REDUCTION OF CO_2 EMISSION AS A BENEFIT OF ENERGY EFFICIENCY IMPROVEMENT
Kindergartens in the City of Nis – Case Study

by

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The analysis conducted in this paper was initiated by the fact that Serbia emitted around 80 million tons of CO_2, equivalent in 1990, and in between 85-89 million tons in 2010, which places it among ten countries with the highest emission of CO_2 per capita in the world (data by Cener for Ecology and Sustainable Development, Subotica, Serbia). This paper is aimed at making a correlation between the improvement of thermal performance of structural elements of buildings in order to enhance their energy efficiency, which is also economically justified, and reduction of GHG (CO_2) emission whose economic benefits are not so easy to assess even though it represents an environmental problem. The case study analysis, presented by this paper, using the example of a select number of kindergartens in the territory of the city of Nis, Serbia, is aimed at determining the correlation of the effects of improvement of their energy performances on the reduction of GHG emission reduction by quantifying the benefits of CO_2 emission reduction as a result of energy efficiency improvement reflected through the increase of energy class. The specific review conducted in this paper indicates the environmental importance of improvement of energy efficiency by valorizing the quantitative reduction of CO_2 emission as a benefit of implementation of energy revitalization of buildings.

Key words: *kindergarten, energy efficiency, energy revitalization, CO_2 emisssion, benefit, sustainable upbuild*

Introduction

Various gases are emitted in process of production, transformation, and consumption of fossil fuels. Unfortunately, most of them are harmful gases – GHG whose impact on global climate change is more than evident [1-5]. It is known that all the gases released in fuel combustion can be classified as fugitive emission and fossil fuel combustion emission. The fugitive emission comprises vapors created in the process of coal mining, and crude oil and natural gas processing, transport, and storing, and the gas released is mostly CH_4. The most characteristic gas released in combustion of fossil fuel is CO_2, even though certain gases such as: CH_4, N_2O, NO_x, CO, non-methane volatile organic compounds, and SO_x are also present to a certain degree.

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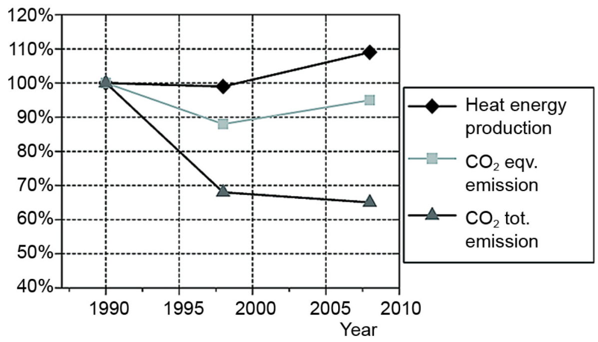

Figure 1. Changing the amount of generated heating energy and the amount of the emitted CO_2 in the period 1990-2008 [9]

When discussing the emission of CO_2 at the level of Serbia [6-8], the results of one of the conducted studies indicate that emissions of CO_2 from district heating plants in 1998 amounted to 88.83% of emissions in comparison to 1990 at fuel consumption of 0.535 Mtoe, while in 2008 at fuel consumption of 0.590 Mtoe, the emission of CO_2 reached the level of 94.28% of the emission in comparison to 1990. Variation of the amount of produced heat energy and amount of emitted CO_2, CO_{2ekv}, and CO_{2tot}, in comparison to the value of emission in 1990 is presented in fig. 1.

The procedures aimed at reducing emission of GHG, are the priority in all segments of human activities. Observing these priorities, when it comes to the centralized supply of heating energy and hot water in the public sector of Serbia, the existing research and studies recommend potential for reduction of harmful emission of GHG, by favoring [9]:
– reduction of specific consumption of heating energy per heated area, through improvement of thermal insulation of the building stock,
– substituting coal and oil by natural gas and/or biomass, and
– introduction of contemporary technological solutions (combined production of electric and heating energy and facilities with gas-steam cycle, and cogeneration).

With these recommendations in view, the presented analyzed kindergarten (KG) structures were chosen based on two criteria: the first comprises that all the structures are connected to the district heating system, and the second that it is possible to fit photovoltaic panels on the buildings. According to the previously set criteria, out of the total number of KG in the territory of the city, five KG were selected, tab. 1.

Table 1. General information about KG

Name of KG	Tag name	Heating surface [m^2]	Built year	Heating plant	Energy source
Petar Pan	KG.1	1,257.00	2005	Majakovski	Gas
Bambi	KG.2	1,240.06	1978	Krivi vir	Gas/heating oil
Plavi Cuperak	KG.3	1,053.66	1983	Krivi vir	Gas/heating oil
Zvoncica	KG.4	1,332.25	1992	Krivi vir	Gas/heating oil
Neven	KG.5	1,117.01	1981	Jug	Gas/heating oil

The case study conducted by the paper has a goal of evaluating potential benefits of CO_2 emission reduction which was accomplished by the revitalization of energetic features of the existing structures, and by the improvement of their energy efficiency and reduction of total consumption of electric energy through application of photovoltaic panels on the free area of the flat roof.

Existing condition

Measurement

The measurement results obtained in the city were obtained using appropriate devices which were fitted, attested and calibrated according to the standards by an adequate distributer and represent the result of the three year long period of monitoring of total heating energy and electric energy consumption of five chosen KG in the territory of the City of Nis. By using the obtained results the total emission of CO_2 was calculated according to the standing code book; the emission was used for evaluation of the condition prior and after the revitalization of the energetic features of the chosen structures.

In addition of the values of heating energy consumption expressed in [kWh], also given are the data about the distributer of heating energy, heated surface area of the structures, and built year. Heating energy consumption measurements were performed for three heating seasons from 2011/2012 to 2013/2014 for each of the structures (KG.1 to KG.5). The obtained results were presented in tab. 2, and they present the total consumption of the heating energy supplied by the adequate heating plants, tab. 1 for each of heating season from October 15^{th} to the April 15^{th}, fig. 2.

Table 2. Measured values of heating energy consumption and calculating primary energy

Tag name	Total delivered heating energy for heating season [kWh]			Calculated primary energy E_{prim} [kWh]		
	2011/2012	2012/2013	2013/2014	2011/2012	2012/2013	2013/2014
	October-April	October-April	October-April	Conversion factor, f_{prim} = 1.8		
KG.1	111,761.00	99,540.00	81,477.00	201,169.80	179,172.00	146,658.60
KG.2	230,983.00	194,594.00	174,006.00	415,769.40	350,269.20	313,210.80
KG.3	165,458.00	149,050.00	132,491.00	297,824.40	268,290.00	238,483.80
KG.4	161,727.00	123,430.00	104,017.00	291,108.60	222,174.00	187,230.60
KG.5	212,366.00	172,617.00	146,112.00	382,258.80	310,710.60	263,001.60

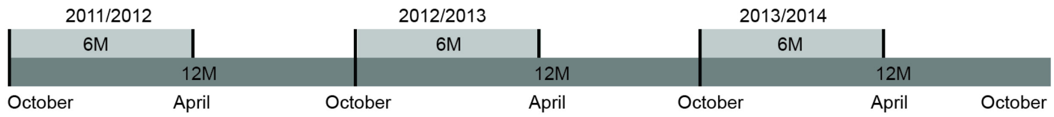

Figure 2. Measurement period – graphical presentation of the heating seasons (6 months) and annual period of electric energy measured (12 months)

In order to obtain complete image about the total emission CO_2 of the existing condition, in addition to the emission created by the consumed heating energy for each of five chosen KG, the calculation includes the emission created by the consumed electric energy. Measurement of electric energy consumption is carried out for a period of 12 months for adequate heating season, but for the period that covers October 15^{th} to October 15^{th} next year, fig. 2. The measurement provided the results of electric energy consumption of the analyzed KG in the previously described period, and the measured values are presented in tab. 3.

Conversion factors for calculating annual primary energy are taken from tab. 6.12 specified by the *Code on Energy Efficiency of Buildings* [10], and calculated by:

$$E_{\text{prim}} = Q_{H,\text{KG}.n}\ f_{\text{prim}} \tag{1}$$

where $Q_{H,\text{KG}.n}$ is the overall consumption of heating energy (final energy), E_{prim} – the annual primary energy, and f_{prim} – the conversion factor for calculating the annual primary energy.

Table 3. Measured values of electric energy consumption and calculating prymary energy

Tag name	Total electric energy consumption for annual period [kWh]			Calculated primary energy, E_{prim} [kWh]		
	2011/2012	2012/2013	2013/2014	2011/2012	2012/2013	2013/2014
	October-October			Conversion factor, f_{prim} = 2.5		
KG,1	35,500.00	40,440.00	37,080.00	88,750.00	101,100.00	92,700.00
KG.2	32,880.00	34,440.00	32,850.00	82,200.00	86,100.00	82,125.00
KG.3	32,800.00	33,360.00	35,480.00	82,000.00	83,400.00	88,700.00
KG.4	32,380.00	34,160.00	37,810.00	80,950.00	85,400.00	94,525.00
KG.5	41,400.00	28,560.00	20,320.00	103,500.00	71,400.00	50,800.00

Calculation

Taking into account the various methods of calculation considering that for the analysis – case study was chosen the City of Nis, the implemented calculation methodology was specified in [10]. The emission of CO_2 is calculated in the following methodology:

– total emission of CO_2 generated during operation of a building is determined based on the data of specific emission of CO_2 for certain sources of energy, by multiplying the annual necessary primary energy for building operation according to the specific energy source with the corresponding specific CO_2 emission parameter, which is provided in table 6.13 in [10], and summing up the values, and
– the indicators of CO_2 emission are expressed in the form of the annual emission of CO_2 [kg per year] and specific annual emission of CO_2 per surface area unit [kg/m^2 per year].

Data of specific emissions of CO_2 for certain types of energy, according to the code, for electric energy is EM_{CO_2} = 0.53 kg/kWh, and for the district heating EM_{CO_2} = 0.33 kg/kWh. Data for district heating are used in case when the fuel supplier does not provide emissions for its fuels, *i. e.* energy. Annual emissions of CO_2 determined by the following equation:

$$CO_2 = E_{\text{prim}}\ EM_{CO_2} \tag{2}$$

where EM_{CO_2} is the specific emissions of CO_2, and E_{prim} – the annual primary energy.

The previously proscribed methodology is used to calculate emission of CO_2 [kg per year] for the exsisting condition of the analyzed kindergarten structures (KG.1 to KG.5). The measured consumed heating energy and the consumed electric energy, is presented in tab. 4.

The annual (total) emission of CO_2 was obtained by summing up the results of the calculated annual emission generated by the consumption of heating and electric energy for each of the observed three heating seasons (calculated values of CO_2 emission from tab. 4). The total, *i. e.* annual emission of CO_2 of each of the analyzed structures is presented in tab. 5 and by the graphical diagram, fig. 3. The table also presents the energy efficiency classes of the exsisting condition.

Table 4. Calculated CO_2 annual emission generated by the consumed heating energy for heating seasons; (a) 6 months, and electric energy for annual period (b) 12 months

Tag name	(a) The CO_2 emission-heating energy [kg per year]			Tag name	(a) Heating energy
	EM_{CO_2} = 0.33 kg/kWh				The CO_2 emission [kg per year]
	2011/2012	2012/2013	2013/2014		Average value
KG.1	66,836.03	59,126.76	48,397.34	KG.1	58,120.04
KG.2	137,203.90	115,588.84	103,359.56	KG.2	118,717.43
KG.3	98,282.05	88,535.70	78,699.65	KG.3	88,505.80
KG.4	96,065.84	73,317.42	61,786.10	KG.4	77,056.45
KG.5	126,145.40	93,213.18	86,790.53	KG.5	102,049.70
Tag name	(b) The CO_2 emission-electric energy [kg per year]			Tag name	(b) Electric energy
	EM_{CO_2} = 0.53 kg/kWh				The CO_2 emission [kg per year]
	2011/2012	2012/2013	2013/2014		Average value
KG.1	47,037.50	53,583.00	49,131.00	KG.1	49,917.17
KG.2	43,566.00	45,633.00	43,526.25	KG.2	44,241.75
KG.3	43,460.00	44,203.00	47,001.00	KG.3	44,888.00
KG.4	42,903.50	45,262.00	50,098.25	KG.4	46,087.92
KG.5	54,855.00	37,824.00	26,924.00	KG.5	39,867.67

Table 5. Existing condition – energy efficiency class and calculated (A + B) annual CO_2 emission

Tag name	Existing condition	Annual CO_2 emission [kg per year]			
	EE class	2011/12	2012/13	2013/14	Average value
KG.1	D	113,873.53	112,709.76	97,528.34	108,037.21
KG.2	E	180,769.90	161,221.84	146,885.81	162,959.18
KG.3	E	141,742.05	132,738.70	125,700.65	133,393.80
KG.4	D	138,969.34	118,579.42	111,884.35	123,144.37
KG.5	E	181,000.40	131,037.18	113,714.53	141,917.37

Based on the previous measuring results in all the presented analyzed examples, it is evident that the consumption of heating energy for the observed heating seasons, see tab. 2, decreased. The direct consequence of decrease of the heating energy consumption is the expected trend of decrease of CO_2 emission for every of the analyzed KG, as presented by the diagram in fig. 3, in the heating seasons 2011/2012-2013/2014. Such result, exhibiting decrease of heating energy consumption is a consequence of slightly higher average daily tem-

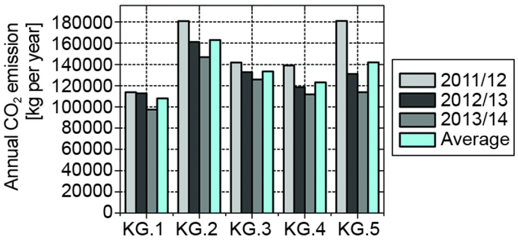

Figure 3. Existing condition – graphical presentation of the annual emission of CO_2 for overall annual consumption of electric and heating energy by the analyzed period

peratures, which, according to the data of the Republic Hydrometeorological Service of Serbia rose in 2012 for around 0.3 °C in average, and in 2013 for almost 1.0 °C.

The mentioned data clearly indicated that the main cause of the CO_2 emission reduction trend is primarily the results of the rise in the average daily temperature in comparison to the reference year 2011, than a consequence of a targeted intervention. It is necessary to point out that in addition to the rising temperature the CO_2 emission reduction was affected by the fact that the City District Heating Plant of Nis (the list of constituent heating facilities is provided in tab. 1) increased the share of gas used as fuel to around 90%, while the remaining 10% still belonged heating oil [11].

New condition – after energy efficiency improvements (EEI)

Energy revitalization of structural elements

All five KG included in this research were built in different time periods, with insufficient thermal insulation of structural elements, which resulted in the inadequate energy efficiency of the structures. Such status has an equivalent impact on the calculated (actual) emission of CO_2, on whose bases it can be concluded that KG built by end of 70's and beginning of 80's (KG.2, KG.3, and KG.5) in terms of their usable surface area have higher emissions of GHG (CO_2) than KG.4, which was built at the beginning of 90's or KG.1, which was built in 2005.

The importance of applying the principle of energy efficiency in Serbia is more than evident. Regarding the initial hypothesis and goal of this study, it is necessary to revitalize all the buildings of the chosen KG in energy terms and they determine and quantify the CO_2 emission reduction benefit which is an indirect result of the improvement of energy efficiency after the performed energy revitalization measures.

Energy revitalization of the building of all five KG was performed by adding a thermal insulation material from expanded polystyrene (EPS) and extrudet polystyrene (XPS) of adequate thickness for every structural element (walls, flat roofs, slant roofs, and ground flooring). Revitalization of transparent surfaces (windows and external doors) comprised replacement of the existing ones with the new ones complying with the maximum permissible heat transfer coefficient from the code, U_{max} [$Wm^{-2}K^{-1}$].

Improvement of energy efficiency of buildings was performed by energy revitalization of structural elements in the following way.

– The EPS as used for thermal insulation of the façade cladding of external walls in the blocks with thickness d = 10 cm, density is ρ = 30 kg/m^3, and thermal conductivity λ = 0.041 W/mK.
– The XPS was used for thermal insulation of the flat roof (KG.2 and KG.5) with thickness d = 20 cm, density ρ = 33 kg/m^3 and thermal conductivity λ = 0.038 W/mK.

– For thermal insulation of the slant roof of the KG.1, KG.3, and KG.4, with the inclined roof planes, the same thermal insulation material (XPS) was used having thickness of only $d = 12$ cm.
– The XPS was used for improvement of thermal performances of ground flooring of all KG with smooth surface having thickness $d = 10$ cm, density $\rho = 33$ kg/m^3, and thermal conductivity $\lambda = 0.038$ W/mK.
– The existing transparent surfaces (external windows and doors) are replaced with new PVC windows with good sealing properties made from six-chamber profiles and low emission triple window glazing filled with krypton, having dimensions (4 + 8 + 4 + 8 + 4 mm), with heat transfer coefficient $U_w < 1.5$ W/mK.

The energy revitalization design was produced using software package KNAUFTERM 2 PRO, ver. 23 [12]. This software package was designed so that it focuses on energy performance of the buildings, *i. e.* energy passport, with all the accompanying necessary phases.

The software firstly calculated the energy class of the existing status of the kindergarten presented in tab. 6, to find out to which energy class the KG currently belongs, and to what extent it is possible to add thermal insulation material. When the energy class of the current status was determined, energy revitalization was implemented according to the standing Code on Energy Efficiency of Buildings [10], which stipulates that energy revitalization is considered improvement of energy class of the building for only one class, which was implemented as a rule in this research.

Table 6. New condition – energy efficiency class (EE class), calculated primary energy for heating and annual CO_2 emission (heating energy)

Tag name	New condition	Calculated annual primary energy	Specific CO_2 emissions	Annual CO_2 emission after EEI
	EE class	E_{prim} [kWh]	EM_{CO2} [kgkWh^{-1}]	[kg per year]
KG.1	D	110,695.83	0.33	36,529.62
KG.2	D	113,023.04	0.33	37,297.60
KG.3	D	97,972.56	0.33	32,330.94
KG.4	C	105,041.59	0.33	34,663.72
KG.5	D	102,305.64	0.33	33,760.86

On the basis of the previously described procedure of energy revitalization of structural elements, starting from the assumption that in the future the City District Heating Plant – Nis, will use natural gas as a primary fuel for production of heating energy, the yearly primary heating energy E_{prim} was obtained, with the values presented in tab. 6. The table presents the newly obtained energy class as well as the total CO_2 emission for annual consumption of heating energy. Therefore, in tab. 6, for each of the analyzed KG the corrected-newly designed energy class of the building, and annual emission of CO_2 calculated for the building status after energy revitalization were presented.

The energy revitalization performed in this study improved energy class (EE class) for four out of five KG. Only the KG.1, which was designed and built in 2005, remained in the same energy class after the proposed intervention. This resulted in somewhat better construction of thermal insulation of the building, but a more prominent improvement of its energy efficiency requires a larger correction of the *U* coefficient of certain structural elements of the building. For these reasons, the proposed methodological principle of energy revitalization did not considerably contribute to the reduction of CO_2 emission of the KG.1, while in other cases this improvement in CO_2 emission reduction was more prominent, which will be presented and elaborated in detail in the following section.

Energy revitalization by photovoltaic panels

By analyzing potential for fitting of photovoltaic panels on the roof surface of the KG, a considerable saving of electric energy consumption can be made, and thus the benefits of CO_2 emission can be made. Based on this assumption in this study, the final balance will include the benefit made by fitting the photovoltaic panels on the roof structure of the KG.

By analyzing the available surface it was determined that it was possible to fit the photovoltaic panels on all five KG. The paper presents the surfaces where fitting is possible, as well as the total production of solar electric energy. On our market, various manufacturers of photovoltaic panels can be found, with the prices varying depending on the photovoltaic cell technology. For this research photovoltaic panels with 36 cells were used. It was made from the specially tempered glass, with nominal power of 130 W/m^2 per m^2 [13, 14]. The efficiency of the photovoltaic panel is 13%, and the optimal working voltage 17.72 V. The framed photovoltaic panel has a weight of 550 kg/m^2, while the frameless panels have the weight of 245 kg/m^2. The manufacturer issues a warranty of 25 years for the product performance, and 12 years on the product itself. It was adopted that the power of photovoltaic panels per kW is 1,200.00 kWh of electric power per year. Also adopted is the radiation energy of 3.30 kWh/m^2 per day, which is characteristics for Serbia [15, 16]. The angle of panel fitting in relation to the horizontal line yielded the angle of 40.7 degree [17, 18]. This angle was used for flat roof structure, while in case slanted roof structure, the photovoltaic panels were integrated in the construction itself. In these roof structures, the roof ranges between 20° to 33° depending on the roof cover. The spacing of photovoltaic panels of flat roof structures was calculated according to the proposition which determines the spacing as 4 heights of the which in case of the chosen panel type is around 3.90 m.

By using the previously described methodological procedure, an analysis of potential for fitting the photovoltaic panels on the free roof surfaces was made, with the purpose of prediction of the obtained electric power quantity. The results are presented by the last column in tab. 7.

Table 7. New condition – generated electric energy through installed photovoltaic panels

Tag name	Surface area A_{PV} [m^2]	Nominal power PV [Wm^{-2}]	Installed power PV [kW]	Daily insolation [$kWhm^{-2}$]	Electric energy [kWh per day]	Annual insolation [$kWhm^{-2}$]	Electric energy [kWh per year]
KG.1	112.00	130	14.56	3.3	48.00	1,200.00	17,472.00
KG.2	216.00	130	28.08	3.3	92.50	1,200.00	33,696.00
KG.3	94.00	130	12.22	3.3	40.00	1,200.00	14,664.00
KG.4	54.00	130	7.02	3.3	23.00	1,200.00	8,424.00
KG.5	131.00	130	17.03	3.3	56.00	1,200.00	20,436.00

Table 8 presents averaged electric energy consumption based on the annual measured, produced electric energy due to the fitted photovoltaic panels, and in the last column, the calculated reduced annual emission of CO_2. In case of KG.2, the produced electric energy obtained by photovoltaic panels was bigger than the averaged measured consumption of electric energy in the analyzed period. For this reason, the realized reduction of emission of CO_2 has a negative value. Since the measured values of annual electric energy consumption were averaged, in the goal to make objective estimation of total reduction effect, this value was not included in the sum for total reduction presented by the last column in tab. 8.

Table 8. New condition – calculated electric energy by fitting of roof photovoltaic panels, annual CO_2 emission, and reduction of CO_2 emission

Tag name	Average annual electric energy consumption [kWh]	Annual electric energy from PV panels E_{PV} [kWh]	Reduced annual electric energy after EEI [kWh]	Calculated primary energy E_{prim} [kWh]	Annual CO_2 emission after EEI [kWh per year]
KG.1	37,673.34	17,472.00	20,201.34	50,503.35	26,766.77
KG.2	33,390.00	33,696.00	–306.00	–765.00	0
KG.3	33,880.00	14,664.00	19,216.00	48,040.00	25,461.20
KG.4	31,783.34	8,424.00	23,359.34	58,398.35	30,951.12
KG.5	30,093.34	20,436.00	9,657.34	24,143.35	12,795.97

Results and discussion

The methodological principle of energy revitalization of the analyzed buildings is based on correction of heat transfer coefficient of elements of their thermal envelope and by usage of photovoltaic panels as roof active solar collection system. In the case of non-transparent partitions (walls, roofs, and ground flooring) the revitalization was accomplished by reduction of heat transfer coefficient by adding additional thermal insulation layer to achieve $U < U_{max}$ [$Wm^{-2}K^{-1}$], and in the case of the existing transparent surfaces (windows and doors) they were replaced with new elements having higher energy efficient and a lower heat transfer coefficient than the maximum sanctioned $U_w < 1.5$ [$Wm^{-2}K^{-1}$]. Such method of energy revitalization was quantified by the tab. 6, which presents the corrected values of required annual primary heating energy E_{prim}, which produced another benefit – reduction of annual emission of CO_2 Energy revitalization entails, in addition to structural interventions, an active acquisition of solar energy (obtained by fitting the photovoltaic panels on the KG roof structure), whose equivalent reduction of annual CO_2 emission was calculated and displayed in tab. 9.

Table 9. Overview of total annual CO_2 emission before and after energy efficiency improving

Description/tag name	KG.1	KG.2	KG.3	KG.4	KG.5
Existing condition – CO_2 [kg per year]	108,037.21	162,959.18	133,393.80	123,144.37	141,917.37
New condition – CO_2 [kg per year]	63,296.39	37,297.60	57,792.14	65,614.84	46,556.83
Benefit – CO_2 reduction [kg per year]	44,740.82	125,661.58	75,601,66	57,529.53	95,360.54

The recalculated annual emission of CO_2, was obtained by adding up the CO_2 emission of the annual heating energy consumption of corrected energy classes of buildings with

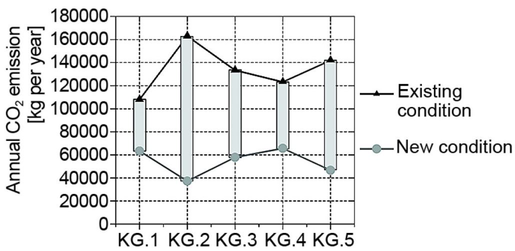

Figure 4. Comparative presentation of calculated annual CO_2 emission

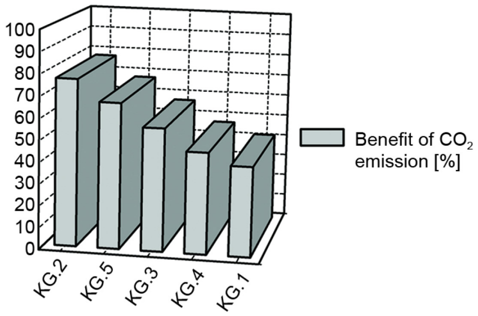

Figure 5. Benefit of CO_2 emission after energy revitalization expressed in percent

newly designed status and averaged CO_2 emission of the electric energy consumption by selected heating seasons, and from the sum obtained in this way, the benefit of CO_2 emission from the fitted photovoltaic panels on the roof structure of the kindergarten was subtracted.

The benefit created by reduction of the CO_2 emission after energy efficiency improving is graphically presented in fig. 4. The referenced values was annual averaged emission of CO_2 of the existing condition and averaged emission of CO_2 of the new condition, tab. 9.

The highest reduction of CO_2 emission amounting to 125661.21 kg was achieved in case of KG.2, and then in KG.5, where the benefit of 95,360.54 kg was achieved. Energy revitalization and fitting of photovoltaic panels on KG.3 produced CO_2 emission reduction amounting to 75,601.66 kg, and in KG.4 to 57,529.53 kg. The least benefit on the annual level was achieved in case of KG.1 and it amounts to only 44,740.82 kg. Figure 4 presents the curve of the realizee quantitative benefits of CO_2 emission in kilograms, and fig. 5 shows the diagram of the realized benefit in percents.

Conclusions

Based on the presented results of the measurements and calculated values it can be concluded that he highest benefit in the CO_2 emission of 77.11% was achieved in case of KG.2. This KG was built as early as in 1978, and it is the oldest KG in this study. Since there were no attempts to improve its energy efficiency since the time of construction, the achieved benefit obtained by energy revitalization is the highest in its case. The lowest benefit of CO_2 emission of 41.41% was achieved in case of KG.1, which was built in 2005.

The reason for this is that it is a relatively new KG having slightly better energy performance, which eventually implies slightly lower improvement of energy efficiency, and thus smaller benefit of CO_2 emission. Apart from the analyzed KG, in the City of Nis territory, there are seven other KG built in the period till 1980 which could undergo a very successful energy revitalization. By implementing the analyzed method of energy revitalization, it can be concluded that a significant reduction benefit for CO_2 emissions could be achieved for each of them. In addition to these, there are further six relatively old KG in the City of Nis territory, which were constructed or reconstructed at a later date. They can be classified in two groups. One group consists of KG built between 1980 and 2000, and for them it is possible to realize the emission reduction benefit of cca 50-80%. The second group is composed of KG which are constructed or reconstructed in the period after year 2000. These KG are with relatively good energy performances, so the achievable benefit of CO_2 emission for them is slightly lower, and it would amount to cca 30-50%. The reason for that is the limited potent of a significant improvement of the energy efficiency which can be realized in these structures only by replacing transparent surfaces and by installing phptpvoltaic panels.

By the preliminary analysis of the status of structures in the territory of the City of Nis, it was determined that out of the total number of KG, only seven partially satisfies the regulations from the Code on Energy Efficiency of Buildings, while the remaining fourteen buildings do not satisfy them at all. Should the required energy revitalization according to the describe methodology be performed on them, which would primarily reduce the need for higher consumption of heating and electric energy, it is possible to achieve the total averaged benefit in CO_2 reduction for about 50-60%.

Therefore, based on the presented case study qualitative analysis in the paper, on a certain number of selected KG in the territory of the City of Nis, it can be concluded that corollary of the adequate energy revitalization is very considerable environmental benefit expressed through reduction of CO_2 emission. A benefit realized in such way would have positive effects regarding contribution to CO_2 emission reduction, both on the level of the City of Nis and on level of the Republic of Serbia.

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