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ANALYSIS OF CO_2 EMISSIONS IN THE PUBLIC SECTOR - THE EXAMPLE OF THE CITY OF KRAGUJEVAC

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ABSTRACT

Local governments play an important role in fighting the climate changes, as much in reducing emissions as in raising the awareness of citizens in the fight against climate changes. By analyzing CO_2 emissions - from which sectors the largest emissions originate - it is possible to propose adequate measures that will contribute to the target values of CO_2 emission reduction.

The paper analyzes the extent to which the public sector affects the total CO_2 emissions in the entire city. For the public sector, emissions from the district heating system, public transport and public lighting were observed.

Keywords: CO_2 emissions, public sector.

INTRODUCTION

The environment is threatened by global warming and upcoming climate change, which are a direct consequence of energy consumption. Carbon dioxide (CO_2) is a gas that is also formed as a result of burning fossil fuels, and it is responsible for the "greenhouse" effect. In order to limit the increase in average temperature and mitigate climate change, it is considered necessary to halve the world's CO_2 emissions by 2050 (compared to 1990), from 20 billion tons per year, to about 10 billion tons. Serbia has set a goal of reducing carbon dioxide emissions by 9.8% by 2030 compared to 1990.

Local authorities have a major role to play in reducing CO_2 emissions by implementing energy efficiency measures and using renewable energy sources. According to the driving factors of energy consumption and CO_2 emissions, policy implication of energy efficiency and emission reduction can be summarized into two categories: improve the policy, standard and identification of energy conservation and environmental protection; adjust energy structure, use clean energy (Tian, Feng, Li, & Xu, 2019).

Cities play a key role in the climate challenge and are the place where local experimental governance aiming at meeting low carbon objectives can be tested (Castán Broto, & Bulkeley, 2013). There are a number of initiatives to reduce CO_2 emissions locally, the most famous of which is the Covenant of Mayors. The Covenant of Mayors (CoM) is a successful European initiative which encourages local authorities to be proactive in fighting climate change. The methodology is applied to over 1600 signatories in Europe, representing over 80 million inhabitants (Peduzzi, et al., 2013). Signatory cities pledge actions to support the implementation of the 40% greenhouse gas-reduction target by 2030. For a baseline year of their choice, summarising energy consumption and CO_2 emissions for different sectors and fuels (referred to as energy carriers) (Palermo, Bertoldi, Apostolou, Kona, & Rivas, 2020). The EU Covenant of Mayors (CoM) is an international initiative, part of the Global Covenant of Mayors, that directly engages local governments to adopt climate and energy targets at least matching the EU targets. By voluntarily adhering to the CoM, local authorities

committed to decarbonise and increase resilience in their territory and share their emission inventories and climate action plans (The Covenant of Mayors).

A study done for the Utsunomiya City, Japan, analyzed the capacity for implementation and impacts on energy savings and subsequent greenhouse gas (GHG) reduction, potential of mitigation technologies such as photovoltaic cells (PV) and combined heat and power (CHP) technologies were analysed with respect to three potential urban forms. Given current building use patterns, scenarios for 2030 and 2050 showed the medium density averaged form, which benefits from both PV and CHP technologies, to outperform the other forms, resulting in an energy savings and GHG reduction potential of 27.6% in 2030 and 67.6% in 2050. Interestingly, GHG reduction in 2050 was primarily attributable to PV, while CHP technology had the greater influence in 2030 (Ishii, Tabushi, Aramaki, & Hanaki, 2010). At the same time, there are dilemmas as to whether short-term or long-term strategies are better. This paper shows that, under certain conditions (including path dependence and lock-in), policies and measures leading to a cost-effective GHG emissions mitigation in the short term may not allow reaching long-term emissions targets at the lowest possible cost, that is, they might not be cost-effective in the long term. The reason is that, in a situation where currently expensive technologies have a large potential for cost reductions through learning effects and R&D investments, the implementation of incentive-based mitigation policies such as taxes or tradable permits will encourage the adoption and diffusion of currently low-cost abatement technologies, but might not be enough to make attractive the diffusion of expensive ones, which is a necessary condition for these technologies to realise their cost-reduction potential through the aforementioned effects. A simple model and a numerical simulation are provided to show this possible conflict between static and dynamic efficiency, which points out to the need to combine different instruments, some aiming at short-term cost-efficiency (such as incentive-based environmental policy) and others at encouraging dynamic cost reductions (such as technology/innovation policy) (Del Río González, 2008). When we talk about reducing CO_2 emissions, we also come to the notion of a carbon neutral public sector.

This paper argues for research into the effectiveness of government strategies for a 'carbon neutral public sector'. We review initiatives in three OECD countries: New Zealand, Australia and the UK. In all jurisdictions, government agencies have consistently stressed 'leading by example' as a rationale for adoption. 'Direct mandate' by the Prime Minister (NZ); 'organic development' from wider central government sustainability initiatives (UK); and a more 'laissez faire' approach by Australian Federal and State Governments, were identified as the general pathways leading to implementation. Our assessment indicates: a lack of understanding of the implementation process for carbon neutrality; a need to identify and critically examine the 'offset threshold' at which mitigation efforts cease and offsetting is adopted; an absence of any evaluation of the 'leading by example' rationale; a lack of inter-country comparisons; a gap in understanding the relationship with economic and social aspects of sustainability; and a need to evaluate the utility of core government departments as the focus of carbon accounting. We urge colleagues to consider research in this area with a view to contributing to the interdisciplinary solutions which we believe are required (Ball, Mason, Grubnic, & Hughes, 2009). This paper analyzes energy consumption and CO_2 emissions in the public sector, which includes three sectors - public buildings, public lighting and public transportation. For the commercial sector, data for commercial buildings and transportation were analyzed. Transportation data were available and taken from the Ministry of the Interior, while data on the quantities of natural gas and electricity delivered were obtained from the companies that supply the city with energy. After that, a comparison of these data was made, how much CO_2 emissions from the public sector affect the total CO_2 emissions.

METHODOLOGY

In this paper, we used the data from the Energy Efficiency Program (Official Bulletin of the City of Kragujevac, 2018). The analysis was performed in accordance with the modified methodology prescribed in the Instruction for the preparation of energy balance in municipalities (Karamarković et al., 2007), and in the Manual for energy managers for municipal energy issues (2016). 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 Strategy of Sustainable Development of Kragujevac for period 2013 to 2018 (The City of Kragujevac, Serbia, 2013).

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.

Tabela 1. Podaci o grejnim stepen danima za Kragujevac
Table 1. Data on heating degree days for Kragujevac

Heating degree days	Calculated	2014	2015	2016
	2.610	2.133	2.510	2.349

Tabela 2. Faktori konverzije za izračunavanje emisije CO_2
Table 2. Conversion factors for calculating CO_2 emission

Energent/Fuel	Jedinica/Unit	kWh/jm	Emisija/Emission kg/kWh
Raw lignite/Sirovi lignit	t	3.600,0000	0,35
Dried lignite/Sušeni lignit	t	4.500,0000	0,35
Brown coal/Mrki ugalj	t	5.000,0000	0,35
Stone coal/Kameni ugalj	t	6.000,0000	0,35
Coal – coke/Ugalj-koks	t	7.000,0000	0,35
Drvo/Wood	m^3	1.680,0000	0,30
Drvni otpad/Wood waste	t	4.500,0000	0,30
Biomasa/Biomass	t	3.600,0000	0,35
Heating oil/Lož ulje	t	4.500,0000	0,35
Crude heating oil/Mazut	t	5.000,0000	0,35
Propan-butan/Propane-Butane	t	6.000,0000	0,35
Prirodni gas/Natural gas	t	7.000,0000	0,35
Biogas/Biogas	m^3	1.680,0000	0,30
Električna energija/Electric energy	t	4.500,0000	0,80
Solarna energija/Solar energy	t	3.500,0000	0,30
Geotermalna voda/Geothermal water	m^3	11.390,0000	0,25
Energja vetra/Wind energy	t	11.000,0000	0,28

ANALYSIS OF ENERGY CONSUMPTION IN THE PUBLIC SECTOR

According to the Energy Efficiency Program of the City of Kragujevac, estimates of annual energy consumption and costs in the analyzed sectors are shown in the Table 3. Based on the estimation of annual energy consumption presented above, we were able to come up with the structure of primary energy consumption in the public sector of the City of Kragujevac, as shown in Figure 1. The balance of final energy (by energy sources) in the city of Kragujevac is shown in Table 4. In the structure of final energy sources, electricity and district heating have the largest share (together 57%).

Tabela 3. Procena godišnje potrošnje u javnom sektoru grada Kragujevca
Table 3. Estimation of annual consumption in the public sector of the city of Kragujevac

Sektor potrošnje/ Consumption sector	Finalna energija/ Final energy [kWh]	Primarna energija/ Primary energy [toe]
Javne zgrade/Public buildings	44.623.803,41	6.133,17
Javno osvetljenje/Public lighting	15.997.937,60	3.438,94
Saobraćaj/Transportation	21.292.824,95	1.830,85
UKUPNO/TOTAL	**81.914.565,96**	**11.402,96**

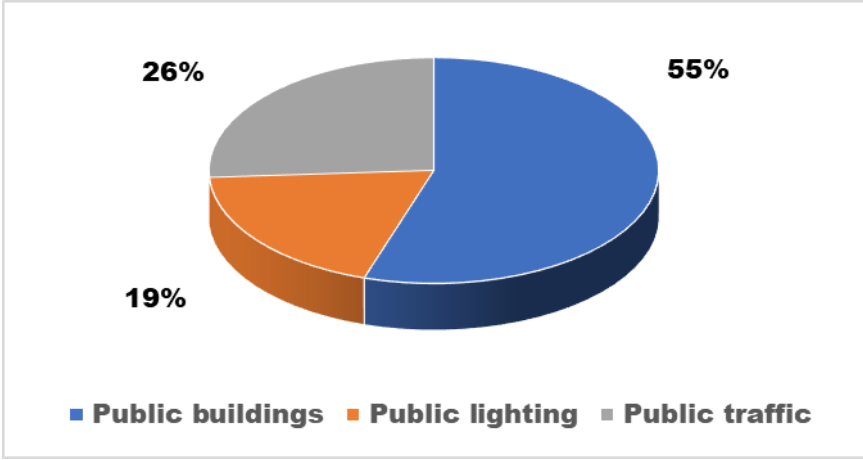

Figure 1. The structure of primary energy consumption in the public sector of the city of Kragujevac
Slika 1. Struktura potrošnje primarne energije u javnom sektoru grada Kragujevca

Tabela 4. Bilans finalne energije (po energentima)
Table 4. The balance of final energy (by energy sources)

Energent/Energy source	Javne zgrade/Public buildings [kWh]	Javno osvetljenje/Public lighting [kWh]	Javni prevoz/Public transport [kWh]	UKUPNO/TOTAL [kWh]
Električna energija/Electricity	10.090.378,48	15.997.937,60	-	**26.111.822,08**
Prirodni gas/Natural gas	7.708.958,83	-	-	**7.708.958,83**
Lož ulje/Fuel oil	1.032.480,15	-	-	**1.032.480,15**
Daljinsko grejanje/ District heating	20.567.790,67	-	-	**20.567.790,67**
Čvrsta goriva/Solid fuels	5.224.195,29	-	-	**5.224.195,29**
Benzin/Gasoline	-	-	1.818.210,22	**1.818.210,22**
Dizel/Diesel	-	-	13.820.823,70	**13.820.823,70**
TNG (tečni naftni gas)/LPG (liquid petrol gas)	-	-	368.314,23	**368.314,23**
KPG (kompres. prirodni gas)/ CNG (compres. natural gas)	-	-	5.285.476,80	**5.285.476,80**
UKUPNO/TOTAL	**44.623.803,41**	**15.997.937,60**	**21.292.824,95**	**81.914.565,96**

Analysis of energy consumption in the public building sector

According to the type and predominant purpose of the building, public buildings are classified into seven subcategories, as follows:

1. educational institutions,
2. administrative buildings,
3. cultural institutions,
4. sports facilities,
5. health institutions,
6. PUC and PC buildings,
7. buildings of other entities.

According to the Energy Efficiency Program of the City of Kragujevac, estimated final and primary energy consumption data on an annual level for each of the subcategories of public buildings are shown in Table 5.

Tabela 5. Procenjeni podataci o potrošnji finalne i primarne energije na godišnjem nivou za svaku od potkategorija javnih zgrada
Table 5. Estimated data on final and primary energy consumption on an annual basis for each of the subcategories of public buildings.

Kategorija objekta/ Building Category	Potrošnja finalne energija za električnu energiju/Final energy consumption for electricity **[kWh/year]**	Potrošnja finalne energija za toplotnu energiju/Final energy consumption for heating energy **[kWh/year]**	Ukupna godišnja potrošnja primarne energije/Total annual primary energy consumption **[ktoe]**
Obrazovna institucija/ Educational institution	3.857.881,20	23.383.283,24	3.674,35
Administrativna zgrada/ Administrative building	1.155.922,50	1.519.299,61	459,83
Institucija kulture/ Cultural institution	387.896,17	1.474.642,59	264,97
Sportski objekat/ Sports facility	1.299.957,83	3.813.021,43	688,72
Zdravstvena institucija/ Health institution	1.624.609,61	3.033.572,14	692,79
JKP i JP/PUC and PC	1.570.652,17	1.671.164,99	518,54
Ostali objekti/ Other buildings	192.476,00	315.059,32	76,37
Ukupno/Total	**10.090.378,48**	**35.210.043,33**	**6.375,57**

Analysis of energy consumption in the public lighting sector

The public lighting system includes 23,748 lamps, with an installed power of 3,901.94 [kW], whose annual consumption is 15,997,937.60 [kWh]. The structure of electricity consumption and costs is dominated by inefficient high-pressure mercury lamps HPM (about 67%). In this group, the highest consumption of the most numerous light bulbs is the lowest HPM 125 – as much as 53% of total consumption, costs and CO_2 emissions (Figure 2).

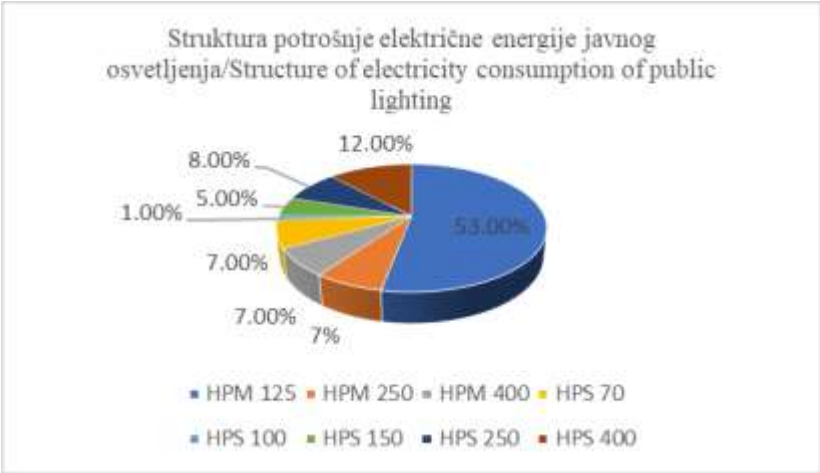

Figure 2. Structure of electricity consumption of public lighting on the territory of the city of Kragujevac
Slika 2. Struktura potrošnje električne energije javnog osvetljenja na teritoriji grada Kragujevca

Analysis of energy consumption in the transport sector

Energy consumption in the transport sector includes energy consumption for public urban and suburban transport and vehicle fleets of institutions/companies in the city of Kragujevac. Data on energy consumption in the transport sector (average consumption in 2015 and 2016) are shown in Table 6. Public city and suburban transport consumed 719,280 liters of diesel fuel in 2015 and 365,720 kg of compressed natural gas, ie. 638,444 liters of diesel fuel and 411,536 kg of compressed natural gas in 2016. The energy equivalent of fuel consumed in public urban and suburban transport averages about 12 GWh.

Tabela 6. Podaci o potrošnji energije u sektoru saobraćaja u gradu Kragujevcu
Table 6. Data on energy consumption in the transport sector in the City of Kragujevac

Gorivo/Fuel	**Benzin/ Gasoline [l]**	**Dizel/ Diesel [l]**	**TNG/ LPG [l]**	**KPG/ CNG [kg]**	**Benzin/ Gasoline [toe]**	**Dizel/ Diesel [toe]**	**TNG/ LPG [toe]**	**KPG/ CNG [toe]**	**Ukupno/ Total [toe]**
Vozni parkovi/ Fleets	209.520	698.675	53.77	-	156,34	602,75	29,76	-	788,85
Javni gradski i prigradski prevoz/ Public city & suburban transport	-	678.862	-	388.638	-	585,65	-	454,47	1.040,12
UKUPNO/ TOTAL	**209.520**	**1.377.54**	**53.77**	**388.638**	**156,34**	**1.188,4**	**29,76**	**454,47**	**1.828,97**

REFERENCE INVENTORY OF CO_2 EMISSIONS IN THE PUBLIC SECTOR

Tabela 7. Emisija CO_2 po sektorima u gradu Kragujevcu
Table 7. CO_2 emission by sectors in the city of Kragujevac

Sektor potrošnje/ Consumption sector	Emisija CO_2/ CO_2 emission [t]
Javne zgrade/Public buildings	22.246,17
Javno osvetljenje/Public lighting	12.798,35
Javni prevoz/Public transport	4.755,10
UKUPNO/TOTAL	**39.799,62**

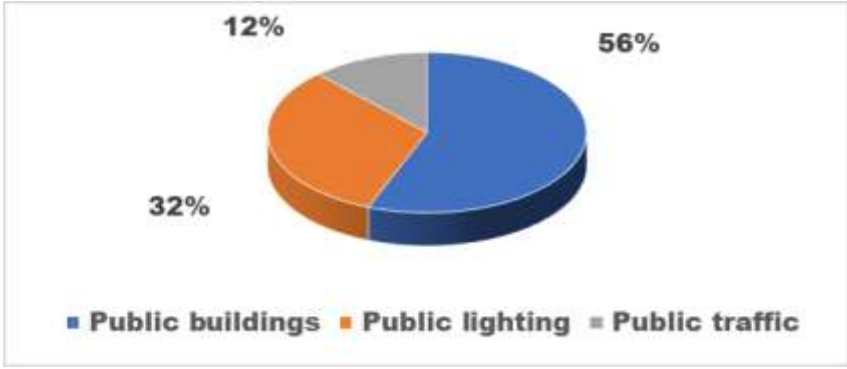

Figure 3. Structure of CO_2 emissions in the public sector of the city of Kragujevac
Slika 3. Struktura emisija CO_2 u javnom sektoru grada Kragujevca

Tabela 8. Struktura emisije CO_2 po energentu u javnom sektoru grada Kragujevca
Table 8. Structure of CO_2 emissions by energy sources from the public sector of the city of Kragujevac

Energent/ Energy source	Ukupno emisija CO_2 u javnom sektoru/ Total CO_2 emissions from public sector [tCO_2]
Električna energija/Electricity	20.889,458
Prirodni gas/Natural gas	2.929,404
Lož ulje/Fuel oil	392,342
Daljinsko grejanje/ District heating	7.815,760
Čvrsta goriva/Soild fuels	1.985,194
Bezin/Gasoline	454,553
Dizel/Diesel	3.731,622
TNG (tečni naftni gas)/ LPG(liquid petrol gas)	77,346
KPG (kompres. prirodni gas)/ CNG (comp. nat. gas)	1.110,364
UKUPNO/TOTAL	**39.386,044**

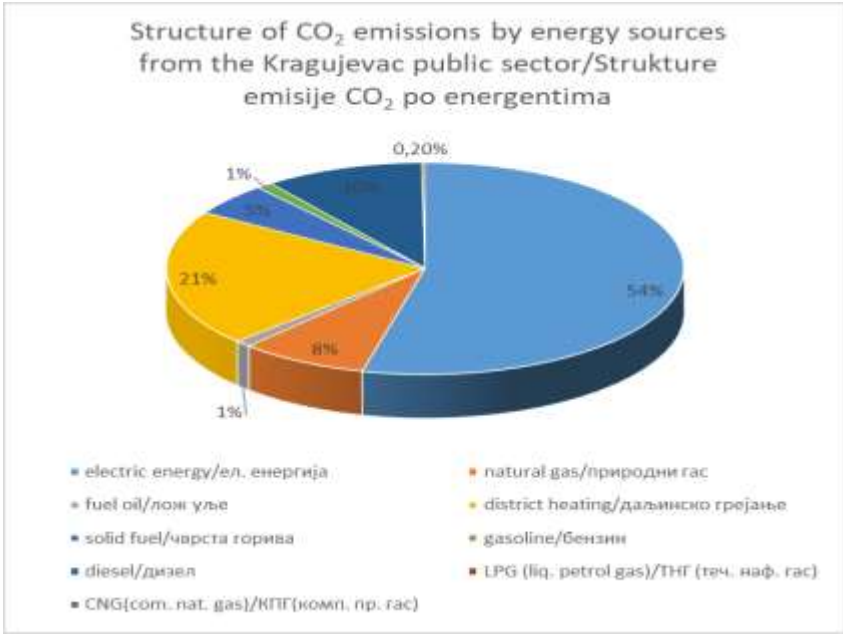

Figure 4. Structure of CO_2 emissions by energy sources from the public sector of the city of Kragujevac
Slika 4. Struktura emisije CO_2 po energentu u javnom sektoru grada Kragujevca

Reference inventory of CO_2 emissions from the public buildings sector

Tabela 9. Procenjeni podaci o potrošnji finalne i primarne energije na godišnjem nivou za svaku od potkategorija javnih zgrada
Table 9. Estimated data on the annual final and primary energy consumption of each of the public building subcategory

Kategorija objekta/ Building category	**Emisija CO_2/ CO_2 Emission - EE [kg]**	**Emisija CO_2/ CO_2 Emission - TE [kg]**	**UKUPNO Emisija CO_2/ TOTAL CO_2 Emission [t]**
Obrazovna institucija/ Educational institution	3.086.304,96	9.862.299,39	12.948,60
Administrativna zgrada/ Administrative building	924.738,00	727.687,00	1.652,42
Institucija kulture/ Cultural institution	310.316,93	622.124,59	932,44
Sportski objekat/ Sports facility	1.039.966,27	1.188.682,96	2.228,65
Zdravstvena institucija/ Health institution	1.299.687,69	1.044.013,89	2.343,70
JKP i JP/PUC and PC	1.256.521,73	624.654,80	1.881,18
Ostali objekti/ Other buildings	153.980,80	104.406,70	258,39
Ukupno/Total	**8.072.302,78**	**14.173.869,33**	**22.246,17**

Reference inventory of CO_2 emissions from the public lighting sector

Tabela 10. Struktura godišnje emisije CO_2 koja potiče iz javnog osvetljenja
Table 10. Structure of annual CO2 emissions originating from public lighting

Tip sijalice/ Source type	Broj sijalica/ Number of sources [-]	Godišnja emisija/Annual emissions [tCO_2]
HPM 125	14.816	6.706,31
HPM 250	969	874,04
HPM 400	656	946,74
HPS 70	3.429	866,03
HPS 100	494	178,24
HPS 150	1.136	614,80
HPS 250	1.168	1.053,54
HPS 400	1.080	1.558,66
UKUPNO/ TOTAL	**23.748**	**12.798,35**

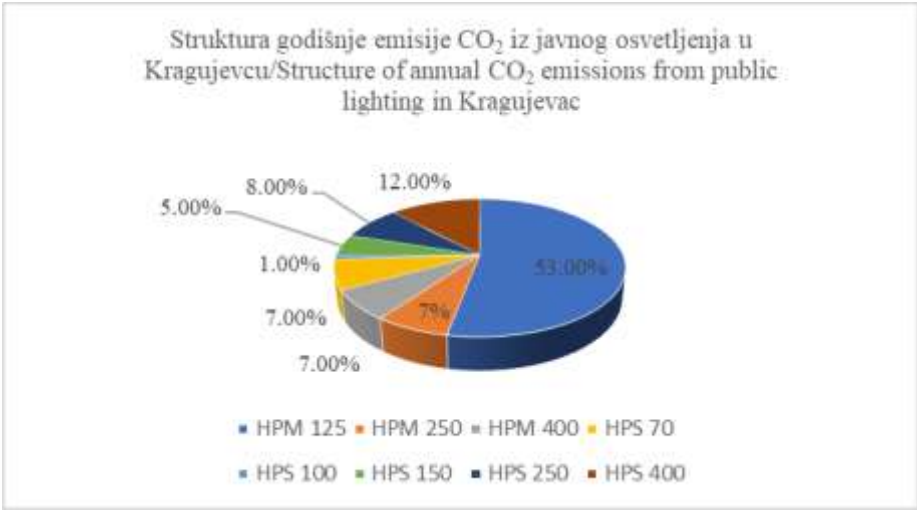

Figure 5. Structure of annual CO_2 emissions originating from public lighting
Slika 5. Struktura godišnje emisije CO_2 koja potiče iz javnog osvetljenja

Reference inventory of CO_2 emissions from the public transport sector

Tabela 11. Podaci o emisiji CO_2 koja potiče iz sektora saobraćaja u gradu Kragujevcu
Table 11. Data on CO_2 emissions originating from the transport sector in the city of Kragujevac

Vrsta javnog prevoza/Type of public transport	Emisija CO_2/CO_2 emissions [t]
Vozni parkovi javnih institucija i preduzeća/ Public institutions and companies' fleets	2.426,76
Javni gradski i prigradski prevoz/Public city and suburban transport	2.328,24
UKUPNO/TOTAL	**4.755,10**

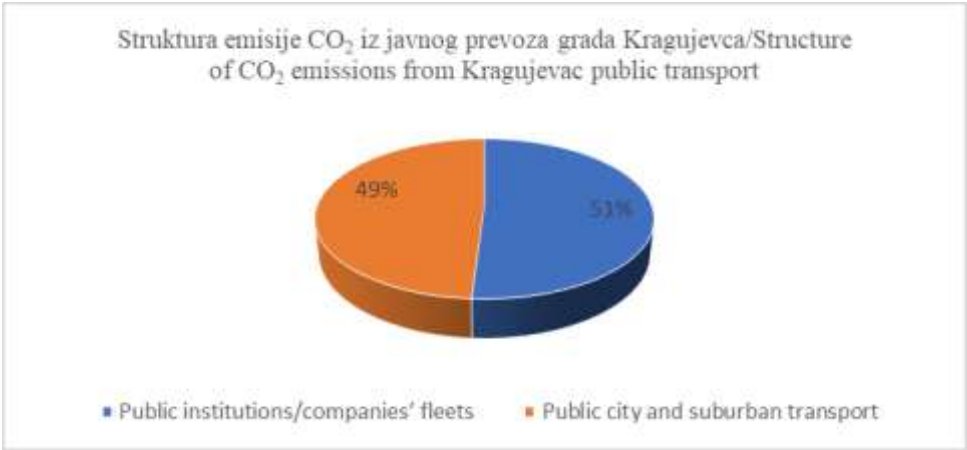

Figure 6. Structure of annual CO_2 emissions originating from public transport
Figure 6. Struktura godišnje emisije CO_2 koja potiče iz javnog prevoza

CONCLUSION

Local governments have an important role to play in the fight against climate change, as much in reducing emissions as in raising the awareness of citizens. The paper analyzes energy consumption and CO_2 emissions for the public sector of the city of Kragujevac, on which local government and decision-makers have the most influence. The public sector includes public buildings, public transport and public lighting.

The analysis of energy consumption of the public sector shows that the most final energy is consumed in the public buildings' sector - 44,623,803.41 kWh, followed by the public transport sector - 21,292,824.95 kWh and the public lighting sector - 15,997,937.60 kWh. The highest CO_2 emissions in the public sector come from the public buildings sector - 22,246.17 t CO_2 (56%), public lighting 12,798.35 (32%) and public transport 4,755.10 (12%). The total CO_2 emission in the public sector of the city of Kragujevac is 39,799.62 t CO_2.

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