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REVIEW OF ENERGY CONSUMPTION AND CO_2 EMISSION IN SCHOOL BUILDINGS: CASE STUDY OF THE CITY OF KRAGUJEVAC

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Ana Radojević[1], Danijela Nikolić[2], Jasmina Skerlić[3]

[1]Ana Radojević, City of Kragujevac, Kragujevac, Serbia
[2]Danijela Nikolić, Faculty of Engineering, University of Kragujevac, Kragujevac, Serbia
[3]Jasmina Skerlić, University of Priština temporarily settled in Kosovska Mitrovica, Faculty of Technical Sciences, Kosovska Mitrovica, Serbia

Abstract:
Annual energy consumption in Kragujevac elementary schools is 1.909 MWh of electric energy and 12.510 MWh of heat energy, while the total CO_2 emission is 6.406 t.
This paper provides an overview of energy consumption and CO_2 emissions in 61 elementary school buildings, divided in 12 groups. The goal of this paper is to determine which group of school facilities, depending on the year of construction and area, consumes the most energy and produces the most CO_2 emissions.
It has been shown that most electrical (36,33%) and heat (41,42%) energy are consumed in the school buildings constructed in the period 1971-1990. Most CO_2 emissions (40,39%) come from energy consumed in the school buildings constructed in the same period. It is this group of buildings that represents a significant potential for energy savings and reduction of CO_2 emissions, through the implementation of various energy efficiency measures.

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1. INTRODUCTION

In order to mitigate global climate changes, it is necessary that research on energy efficiency also includes analyses of how energy efficiency measures and the use of renewable energy sources affect the reduction of CO_2 emissions. In this way, energy efficiency, climate changes and environmental protection are linked, as well as rational energy consumption and sustainable development.

Being the official candidate country to become a member state of the European Union, the Republic of Serbia is required to activate the mechanisms for a faster implementation of the projects pertaining to the use of renewable energy sources and environmental protection in the future [1].

The spearheads of application flows of energy efficiency should be a local government, which should become producers and not just consumers of energy [2].

The issue of public buildings' energy efficiency is especially important, because that is the area where governments can have direct impact.

Thus, for example, energy efficiency and emissions of greenhouse gases were estimated for 15 public school buildings in the city of Santa Rosa, in central Argentina. It is concluded that some standardized designs and management practices, as well as the development of local standards for energy demand and greenhouse gas emissions, are necessary to improve the energy efficiency of buildings in the studied region [3].

CONTACT: A. Radojević, e-mail: aradojevic@kg.org.rs

The South Korean government is likewise working on reducing its GHG emission and it is currently promoting the Green-School Project. In terms of energy efficiency and CO_2 emission reduction, the results showed that the most effective scenario was replacing the existing lighting with LED lighting [4].

In another example, energy efficiency simulation tools have been used on the Architectural Engineering faculty building, at Cairo University, Egypt, to prove that the retrofitting is vital for existing buildings to save energy and lower CO_2 emissions. The simulation showed that retrofitting measures would reduce the electrical energy use by 15 percent from the baseline energy use of an average of 14.6 kWh/m^2 yearly [5].

So, educational buildings, among all public buildings, have proven to be especially interesting for various types of research. Thus, one study of typical educational buildings in Latvia shows that one such building, partly using 16 kW PV system, reduces not only its bill for electricity, but also reduces CO_2 emissions by around 36 tons [6].

Another study in Turkey proposed energy efficient measures for a nearly 60 years old elementary school building through improvement of the thermal properties of the building envelope, which would show financial gain in eight years. If retrofit was applied, annual fuel cost would be reduced by approximately one-third of the current expenses [7].

Finally, education buildings, as the third highest consumer of energy in the United States, provide significant opportunities to lower greenhouse gas emissions by increasing energy efficiency [8].

Pursuant to the Serbian Law on Efficient Use of Energy [9], all local government units with more than 20,000 inhabitants are required to appoint energy managers whose role is to: collect and analyze data on the use of energy by the system users, prepare programs and plans, propose measures that contribute to the efficient use of energy and participate in their implementation, thus accomplishing the goal of saving energy. Energy managers in local government units have responsibility for energy consumption in the public sector, which includes: public buildings, public lighting and public transport.

The membership in the Energy Community bounds the Republic of Serbia to apply European Union legislation, despite not being its full-fledged member, through the Law on the Ratification of the Treaty Establishing the Energy Community, adopted in 2006 [10]. The Energy Community mostly took over the entire applicable EU legislation with minor amendments concerning technical aspects of implementation, primarily in the form of differently set deadlines and the change in scope and framework of the individual obligations. For example, in the negotiation process, taking into account specificities of the state, the criterion was defined for Serbia to rehabilitate 1% of the total surface of buildings owned and used by state authorities, whereas for the EU Member States this criterion was established at 3% in conformity with the 2012 Energy Efficiency Directive (EED).

Knowledge of the characteristics of the school building stock and the assessment of energy consumption in them are necessary for understanding how to improve their energy efficiency and reduce energy consumption, and thus meet the requirements of the national and EU legislation. One way to address the issue of lack of information on building characteristics is to develop large number of models and methods for predicting energy consumption in public buildings.

In the city of Kragujevac, school buildings consume 61% of the total primary energy of all public buildings. This paper provides an overview of energy consumption and CO_2 emissions in school buildings in the city. Overall, 61 elementary school buildings, constructed between 1901-2007, ranging from 145 to 7,000 m^2 in area, were observed. Their energy renewal can reduce energy consumption, but also CO_2 emissions.

2. MATERIAL AND METHODOLOGY

The goal of this paper is to determine which group of school facilities, depending on the year of construction and size, consumes the most energy and produces the most CO_2 emissions.

In this paper, we used the data from the Energy Efficiency Program [11]. The analysis was performed in accordance with the modified methodology prescribed in the Instruction for the preparation of energy balance in municipalities [12] and in the Manual for energy managers for municipal energy issues [13]. In order to estimate the annual energy needs for heating public buildings in the city of Kragujevac, energy consumption data were normalized in relation to the heating degree days, according to the methodology described in [14].

Data on annual consumption and energy costs in the analyzed sectors were obtained by averaging the available collected data on the mentioned sectors for the period 2014-2016. Data on the heating degree days are shown in Table 1.

To calculate CO_2 emissions, the conversion factors given in Table 2 were used.

Table 1. Data on heating degree days for Kragujevac

Heating degree days	Calculated	2014	2015	2016
	2.610	2.133	2.510	2.349

Table 2. Conversion factors for calculating CO_2 emission

Fuel	Unit	kWh/jm	Emission kg/kWh
Raw lignite	t	3.600,0000	0,35
Dried lignite	t	4.500,0000	0,35
Brown coal	t	5.000,0000	0,35
Stone coal	t	6.000,0000	0,35
Coal – coke	t	7.000,0000	0,35
Wood	m^3	1.680,0000	0,30
Wood waste	t	4.500,0000	0,30
Biomass	t	3.600,0000	0,35
Heating oil	t	4.500,0000	0,35
Crude heating oil	t	5.000,0000	0,35
Propane-Butane	t	6.000,0000	0,35
Natural gas	t	7.000,0000	0,35
Biogas	m^3	1.680,0000	0,30
Electric energy	t	4.500,0000	0,30
Solar energy	t	3.500,0000	0,30
Geothermal water	m^3	11.390,0000	0,25
Wind energy	t	11.000,0000	0,28

2.1 THE IMPACT OF PUBLIC BUILDINGS ON ENERGY CONSUMPTION AND CO_2 EMISSIONS IN PUBLIC SECTOR

The public sector includes: public buildings, public transportation andi public lighting.

When we analyzed the public sector, final energy consumption was highest in public buildings - 55%, then in public transportation - 26% and finally by public lighting - 19%, Fig.1.

The highest CO_2 emission in the public sector comes from public buidings - 56%, public lighting - 32% and public transportation - 12%, Fig.2.

Regarding the CO_2 emission from all public buildings, the highest CO_2 emissions come from educational institutions, both from electricity (58%) and heat (80%), and in total (73%), Fig.3.

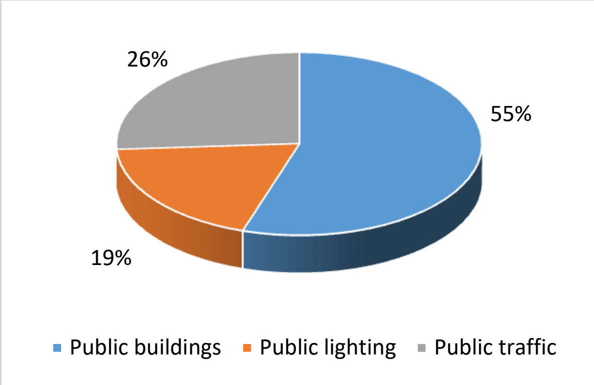

Fig. 1. Structure of final energy consumption in public sector in the City of Kragujevac [%]

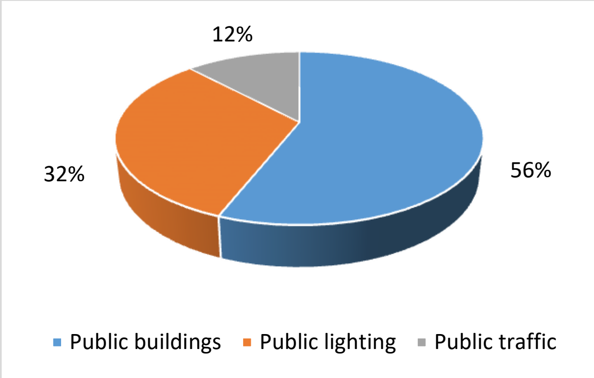

Fig. 2. Structure of CO_2 emission in public sector in the City of Kragujevac [%]

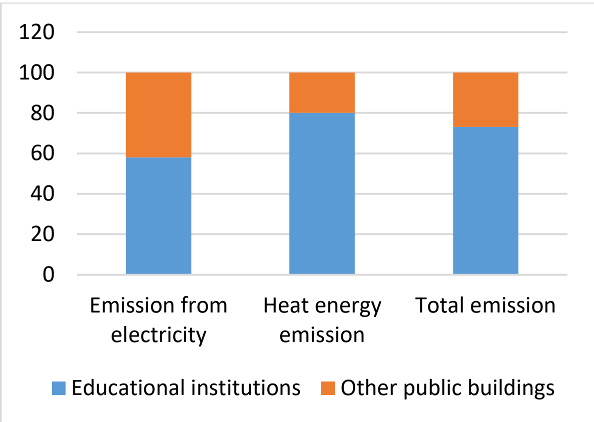

Fig. 3. Structure of CO_2 emissions coming from electrical and heat energy and total emissions – educational institutions vs. other public buildings

Elementary schools have the greatest impact on CO_2 emissions in educational institutions. Thus, out of the total CO_2 emissions coming from educational institutions, elementary schools are responsible for 50% of the emissions from electricity, 53% from thermal energy, and for 50% of total emissions produced, Fig.4.

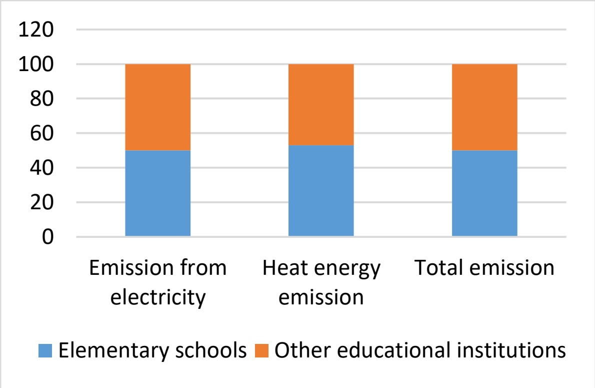

Fig. 4. Structure of CO_2 emissions coming from electrical and heat energy and total emissions – elementary schools vs. other educational institutions

2.2. TYPOLOGY OF SCHOOL BUILDINGS IN KRAGUJEVAC

In order to define the physical characteristics of the sample buildings, a research conducted in Serbia was used as a part of the European project of creating typologies of buildings called TABULA [15].

The importance of the typological classification of school buildings is reflected through the wide applicability in making strategic decisions on the measures to be implemented on school buildings. The typology of elementary school buildings includes the classification of buildings by size and construction periods, with the aim of defining possible levels of energy renewal.

Therefore, we used this typology to analyze Kragujevac school buildings to get a clear picture of energy consumption and CO_2 emission of each school, which would then be a base for deciding on possible energy measures to be applied where needed. Implementing these energy measures on a school building envelope, on mechanical and electric power systems, as well as using renewable energy sources, would accomplish an ultimate goal, and reduce energy consumption, improve the energy efficiency and reduce CO_2 emissions of Kragujevac elementary schools.

The basic matrix of the typology of school buildings is defined through four time periods:

- before 1945;
- 1946-1970;
- 1971-1990;
- after 1991,

and three types by school size (gross floor area):

- smaller than 500 m^2;
- from 500 to 2000 m^2;
- larger than 2000 m^2.

According to this matrix, all schools in Kragujevac are divided into 12 groups, as shown in Table 3.

Table 3. Matrix of the typology of school buildings in Kragujevac (based on the national typology of school buildings in Serbia)

Period (year)	**Gross floor area**		
	Smaller than 500 m^2	**500-2,000 m^2**	**larger than 2,000 m^2**
Before 1945	Number of schools - 14 Share in total area - 3,74%	Number of schools - 3 Share in total area - 4,28%	Number of schools - 2 Share in total area - 7,48%
1946 –1970	Number of schools - 9 Share in total area - 2,27%	Number of schools - 7 Share in total area - 3,86%	Number of schools - 6 Share in total area - 27,93%
1971 –1990	Number of schools - 2 Share in total area – 0,72%	Number of schools - 4 Share in total area - 2,25%	Number of schools - 7 Share in total area - 41,23%
After 1991	Number of schools - 3 Share in total area - 0,72%	Number of schools - 4 Share in total area - 5,15%	
NA	Number of schools - 2 Share in total area - 0,37%		

3. RESEARCH RESULTS

3.1. OVERVIEW OF ENERGY CONSUMPTION AND CO_2 EMISSION DEPENDING ON THE PERIOD OF CONSTRUCTION AND SIZE OF SCHOOL FACILITIES

The analysis of energy consumption and CO_2 emission depending on the period of construction and size of school facilities was performed (as shown in Table 4) in order to select facilities on which energy efficiency measures will be implemented first. After the initial analysis of the school buildings' stock, energy modeling of representative buildings would be initiated. The modeling would estimate the current energy consumption, compare the calculated and actual values and then simulate the effects of improving energy efficiency - by measures on the building envelope, mechanical and electrical systems and the use of renewable energy sources (PV panels).

Table 4. Matrix of electricity and heat consumption share and CO_2 emission share [%] depending of on the period of construction and size of school facilities

Period (year)	Gross floor area		
	Smaller than 500 m^2	from 500 to 2000 m^2	larger than 2000 m^2
Before 1945	-Electricity consumption share - 2,42% -Heat consumption share - 3,45% -CO_2 emission share - 3,08%	-Electricity consumption share-8,45% -Heat consumption share-2,32% -CO_2 emission share-3,26%	-Electricity consumption share - 3,3% -Heat consumption share-9,03% -CO_2 emission share - 5,1%
1946-1970	-Electricity consumption share - 1,44% -Heat consumption share - 2,43% -CO_2 emission share - 2,06%	-Electricity consumption share - 2,32% -Heat consumption share - 2,63% -CO_2 emission share - 2,3%	-Electricity consumption share - 32,04% -Heat consumption share - 28,89% -CO_2 emission share - 34,14%
1971–1990	-Electricity consumption share - 0,72% -Heat consumption share - 0,77% -CO_2 emission share - 0,59%	-Electricity consumption share - 7,83% -Heat consumption share - 4,92% -CO_2 emission share - 2,6%	-Electricity consumption share - 36,33% -Heat consumption share - 41,42% -CO_2 emission share - 40,39%
After 1991	- Electricity consumption share - 0,72% - Heat consumption share - 1,2% - CO_2 emission share - 1,02%	-Electricity consumption share - 7,83% -Heat consumption share - 4,92% -CO_2 emission share - 4,99%	
NA	-Electricity consumption share - 1,65% -Heat consumption share - 0,09% -CO_2 emission share - 0,47%		

The research results showed that the most electricity was consumed in schools built between 1971 and 1990 - 36,33%, Fig.5.

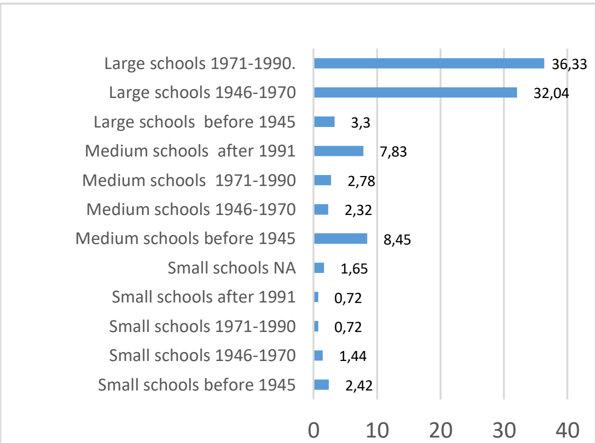

Fig. 5. Distribution of electricity consumption [%]

Also, the highest heat consumption was shown in schools that were built between 1971 and 1990 - 41,42%, Fig.6.

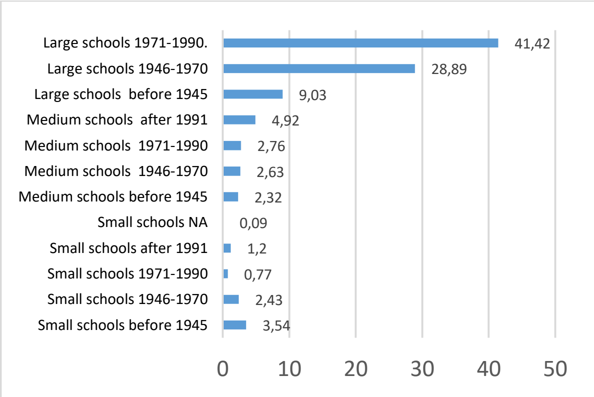

Fig. 6. Distribution of heat consumption [%]

Finally, the highest CO_2 emissions were recorded in schools that were built between 1971 and 1990 -40,39%, Fig.7.

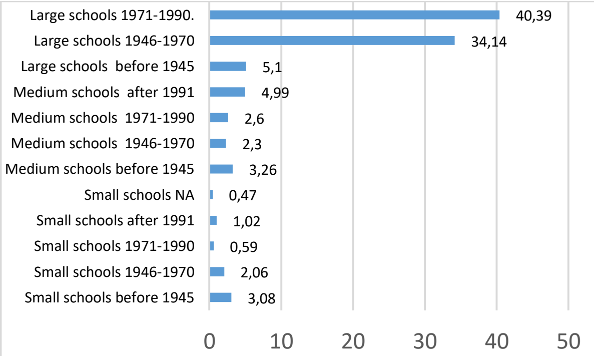

Fig. 7. Distribution of CO_2 emissions [%]

4. CONCLUSION

School buildings consume 61% of the total primary energy of all public buildings in Kragujevac. Their energy renewal can reduce energy consumption, but also CO_2 emissions.

Most primary energy is consumed in school buildings built in the periods 1971-1990 and 1946-1970. These two periods also have the highest CO_2 emission - 40.39% and 34.14%.

Most electricity (36.33%) and heat energy (41.42%) are consumed in school buildings constructed in the periods 1971-1990 and 1946-1970 - electricity (32.04%) and heat (28.89%).

The highest CO_2 emissions (40.39%) come from energy consumed in school buildings built in the periods 1971-1990 and 1946-1970 - 34.14%.

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