1
Conference room	93.8	397.9
Offices (east)	330.9	1403.9
Corridor	111.9	525
Offices (west)	290.4	1169.8
Caffe	24.2	92.5
WC (women)	20.6	93
Entrance hall	12	55.2
WC (men)	13.3	55.7
Total	914.1	3855.9

Table 6. Final energy needed for heating +and cooling of the building

Condition of the building	Heating [MWh]	Heating [kWhm^{-2}]	Heating [kWhm^{-3}]	Cooling [MWh]	Cooling [kWhm^{-2}]	Cooling [kWhm^{-3}]
Current condition	147.61	161.49	38.28	15.62	17.09	4.05
Scenario 1	17.66	19.87	5.19	5.29	5.95	1.55
Scenario 2	17.57	18.60	4.90	8.83	9.35	2.46
Scenario 2(a)	17.57	18.60	4.90	7.99	8.46	2.23
Scenario 3	21.84	23.12	6.09	3.11	3.30	0.87
Scenario 3(a)	21.84	23.12	6.09	2.83	3.00	0.79

Based on the total final annual energy use for heating of the building tab. 6 it is concluded that this approach of rehabilitation of the building envelope can achieve substantial energy savings and 6.75 to 8.36 times less energy consumption compared to the current state of the building. According to scenario 1, the rehabilitation of the building envelope annual energy consumption for heating is reduced even 8.36 times, respectively, to 88.04%. According to the scenarios 2 and 2a which include application of a double skin façade, annual energy consumption for heating of the building is reduced by 8.4 times, respectively, to 88.10%. According to scenarios 3 and 3a, which include the use of a double façade with blinds, annual energy consumption for heating of the building is reduced by 6.75 times, respectively, to 85.20%, chart 1, left.

Minimum quantity of final energy for heating is required in the case of rehabilitation under scenario 2 and 2a, which does involve the use of a double skin façade, but does not represent a significant difference from the liner of scenario 1. On the basis of the energy consumption for heating per unit area, 18.60-23.12 kWh/m^2, we can conclude that any scenario of proposed rehabilitation of existing building can improve the energy to a class „B" category (allowed 17-33 kWh/m^2) [23].

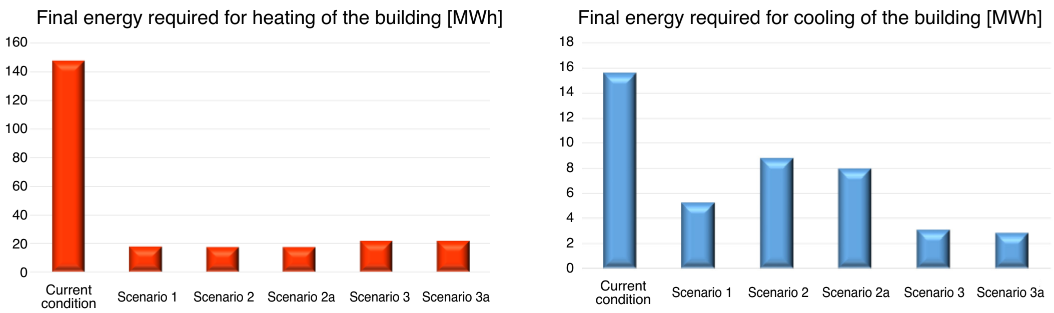


Chart 1. Final energy needed for heating (left) and cooling (right) of the building

Based on the total final annual energy use for cooling of the building tab. 6 it is concluded that this approach of rehabilitation of the building envelope can achieve substantial energy savings and 1.77 to 5.52 times less energy consumption compared to the current state of the building. According to scenario 1, the rehabilitation of the building envelope annual energy consumption for cooling is reduced even 2.95 times, respectively, to 66.12%. According to the scenarios 2 which include application of a double skin façade, annual energy consumption for cooling of the building is reduced by 1.77 times, respectively, to 43.46%. According to the scenarios 2a which is enhanced by introducing rehabilitation scenario 2 night ventilation, annual energy consumption for cooling of the building is reduced by 1.95 times, respectively, to 48.82%. According to scenarios 3 which include the use of a double façade with blinds, annual energy consumption for cooling of the building is reduced by 5.01 times, respectively, to 80.04%. According to scenarios 3a which is enhanced by introducing rehabilitation scenario 3 night ventilation, annual energy consumption for cooling of the building is reduced by 5.52 times, respectively, to 81.88% (chart 1, left).

In tab. 7 are shown results of thermal comfort in the building for all scenarios of the building rehabilitation.

Table 7. Results of thermal comfort according EN 15251

Scenario of rehabilitation	Summer conditions					Winter conditions				
	Operative tempera - ture	Relative humidity	PMV	PPD [%]	Category	Operative tempera-ture	Relative humidity	PMV	PPD [%]	Category
0	29.51	44.18	0.93	23	IV	15.73	53.11	–1.25	38	IV
1	25.77	51.22	–0.56	12	III	18.42	54.83	–0.65	14	III
2	26.57	43.83	–0.29	7	II	18.18	53.54	–0.71	16	IV
2a	26.58	48.76	–0.28	7	II	18.18	53.54	–0.71	16	IV
3	25.43	51.48	–0.70	15	IV	18.18	53.54	–0.71	16	IV
3a	25.48	51.32	–0.68	15	III	18.18	53.54	–0.71	16	IV

Calculation of thermal comfort according to EN 15251 is determined based on operative temperature and relative humidity of interior space. Based on the data in tab. 7, we can conclude that this approach rehabilitation of the building achieves significant thermal comfort during the summer period where the buildings according to EN 15251 can lead to category II rehabilitation according to the scenario 2 and 2a, while the winter period is not possible, except for the scenario 1 when the building had a comfort level III category.

Annual primary energy for the operation of technical systems for space heating and cooling, which takes into account the energy source, according to the Regulations on energy efficiency of buildings [16], is determined by having the annual final energy needed to ensure thermal comfort multiplied by the conversion factor for a particular energy source. The conversion factor for natural gas is 1.1, while the conversion factor for electricity as a source is 2.5. According to the same regulation, the annual CO_2 emissions is 0.20 kg/kWh for natural gas and 0.53 kg/kWh for electricity. The amount of primary energy consumption and CO_2 emissions for the selected type of industrial facility are shown in tab. 8.

Table 8. Primary energy needed for heating and cooling of the building and the amount of CO_2 emissions

Condition of the building	Primary energy heating [MWh]	Primary energy cooling [MWh]	Primary energy total [MWh]	CO_2 emission heating, [t]	CO_2 emission cooling, [t]	CO_2 emission total, [t]
Current condition	162.38	39.05	201.42	32.48	20.70	53.17
Scenario 1	19.42	13.23	32.65	3.88	7.01	10.90
Scenario 2	19.33	22.08	41.41	3.87	11.70	15.57
Scenario 2a	19.33	19.98	39.31	3.87	10.59	14.46
Scenario 3	24.03	7.79	31.82	4.81	4.13	8.94
Scenario 3a	24.03	7.08	31.10	4.81	3.75	8.56

Based on these results, with the exception of the current situation, the greatest need for energy would have a building rehabilitated under scenario 2, then under scenario 2a, 1, and 3, while the building rehabilitated by scenario 3a would require a the smallest amount of total primary energy for heating and cooling of the object (chart 2, left).

As for CO_2 emissions, with the exception of the existing condition of the property, the order of repaired structures according to this criterion would be the same as to the necessary amount of primary energy. All scenarios of rehabilitation significantly reduce emissions of CO_2, as follows: 2 scenario to 37.60 tons per year (70.72%), 2a scenario to 38.71 tons per year (72.81%), scenario 1 to 42.27 tons per year (79.51%), scenario 3 for 44.24 tons per year (83.19%) and scenario 3a for 44.62 tons per year (83.91%), (chart 2, right).

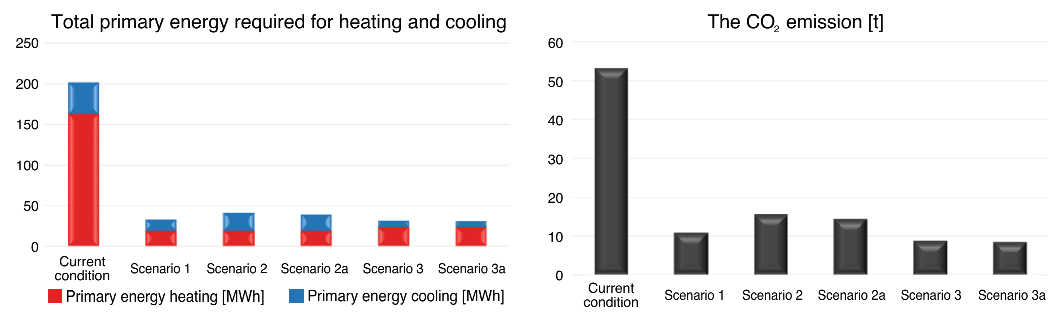


Chart 2. The total primary energy needed for heating and cooling facility [MWh] and the total amount of CO_2 emissions [t]

Conclusions

This paper presents a case study of one type of industrial facility in the climatic conditions of the Republic of Serbia and shows how different concepts of the double façade affect the energy efficiency when rehabilitating and repurposing of industrial facilities. The survey was conducted by means of numerical computer simulation of a specific model of industrial buildings and its various rehabilitation scenarios using *EnergyPlus* simulation platform. Ranking energy performance simulation results was carried out in terms of energy certification of the facility on the basis of impact on the environment, reduction of CO_2 emissions. The main objective of this study was to investigate the effect of the double skin façade on the energy performance of buildings, namely the energy required for heating and cooling, and to choose the optimal scenario of rehabilitation of industrial buildings of the terrestrial level with gabled roof.

Energy simulation results showed variation between the energy needs of different rehabilitation scenarios. The most energy efficient scenario is rehabilitation scenario 3a, renovation with the implementation of the double skin façade with fixed blinds and night ventilation during the summer. This is also the approach to the renovation of the building with the lowest primary energy required for heating and cooling of the building, as well as rehabilitation in which a minimum CO_2 emission has been registered. Other rehabilitation scenarios have advantages both in terms of energy and the design concepts, which remains the choice of architects and investors in finding the best solutions, taking into account all the necessary factors.

This research could contribute to architectural design practice as it shows concrete results of energy simulation of industrial facilities with a double skin façade in the process of repurposing and renovation into the office building. In addition, it demonstrates how operational research techniques can be applied to theory of management of renovating to the specific purpose. We hope that this research will provide specific information in the design of rehabilitation and reuse of industrial buildings in the administration, with a double skin façade in the climatic conditions of the Republic of Serbia, because it best represents the methodological approach of combining different scientific fields in order to achieve the best solutions and designs that can improve the quality of space around us.

Recommendations for further research include analysis of various types of industrial facilities with the possibility of reassigning and application of double skin façades and their energy performance in a variety of climatic conditions. In addition, the input parameters in the simulation can be varied to achieve the best energy performance of the building and find the most acceptable solution.

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