MSc Program
Renewable Energy Systems

Energy Savings Analysis of the City of Novi Sad

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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Vienna, 11.10.2019

Affidavit

I, **Ana Popovac Rakic**, hereby declare

1. that I am the sole author of the present Master Thesis, "Energy Saving Analysis of the city Novi Sad",
   68 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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ABSTRACT

Energy efficiency in the Republic of Serbia is two to three times lower than in the European Union countries. The largest consumer of energy is the housing sector, and some public buildings have energy consumption that is even 100% higher than in similar facilities at the EU level.

Main goal of the study was directed towards a research of energy savings with the public buildings in City of Novi Sad after the energy efficiency measures were applied. The aim of this work as well was to define the financial and environmental savings following the application of energy efficiency measures.

Key methodology that was used in researching was the Bottom-Up methodology (BU). It is a methodology that is widely accepted for this kind of exploratory works.

The research results have shown that in the observed period from 2014 to 2016 significant savings were achieved by applying energy efficiency measures in public buildings in the City of Novi Sad. Specifically, the total annual savings of final energy amounted to 1,812,998 kWh/year, the savings in finances on an annual basis due to energy savings amounted to 77,718 €/year, and the savings in reduced CO_2 emissions on an annual basis amounted to 439 t CO_2/year.

The average annual growth of investments in the observed period for energy renovation of public buildings at the level of the City of Novi Sad was 211%. Analyses have shown that € 0.48 worth of investments can generate final energy savings of 1 kWh/year. Analyses have also shown that for a € 1 investment in energy renovation of buildings, we can achieve emission reduction of $5.04 \cdot 10^{-4}$ tCO_2/year.

The energy savings research results, after the application of energy efficiency measures on the example of the City of Novi Sad, have shown that in 2015 they were: 14,1% above the average in comparison with the other observed cities in the Republic of Serbia, i.e. from 49.6% to 74.6% bellow the average compared to the observed cities from the region.

Republic of Serbia in terms of energy efficiency in the housing construction sector lags significantly behind the developed EU countries. Among others, the following factors have contributed to such an occurrence: lagging behind with passing the

legislation which regulates this area, technologically outdated equipment, low purchasing power of citizens, lack of state subsidies, low level of environmental awareness about the pollution and energy savings etc. The biggest motivational problem for energy savings with the citizens in Republic of Serbia today lies in a low price of electrical energy (which continues to be an instrument of social policy) compared to that at the EU level.

CONTENTS

1. Introduction

1.1. Motivation

Certain regions in the world and certain states perceive differently the savings that could be achieved through the application of energy efficiency measures (EE) and their influence on the environmental condition. Thus, the Middle Eastern countries rich in energy sources (primarily in oil and gas) do not perceive this problem as a personal and a global one, and small countries and cities (like the Republic of Serbia and the City of Novi Sad) that are dependent on the energy sources import, perceive this problem as a personal and a global one.

The reason why particularly this area of energetics and energy efficiency was chosen for this work, lies in a fact that the author of this paper, during the last three years, has been cooperating with the local City Agency for Energetics, and had participated with the aforementioned in the creation of several energetics projects, primarily concerned with the EE and renewable energy sources (RES).

The reason of choosing to research the public buildings in this paper lies in the predominance of scientific, and other broader societal (social and ecological) reasons.

Primary scientific reason to choose the public buildings for research is the one that stipulates that public buildings consume 60% of total energy consumption, while the rest of 40% is being consumed by the residential housing *(Bhati et al., 2017: 231)*. This assumption leads to the fact that, by applying the measures of EE on the public buildings, the biggest energy savings in the housing construction sector may be achieved, and on the other hand, the public buildings must be the leaders, especially to the private sector and households, by showing how and in what way the energy should be rationalized, and how the environment should be protected.

Societal reasons of choosing the public buildings for research are based on the fact that every improvement in living conditions in public buildings leads to an improvement in quality and comfort in staying thereto. Because only arranged interiors in terms of regulation of temperature, humidity etc. are the ones that create optimal preconditions for people who reside in them to give their maximum contributions and maximum working and other effects. These benefits could be directly felt on everyday basis by the users of these objects (students, athletes etc.), and indirectly by all the other citizens within the city territory who occasionally use these objects (cultural institutions, health-care institutions etc.). Also, it is expected that new jobs should be opened and new people employed in the Energy Efficiency sector.

From the environmental point of view, a research motivation is based on the fact that each and every continuous reduction in energy consumption, especially with the large objects such are public buildings, can significantly improve the environmental condition. Lower energy consumption is directly proportional to the lower emission of CO_2 and other pollutants.

Motivation to choose the City of Novi Sad for research lies primarily in personal and specific reasons. Personal reasons which have prevailed are related to the fact that the author of this paper lives and works in the City of Novi Sad, and wishes that one day this city will look like the majority of European cities in terms of energy consumption and emission of polluting substances from the sector of housing construction. Specific reasons were present in the form of an aspiration to show on the example of city such as Novi Sad is, that the applications of EE measures can lead to the significant savings in energy, money and CO_2 emissions.

1.2. Core objectives (incl. aim of research and hypotheses)

Main research goal in this paper was directed towards the exploration of energy savings on public buildings in the City of Novi Sad after the application of EE measures. Main research goal set in this manner has established the influence of applied EE measures primarily on the energy and financial savings, as well as on the environmental protection.

Basic research goals are identified as follows:

I. Savings that could be achieved on an annual level by applying the EE measures and with the construction of RES facility through the:
- ✓ reduction of final energy consumption (kWh/per year),
- ✓ achieving the financial savings (€/per year),

- ✓ reduction of CO_2 emission and emission of other gases (tCO_2/per year).

II. Current energy savings that should indicate:

- ✓ their amount compared to the ones in other cities within the country and other cities in the neighboring countries in the region,
- ✓ problems in the area of project realization that are concerned with the EE, and
- ✓ proposition of further EE measures and activities that should be conducted in order to improve the EE and to achieve new energy savings.

The research goals set in this manner have defined the purpose of use for the obtained research results, that is, they provided a solution for the researched problem. Basic research goals have shown the positive effects that are further expressed through the:

- ✓ separate goal - for the City of Novi Sad,
- ✓ societal goal - well-being of the people who live on the city's territory,
- ✓ scientific goal - the application of research methods.

Two hypothesis are set within this research :

- ✓ That the implementation of EE measures in public facilities can achieve average total annual final energy savings (for the period 2014-2016) of 500,000 kWh;
- ✓ That the implementation of EE measures in public facilities can achieve average total annual savings of reduced CO_2 emissions (for the period 2014-2016) of at least 150 tCO_2.

1.3. Major literature

In order to present the actual problem - an analysis of energy savings after the application of the EE measures on public buildings - this chapter analyses the energy savings in other cities. In order for the results obtained in the research to be comparable with other research results, energy savings achieved in other cities (within the Republic of Serbia and neighbouring countries from the region) are being presented.

Only 9% of the cities in Republic of Serbia conducts analysis of savings that are achieved through the application of EE measures *(Municipalities in Serbia, 2008)*. Two cities that are recording these savings are the cities of Kragujevac and Bačka Palnka. For example, in the City of Kragujevac, energy savings achieved through the application of EE measures on an annual level for 2015 amounted to 324,276 kWh/per year. *(Radojević, 2016: 14),* and in the City of Bačka Palnka 317,388 kWh/per year *(Fekete, 2016: 8)*.

Analysis of saved energy through the application of EE measures in certain cities in the Republic of Montenegro in 2015 has shown the following results: in the City of Cetinje the achieved energy savings on an annual level amounted to 547,166 kWh/per year, while the savings in the City of Kotor amounted to 571,110 kWh/per year *(Project, 2016: 17)*.

Analysis of saved energy through the application of EE measures in certain cities in the Republic of Croatia in 2015 has shown the following results: in the City of Zagreb the achieved energy savings on an annual level amounted to 653,519 kWh/per year - these values do not include savings obtained through the application of other specific EE measures such are the construction of solar panels, substation automatisation and similar, *(Annual Energy Efficiency Plan, 2015: 18),* while the savings in the City of Varaždin amounted to 650,790 kWh/per year. *(Annual Energy Efficiency Plan, 2015: 5)*.

1.4. Structure of work

The aim of the research with an emphasis on the expected results:
The main aim of the research in the proposed master's thesis topic is focused on the research of energy savings in public buildings in the City of Novi Sad after the implemented energy efficiency measures. The aim of this research is to determine the impact of the implemented measures primarily on energy savings, financial savings and environmental protection.

Scientific results should indicate:

- Total annual final energy savings - FES (kWh/year),
- Total investments for the implemented energy efficiency measures - (€),

- Gross financial savings after the implemented energy efficiency measures - (€/year),
- Gross CO_2 savings - reduced CO2 emissions CO2 (tCO_2/year).

The social results of the research should indicate:

- reduced level of CO_2 emission, which directly affects the state of the environment, and indirectly affects the reduction of global warming,
- reduced consumption of energy generating products (heat and electricity),
- realized financial benefits, etc.

Research programs (phases) and the approximate content of the master's thesis:
In order to successfully achieve the stated objectives of this master's thesis, the program and schedule shall be determined.
The research program will consist of theoretical and experimental research.
Theoretical research will include the analysis of contemporary: literary sources, scientific knowledge about energy efficiency and construction of buildings, energy consumption in the construction of buildings, global warming, basic information about the City of Novi Sad, public buildings in the City of Novi Sad, examples of good practice, etc.
Experimental research will deal with the analysis/calculations of energy savings and other parameters that can be obtained by the implementation of energy efficiency measures. The obtained results will be presented for each building separately as well as together for all buildings.
Research will be done in accordance with national and international regulations (laws, rules, standards, etc.).
The obtained research values will be statistically processed and the research results in an appropriate manner, which will enable them to be analyzed in an adequate manner.

Research hypotheses:
For the purposes of research papers, 2 hypotheses have been made:

I. By implementing energy efficiency measures in public buildings, the average annual final energy savings (for the period of 2014-2016) of 500,000 kWh/year can be achieved;
II. By implementing energy efficiency measures in public buildings, the average annual reduced CO_2 emissions can be achieved (for the period of 2014-2016) of minimum 150 tCO_2/year.

Research issues:

One of the main reasons for implementing energy efficiency in buildings is environmental protection, reduction of energy-generating product consumption, reduction of CO_2 emission and the emission of other harmful gases into the atmosphere. The construction sector is responsible for 40% of global energy consumption and 30% of anthropogenic greenhouse gas (GHG) emissions. Thirty eight percent of CO_2 emission, 52% of SO_2 emission and 20% of Nox emission come from the construction of buildings.

The research problem concerns the assessment of energy savings in public buildings in the City of Novi Sad. This problem can be solved by implementing energetic efficiency measures, that is, by analyzing these measures. These energetic efficiency measures are (reconstruction of the heating system, replacement of worn-out joinery, replacement of energy-inefficient lighting with energy-efficient lighting, building insulation, etc.).

Research subject:

Based on the defined research problem, the subject of this research is: "*Energy savings analysis of the City of Novi Sad*"

The subject of this research is energy savings in public buildings that can be achieved by implementing energy efficiency measures. The subject of the research are all public buildings in the City of Novi Sad, but only those buildings with implemented energy efficiency measures will be in the analysis of the energy savings assessment.

Methodology/Methods to be applied:

The following methodology/methods will be used for the research of this master's thesis topic:

- "Bottom-up" methodology (BU), and
- Statistical methods.

The "bottom-up" (BU) methodology assesses energy savings for 12 separate energy efficiency measures that can be implemented in the construction of buildings. This methodology is defined in the Rulebook on the methodology for monitoring, checking and evaluating the assessing of the implementation of the Serbian National Energy Efficiency Action Plan (NEEAP).

In the calculations, depending on the implemented energy efficiency measures in the observed buildings, some of the BU measures/models will be applied.

The statistical data processing method will consist of the following:

- Collecting (selecting statistical samples),
- Presentation (classification),

- Interpretation (of selected data),
- Calculation of statistical data, and
- Analysis of statistical indicators and drawing conclusions.

Selection method, size and structure of the sample:
The research will process 200 public buildings (buildings of educational institutions, cultural institutions, health institutions and administrative buildings) in the territory of the City of Novi Sad. For the purpose of researching the assessment of energy savings after the implemented energy efficiency measures in public buildings, the period of 2014-2016 will be taken.

Location of experimental research:
The research will be carried out within:
- Energy Agency of the City of Novi Sad
- Public buildings

2. Background information (state of the art)

This chapter presents the backgroung information which adequately identify and describe the nature of defined research problem.

2.1. Environmental pollution from the housing construction sector

CO_{2e} emissions for buildings of different purposes, i.e. different objects, range between 300-1,650 $kgCO_{2e}/m^2$ *(Clark, 2013: p.263)*. The housing sector alone produces 30% of CO_2 emissions, and according to the British Government, this is the key area where the reduction of CO_2 emission can be achieved *(Palme et al., 2013: 337)*.

U.S. buildings, for example, currently consume about 40% of primary energy and about 70% of electricity *(Alirezaei et al., 2016: 465)*. At the same time, the amount of energy consumed by buildings will increase in the future, given the increase in population and its needs. Empirical results of a study conducted in China showed that a 1% increase in population caused an increase in energy consumption of 1.33% *(Yang et al., 2019: 176)*.

Influenced by climate change and the pursuit of energy independence / security, a significant place is attached to energy efficiency in all walks of life *(Bukarica and Tomšić, 2017: 968)*, from housing, industry, transportation, agriculture, etc. The main reason for the use of EE in buildings is the reduction of energy consumption, i.e. environmental protection (reduction of CO_2 and other hazardous gases' emission into the atmosphere) *(De Wolf et. al., 2017: 68)*. Today, construction sector is globally responsible for 36% of global final energy consumption and for 39% of anthropogenic gas emissions (GHG) *(Global Status Report 2017, 2017: 6),* that is, he emits 38% of CO_2 emissions into the atmosphere, 52% of SO_2 and 20% of NOx *(Wang et al., 2005: 1512)*.

Today, the world faces the challenge of global warming and environmental pollution as a result of continued warming caused, inter alia, by excessive increases in energy consumption *(Mahlia, 2002: 294)*. In an economic context, various studies have been conducted that focused on monitoring economic growth due to the consequences of CO_2 emissions, energy consumption, and the like. Thus, electricity consumption certainly has a negative impact on CO_2 emissions, but it can have a beneficial impact on the economy if RES plants are built *(Maksimović et al., 2019: 40)*. Today, considering the impact of energy consumption on environmental pollution and climate change, it is very important for us to know how much energy we consume every day, every year, and what changes we can expect in the future *(Kos Grabar Robina and Kinderman Lončarević, 2017: 1010)*.

The Republic of Serbia, as a member of the Energy Community and a candidate for accession to the European Union (EU), has formally adopted and implements EU energy policy. This also includes Directive 2009/28/EC, which is incorporated into the laws of the Republic of Serbia. The most significant benefit of these documents relates to the environmental protection, i.e. reducing greenhouse gas emissions (*Greenhouse Gases – GHG*).

2.2. Cities - from the point of view of energy production and consumption

According to research *(Shan, et al., 2017: 1215 and Sununta et al., 2019: 1345)* urban energy consumption will grow by 1.8% annually between 2006 and 2030, with an increase in the share of global CO_2 emissions from 71% to 76%. According to the same research, under the influence of urbanization, the world population increased from 220 million in 1900 (3% of the total population) to 3.530 million in 2011 (52% of the world population). The urbanization of cities increases the consumption of electricity *(Wang, 2014: 332)*. Cities still occupy less than 5% of the earth's area, while consuming about 80% of total resources *(Carreon and Worrel, 2018: 258)*. They are also responsible for more than 60% of global energy consumption and 75% of total gas emissions *(Seto et al., 2014: 940)*.

Cities and municipalities should be a driving force in implementing EE and RES measures. Often, they are exploited at the state level due to their characteristics such as: alienation, disconnection, disinterest etc. In order for things to change in a positive direction, social and economic aspects should prevail, municipalities and cities should be independent, while being able to make a profit and employ some workforce at these plants.

Decentralization and energy autonomy of energy systems should be one of the priority goals of municipal energy *(Sperling et al., 2011: 1139)*. Extensive research has shown that a large number of municipalities strive for energy independence compared to their own countries, where they usually focus on electricity production *(Engelken et. al., 2016: 366)*. Local communities can be more efficient in implementing energy goals due to smaller energy losses during transmission, closer contacts with end users, faster local decision making etc. *(Kostevšek et. al., 2015a: 83).*

The role of local authorities in the fight against climate change is reflected in the implementation of local sustainable energy plans, because only in this way can the environment or emission reduction be affected with great certainty *(Neves and Leal, 2010: 2724)*. For example, the introduction of ISO 50001 Standard - an energy management system, can lead to better energy management mechanisms and significant energy savings in municipalities *(Kamenders et al., 2017: 174)*. Furthermore, the integration of RES at the city level represents one of the possibilities for achieving sustainable transformations of municipal energy systems (*Kostevšek et al., 2015b: 1014*).

Local energy production, despite great investments, is very optimal when it comes to using local resources. Such models can lead to a reduction in electricity consumption since e.g. transmission and distribution losses of electricity only amount to about 7% *(Ašonja et. al. 2017: 22).*

Cities and municipalities may also appear on the production side of certain energy services, either as owners or resource managers, regulators, motivators, or direct producers through their owned or operated enterprises, as is usually the case in district heating systems, for example, Fig.1, *(Macura and Bilić, 2012: 8).*

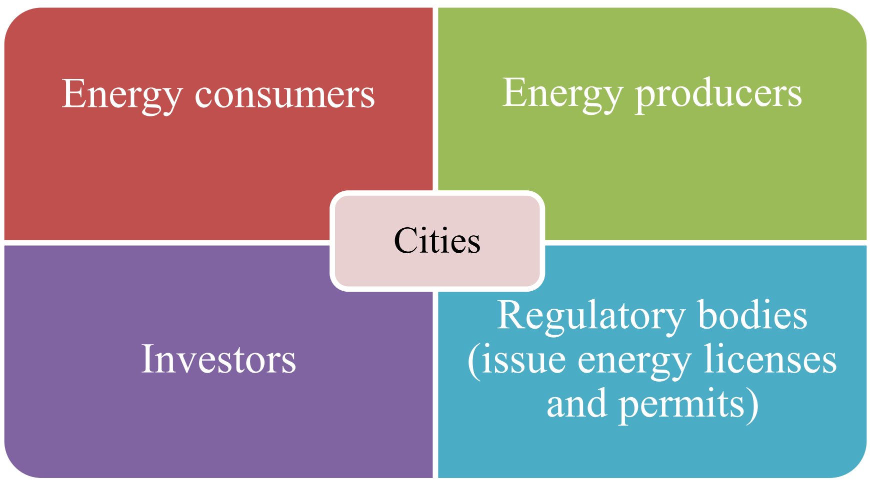

Figure 1: Cities within the field of energy services *(Macura and Bilić, 2012: 8)*

2.3. EE in the Republic of Serbia and national energy policy

According to the International Energy Agency (IEA) estimates, 2/3 of the world's energy consumption in 2050 should be provided by RES, i.e. about 70% of electricity generation will come from RES *(De Santoli et al., 2019: 2 and IEA-IRENA, 2017)*. Thus, for example, Germany already provided 30% of electricity from RES in 2016, including about 50 GW from wind energy, about 7 GW from bioenergy and 40 GW from photovoltaic (PV) plants *(Weinanda et al., 2019: 75 and Statistisches Bundesamt, 2017)*. The foregoing is mentioned because, many critics and experts from the area of energetics think that the Republic of Serbia should follow the path of Germany concerning the application of RES.

2.3.1. *EE in the Republic of Serbia in the building construction sector*

The houses of our ancestors were energetically sustainable because they were made of natural materials, wood, mud, reed, earth, and similar materials. However, after the World War II, the former Republic of Yugoslavia was not concerned with the quality and comfort of the apartment building of the time, but with the quantity in order to resolve the issue of large influx of rural population to cities as soon as possible. The reasons for low EE in the field of building construction in the Republic of Serbia should be sought here.

In general, both in the Republic of Serbia and in its cities, there is a low EE in almost all areas, from the construction system, through energy production and distribution systems, to public transport, the water system, etc. There are a number of factors that influence this, but first of all, we should emphasize delays in the adoption of legislation, literal non-implementation of legislation, very low standard of citizens, very low cost of electricity, etc.

The participation of the housing sector in the consumption of electricity in the Republic of Serbia is over 50%, while the average in the EU countries is around 30%. *(Dimitrijević et al., 2013: 1)*. In the Republic of Serbia, EE is not low only in the building construction, but also in production machines. For example, the age of machinery in the industry of the Republic of Serbia is about 30 years, while the average age at the EU level is about 10 years *(Djukić et. al. 2016: 4)*.

In the Republic of Serbia, the largest losses in the building construction sector were recorded for heat transmission through walls, remote windows, ceilings and raft foundations. Such facilities require a higher amount of energy for heating and cooling, which leads to an increase in the cost of use and maintenance of such facilities. By implementing some of the EE measures in facilities with e.g. thermal insulation, savings of 20 to 80% can be achieved *(Ašonja, 2018: 3)*.

The average energy consumption in the Republic of Serbia for older houses and buildings is 200-300 kWh/m^2 per year, for standard insulated houses around 90-160 kWh/m^2 per year, for low-energy houses from 40-60 kWh/m^2 per year and for passive houses around 15 kWh/m^2 per year. *(Adamović et al. 2013a: 99)*.

At the level of the Republic of Serbia, a national typology of residential buildings was performed according to the number of buildings, the number of apartments and the energy required for heating *(Jovanović et al., 2013: 26 and 31)*. According to this typology:

- ✓ Objects for family housing of up to 4 apartments make up 97.32% of the objects (92.13% of which are freestanding objects and 5.19% buildings in a row), i.e. multi-family dwelling buildings with more than 4 apartments per entrance make up 2.65% of the buildings (of which 1.43% are freestanding buildings, 0.67 bays, 0.54% buildings in a row and 0.04% tall residential buildings), Tab.1;
- ✓ According to the consumption of thermal energy, family dwellings of up to 4 apartments consume 76.21% of thermal energy (of which freestanding buildings 72.16% and buildings in a row 4.05%) i.e. multi-family residential buildings with more than 4 apartments per entrance consume 23.79% (of which freestanding facilities 8.62%, bays 10.53%, buildings in a row 3.77% and tall residential buildings 0.87%), Tab.2.

Through the Law on Housing and Building Maintenance, improvement of EE in buildings is established as a public interest in the Republic of Serbia *(The law, 2016: 2)*. Through the efficient use of energy, the following objectives are achieved *(The law, 2013: 1)*:

- ✓ increase in security of supply,
- ✓ more efficient use of energy,
- ✓ increase in the competitiveness of the economy,
- ✓ reduction of adverse environmental impacts etc.

Basic energy indicators for the Republic of Serbia for the period 2015-2017 are shown in Tab.3.

In recent years, the expression that energy efficiency (EE) is the latest renewable energy source (RES) has been adopted. EE is certainly the most current topic in the world today, in addition to sustainable development and environmental protection. EE and environmental issues are two major cause-and-effect issues that will be addressed by today's generations as well as future generations.

Table 1: Representation of housing types in RS by number of buildings ***(Jovanović et al., 2013: 26)***

Construction year	Family housing (up to 4 apartments)		Multi-family housing (more than 4 apartments per entrance)				Total	
	Freestanding building	Building in a row	Freestanding building	Bay	Building in a row	Tall residential building	Σ pcs.	%
<1919	117,985	17,394	183	40	345		135,947	6.05
1919-1945	194,546	10,937	1,530	170	1,663		208,846	9.30
1946-1960	286,259	12,034	2,013	1,175	1,344	34	302,859	13.48
1961-1970	376,057	23,328	5,624	2,113	1,661	242	409,025	18.21
1971-1980	454,893	20,636	8,104	4,337	1,876	415	490,261	21.83
1981-1990	386,958	19,768	7,837	4,176	2,024	163	420,926	18.74
1991-2011	252,884	12,567	6,757	2,971	3,277		278,456	12.40
Σ pcs.	2,069,582	116,664	32,048	14,982	12,190	854	2,246,320	100.00
%	92.13	5.19	1.43	0.67	0.54	0.04	100.00	

Table 2: Representation of housing types in RS according to the required heat energy ***(Jovanović et al., 2013: 31)***

Construction year	Family housing (up to 4 apartments)		Multi-family housing (more than 4 apartments per entrance)				Total	
	Freestanding building	Building in a row	Freestanding building	Bay	Building in a row	Tall residential building	ΣMWh/year	%
<1919	2,317,797	512,229	38,064	21,129	52,988		2,942,206	4.05
1919-1945	3,402,572	284,831	196,427	75,299	272,583		4,231,713	6.48
1946-1960	4,969,091	232,095	322,215	491,395	348,625	20,151	6,383,572	9.77
1961-1970	6,824,367	667,268	1,111,817	987,025	420,887	121,717	10,133,081	15.51
1971-1980	12,433,068	253,656	1,943,674	2,394,931	498,339	324,080	17,847,749	27.32
1981-1990	11,638,272	462,456	1,369,332	2,023,959	397,938	101,882	15,993,838	24.48
1991-2011	5,551,047	230,527	652,251	884,913	473,820		7,792,558	11.93
ΣMWh/year	47,136,215	2,643,062	5,633,780	6,878,652	2,465,179	567,830	65,324,717	100.00
%	72.16	4.05	8.62	10.53	3.77	0.87	100.00	

Table 3: Basic energy indicators for the Republic of Serbia ***(Energy balance for 2017, 2018: 13)***

Indicators	2015	2016	2017
Transformation efficiency (final energy / primary energy)	0.546	0.542	0.547
Primary energy consumption per capita	2,055.44	2,128.99	2,138.98
Electricity consumption per capita	3,761	3,752	3,807
Household share in electricity consumption	52	51	51

2.3.2. National energy policy

In line with the 2007 Treaty of Lisbon, the EU's main energy policy goals are *(Franjić, 2016: 41)*:

- ✓ ensuring the functioning of the energy market,
- ✓ ensuring security of energy supply,
- ✓ ensuring the competitiveness of companies,
- ✓ promoting environmental sustainability and fighting climate change.

By adopting the law on ratification of the energy community treaty, 2006, the Republic of Serbia became a member of the energy community. The Republic of Serbia hereby undertakes to implement the European Directives 2001/77/EC and 2003/30/EC concerning the promotion of electricity from RES and the promotion of biofuels *(Report, 2018: 3)*. These directives have changed over time. The Republic of Serbia and the other contracting parties of the energy community have the same obligations as the EC member states, to develop and implement the National EE Action Plans (NEEAP) just as the member states of the European community do.

The legal framework defining EE in the Republic of Serbia consists of the following laws:

- ✓ Energy Law ("Official Gazette of RS", No. 145/14, 95/18 etc.),
- ✓ Energy Efficiency Act ("Official Gazette of RS", No. 25/13),
- ✓ Planning and Construction Law ("Official Gazette of RS", No. 72/09, 37/19 etc.).

The national legal framework for EE of the Republic of Serbia consists of *(Djukanović, 2016: 16):*

- ✓ The first Energy Efficiency Action Plan for the Republic of Serbia for the period 2010-2012,
- ✓ The second Energy Efficiency Action Plan for the Republic of Serbia for the period 2013-2015 ("Official Gazette of RS", No. 98/2013),

- ✓ The third Energy Efficiency Action Plan for the Republic of Serbia for the period until 2018 ("Official Gazette of RS", No. 1/17 dated January 06, 2017),
- ✓ Rulebook on the manner and deadlines for submission of data necessary for monitoring the implementation of the Energy Efficiency Action Plan in the Republic of Serbia and the methodology for monitoring, verifying and evaluating the effects of its implementation ("Official Gazette of RS", No. 37/15),
- ✓ Instruction on the method of filling in the forms for submission of data on applied EE measures in the Republic of Serbia,
- ✓ BU1 - BU13 methodology.

The most important commitments made by the Republic of Serbia in the field of EE are:

- ✓ reduction of final energy consumption by 9% in the period 2009-2018 (Energy Efficiency Directive, Directive 2012/27/EU),
- ✓ increase in the share of renewables from 21.2% in 2009 to 27% by 2020 (RES Directive from 2009/28/EC), and
- ✓ reduction of hazardous gas and greenhouse gas emissions (Industrial Emissions Directive 2010/75/EU and Large Combustion Plant Directive 2001/80/EC).

Tables 4 and 5 include the goals of the Republic of Serbia derived from the first and second NEEAPs.

Legislation in the Republic of Serbia stipulates that from 2012 all buildings must have energy passports, and the promotion of EE is considered a public interest. The leaders of the EE implementation processes should be cities and municipalities, which should become producers, and not just energy consumers. For example, as of December 31, 2020, all buildings being constructed in the EU will have to have zero energy consumption.

Table 4: The goals of the Republic of Serbia derived from the first NEEAP *(The First Action Plan 2010: 62-63)*

The First NEEAP	
Medium-term energy savings goal in 2012	1.5% - 0.1254 Mtoe
Final energy savings goal in 2018	9% - 0.752445 Mtoe

Table 5: The goals of the Republic of Serbia derived from the second NEEAP *(The Second Action Plan 2013: 4)*

The Second NEEAP	
Medium indicative energy savings goal in 2015	3.5% - 0.2952 Mtoe
Final energy savings goal in 2018	9% - 0.752445 Mtoe

2.4. City of Novi Sad Energy Efficiency

2.4.1. Costs of energy-generating products for public buildings

The costs of energy-generated products in public buildings owned by the City, with respect to the total budget of the City and their interrelationship, are shown in Fig.2 and 3. Fig.2 shows the share of costs for the procurement of energy-generated products in relation to the total City budget for 2015. Out of the total budget of € 166,346,735, 2.57% was spent on energy and water costs for public buildings, and the rest of 97.43% was used for other purposes, Fig.2. Fig.3 shows the shares of energy (separately heat and electricity) and water in the costs for the City for 2015. Total heat energy costs were 61.47%, electricity costs were 23.59%, and water costs 14.94%, Fig.3.

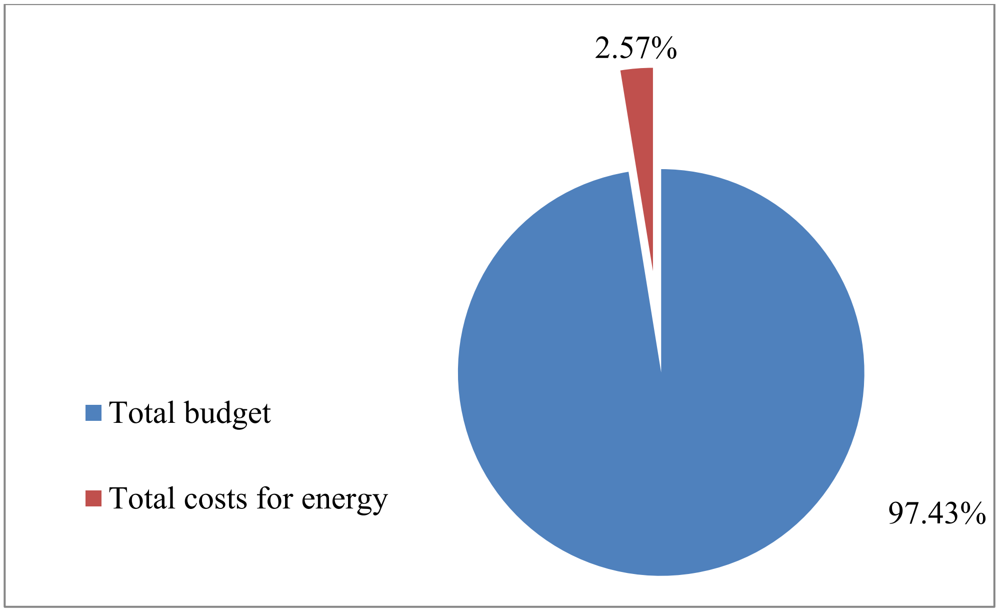

Figure 2: The ratio of costs of energy-generated products to the budget *(Energy efficiency program, 2016: 29)*

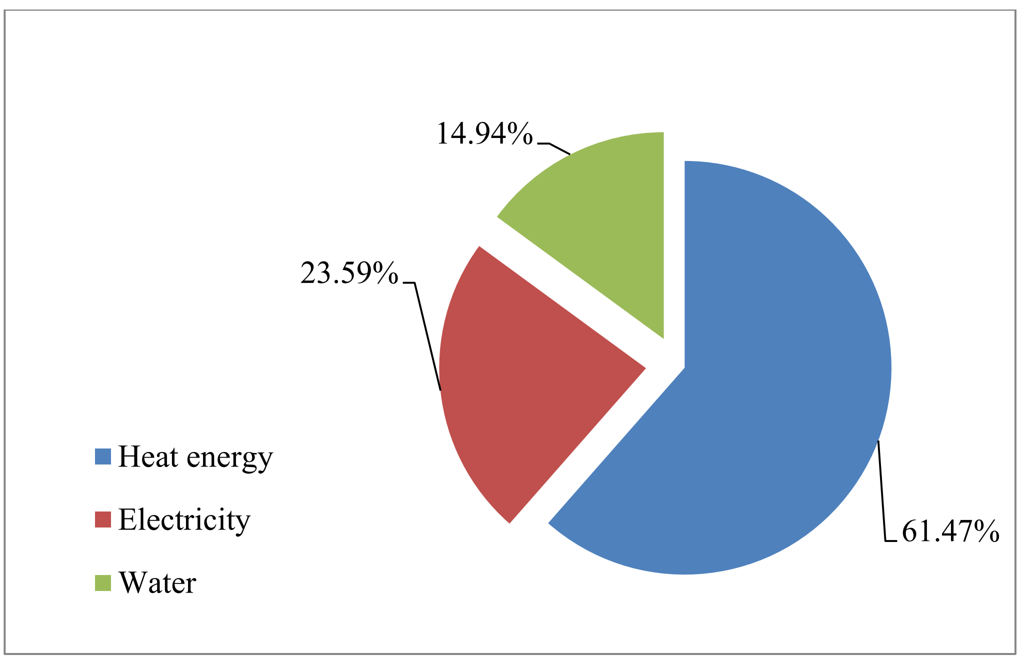

Figure 3: Costs of energy-generated products and water *(Ašonja and Ćirilović, 2017: 267)*

2.4.2. Public utility energy companies

The district heating system in the Republic of Serbia exists in 55 cities, so public buildings in these places are mostly connected to district heating.

On the territory of the City of Novi Sad, Public Utility Company "Novosadska toplana" Novi Sad - is an energy utility company providing district heating and hot water for the needs of the City. There are six district heating plants within the PUC "Novosadska toplana". PUC "Novosadska toplana" provides thermal energy for 75% of the urban area, and the other 25% of the urban area gets heat from other sources:

- Natural gas is supplied by SE "Novi Sad – Gas", which is a social enterprise and is not within the jurisdiction of the city. SE "Novi Sad - Gas", accounts for about 20% of the city's heating;
- Electricity is supplied by "EPS Distribucija (EPS Distribution)" Ltd. Belgrade, accounts for about 5% of the city's heating.

Data on the types of energy-generated products in use and the percentage of households using these energy products are shown in Tab.6.

Table 6: Data on the types of energy-generated products in use and the percentage of households using these energy products *(Energy efficiency program, 2016: 37)*

Type of an energy product	Number of households	Percentage share in consumption
District heating	103,609	75%
Natural gas	32,069	20%
Electricity	N/A	5%
Coal, wood, etc.	N/A	5%

Most of the city's facilities connected to the district heating system pay bills by the amount of energy consumed, while a small fraction of consumers, around 1,150 of them (mostly old buildings), still pays bills by square footage and installed power. In the City of Novi Sad, there are over 150 facilities or about 5,200 housing units in the energy class S *(TOP New, 2017: 8)*.

The heating season in the City begins on October 15 of the current year and ends on April 15 of the following year. Mean annual temperature indicators, number of heating days and degree of hours for the period 2012-2017 are presented in Tab.7.

Table 7: Indicators of heating values for the City of Novi Sad *(Data from the EMIS / ISEM information system)*

Indicators	2012	2013	2014	2015	2016	2017
Mean annual temp. (^{o}C)	4.62	6.07	7.48	5.99	6.70	6.08
Number of heating days (day)	190	194	190	194	213	202
Degree of hours (h)	70,162	64,868	57,120	65,254	67,989	68,524

2.5. State of the art in the City of Novi Sad

In recent years, much has been done to promote and implement EE and RES in the City of Novi Sad. A number of projects have been implemented with the support of the public sector (city, province, republic), the private sector and scientific research organizations. Some of the projects were:

- ✓ one high-efficiency 10 MW cogeneration plant built by PUC "Novosadska toplana", and another 4 MW plant under construction,
- ✓ continuation of automation and connection to the district monitoring and control system for 423 new, primary substations in the district heating system,
- ✓ installation of RES generating plants in 15 public facilities,
- ✓ heat pumps (air water) were built in 10 elementary schools,
- ✓ 100 streetlamps with solar panels were installed, etc.

Below are three recent EE projects in the City of Novi Sad: CHP plant of 10 MW, the first public building in energy class "B" and street solar lighting.

2.5.1. CHP plant

In 2016, the first high-efficiency cogeneration (CHP) in the Republic of Serbia was put into operation, using natural gas as a fuel. This facility was built by the PUC "Novosadska toplana" in the "Zapad" heating plant in Novi Sad, Fig.4. The total investment for the plant was € 6.3 million. The amount of electricity sold saves around € 7 million annually. The total value of the investment was repaid in 1.5 years. In one year, the CHP plant produced 76 million kWh of electricity and 77 million kWh of heat *(TOP New, 2017: 6)*. It is estimated that these quantities of energy are sufficient to supply about 18,000 households under normal conditions.

The basic information for the CHP plant is shown in Tab.8.

a) *b)*

Figure 4: CHP 10 MW plant in the Zapad heating plant, a) view from the outside, b) view from the inside

Table 8: Basic information about the CHP plant in the Zapad heating plant *(Balkan Green Energy News, 2017)*

Number and type of a cogeneration module	3 x JMS 620 GS-N.LC F0.9
Electric power	3 x 3,328 kW = 9,984 MW
Thermal power (90/70°C)	3 x 3,345 kW = 10,035 MW
Thermal power (44.4/40°C)	3 x 207 kW = 0,621 MW
Electrical efficiency	45.6%
Thermal efficiency	45.8%

2.5.2. The first public facility in energy class B

During 2018, in the City of Novi Sad, a shelter facility (Social Welfare Institution: Gerontology Center, Novi Sad) located in Futog settlement was energetically renovated, Fig.5. The building was also built onto during the reconstruction. The total value of the investment is € 698,905. The basic technical data on the reconstructed building is *(Energy Passport for Residential Buildings, 2018: 3)*:

- ✓ the area of the object 1,321.45 m^2,
- ✓ volume of the heated part of the building 5,329.35 m^3,
- ✓ annual energy required for heating 54,250.04 kWh/year,
- ✓ average heat consumption after the reconstruction is 41.05 kWh/year, Fig.6.

The EE measures applied were characterized by the following measures and values:

- ✓ installation of new PVC joinery of eight-chamber profiles (Uf ≤ 0.89 W/m^2K),
- ✓ low-emission argon-filled glass d=4+16Ar+4 mm (Ug=1.0 W/m^2K),
- ✓ styrofoam insulation of the envelope 10 cm (16-20 kg/m) and
- ✓ floor insulation with 8 cm styrodur - Styrodur 2800 C BASF (30 kg/m).

a)

b)

Figure 5: An example of good practice - Energy reconstruction of the building (Energy Class B)

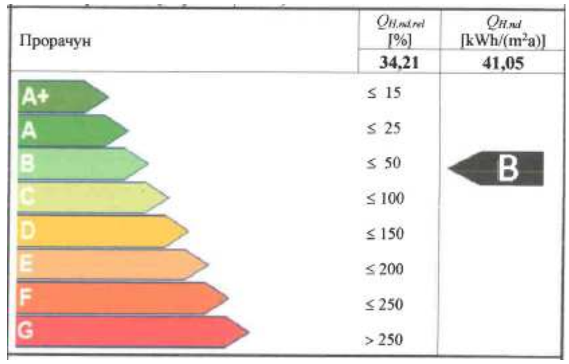

Figure 6: Excerpt from the energy passport of the reconstructed facility ***(Energy Passport for Residential Buildings, 2018: 3)***

2.5.3. Solar street lighting

During 2018, 100 solar streetlamps were installed in the City of Novi Sad. The mentioned works were performed within the framework of the international project R-SOL-E (Renewable Solar Energy) - IPA Cross-border Cooperation Program Croatia-Serbia 2014-2020. The partners in the project were also the town of Belišće and the Municipality of Gorjani in the Republic of Croatia. The aim of the project was to promote the use of RES and reduce electricity consumption. The total value of the project was € 497,000

The greatest benefits of the project are the installation of 100 solar panels with lamps at 24 children's playgrounds and 24 bus stops, Fig.7. The project included, among other things, a cadaster of public lighting in the city, which recorded nearly 34,000 lamps, creating accurate electronic records of public lighting.

Figure 7: Playground in Novi Sad illuminated with solar lights ***(Picture I, 2019)***

3. Description of the methodical approach (modeling, literature study, information retrieval, etc.)

3.1. Modeling

Models of energy and other savings that are presented in this work in terms of collected data, following the conducted EE measures, have shown in an adequate manner the validity of conducting the EE measures at the City of Novi Sad level. Basis of modeling in this work represents a research procedure during which the saving models are being constructed (energetic, environmental and financial). These models are obtained through the adeqaute way (experimental analysis, calculations and logical analysis) and represent as such a reliable source of information regarding the justification of conducting the EE measures.

Modeling of described research problem has enabled to, by the analysis of applied EE measures on the observed buildings, describe the observed system with all its important parameters and values that are quantifiable and comparable to the other observed parameters and values in other cities. Such defined models present the simpler models, which clearly highlighted the important dimension of observed subject and made their research easier.

For the research provided for in this study, the following methodology / methods will be used:

- ✓ bottom – up (BU) methodology and
- ✓ statistical methods.

The statistical method of data processing will consist of the following operations:

- ✓ collecting (selecting statistical samples),
- ✓ presenting (classification),
- ✓ interpreting (selected data),
- ✓ calculating statistical data and
- ✓ analyzing statistical indicators and drawing conclusions.

For the specified research, the following software and other programs were used:

- ✓ LEP information database - local energy database,
- ✓ Software ISEM / EMIS - Energy Management Information System,
- ✓ Excel.

3.2. Literature study

The purpose of the presented literature study is to critically describe the problem of energy consumption in the housing construction sector both at the levels of EU, and the Republic of Serbia.

In EU countries, the average thermal energy consumption in the period 2011-2014 was 179.59 kWh/m^2 per year, of which 67.17% went to space heating alone. Fig.8 shows the energy consumption per area for the normalized climate, as well as the percentage allocated for space heating *(López-Ochoa et al., 2019: 338)*.

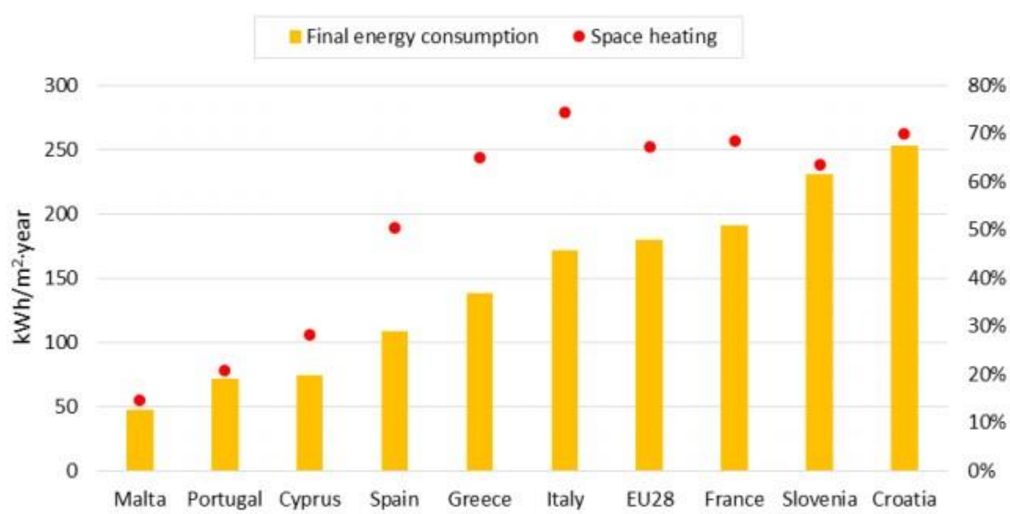

Figure 8: Final energy consumption in the residential sector (in kWh/m^2·year), and thermal energy consumption (in %), in the period 2011-2014 *(López-Ochoa et al., 2019: Annexes paper)*

The average thermal energy consumption for space heating alone in the Republic of Serbia is 175 kWh/m^2 per year, which is about 2.5 more than at the level of EU countries *(Discuss energy, 2014: 23)*. The biggest problem in terms of energy in the Republic of Serbia is that about 70% of buildings are not isolated and that they consume 40% of the total energy needs *(Ašonja 2017: 81)*. Of the total energy consumed in buildings, in the Republic of Serbia 70% is consumed in residential buildings, 18% in commercial and 12% in public buildings *(Ilić et al., 2013: 339)*.

It is unofficially estimated that there are more than 16,000 public buildings in the Republic of Serbia that are in need of energy renovation. Insufficient envelope insulation, outdated heating systems, poor carpentry, etc. are just some of the measures that need to be applied to specified facilities.

3.3. Information retrieval, etc.

The study analyzed the level of EE measures implemented in public buildings, on the basis of which energy savings and savings on reduced annual CO_2 emissions were calculated. The justification for conducting the aforementioned research is covered in:

✓ legislation:

- energy savings,

- Through the Athenian process, the Republic of Serbia committed to reducing final energy consumption by 9% in the period 2009-2018, (1% annually),

- environmental protection;

✓ achieving economic savings.

For the purpose of collecting information in the paper i.e. for the purpose of research, the following were used:

✓ actual scientific sources (scientific and professional works),

✓ professional books,

✓ professional reports,

✓ laws and bylaws that regulate the energetics and environmental sectors,

✓ energy balance sheets on energy consumption,

✓ available and relevant internet sources etc.

The source of data used to fill in the BU forms were:

- ✓ relevant data from technical and other documentation, e.g. from the project documentation, the study on the EE of the building, the energy passport of the building, the bill of accounts of the construction registry, etc.;
- ✓ relevant data from the equipment manufacturer, equipment certification, as well as real data from the field;
- ✓ in the absence of a reliable source of data, the recommended values given in the BU forms themselves were used.

4. Description of the research problem, working definition, working methods, research approach, models, description and discussion of the data used/collected, etc.

4.1. Description of the research problem

Buildings are the largest single energy consumer, and consequently a big environment polluter. Because of the buldings' lifespan, their influence on the environment is long and continuous and cannot be ignored. Most of the existing buildings are energy inefficient, which means that their total heat transfer coefficients are high, meaning that the buildings suffer a great thermal losses due to poor thermal insulation and higher energy consumption. All the above-mentioned is a consequence mostly because in the time of their construction there were no thermal protection standards and the minimum energy quantities that can be consumed.

Public facilities are responsible for a significant percentage of greenhouse gas emissions worldwide. Therefore, energy savings in these buildings can significantly reduce energy consumption, greenhouse gas emissions and maintenance costs. Energy savings will be more efficient only if all employees in these buildings are actively involved in the energy saving process.

Energy savings in public buildings with shared energy meters is more complicated than in private buildings because of the complex behavior and different nature in which people consume energy. Also, in these objects with shared meters for e.g. electricity, energy consumption per capita is usually higher than energy consumption in private homes.

Research problem in this paper was directed towards the public buildings on the City of Novi Sad territory that can be classified as older, and that had, as such, an excessive energy consumption (thermal and electrical). In certain intervals of time, these bildings were subject to the EE measures and those values are subject of the research, in terms of the achieved energy savings.

The research problem of this paper was focused on defining the estimate of the energy savings achieved in public buildings in the City of Novi Sad. This problem was solved by applying a specific methodology to analyze and calculate all implemented EE measures on reconstructed facilities. The EE measures to which the research problem relates are reconstruction of the heating system, replacement of worn-out joinery, replacement of energy-inefficient lighting, insulation of buildings, etc.).

The subject of research in this paper was the analysis of all energy savings in public buildings, which were achieved through the implementation of EE measures. A broader subject of research includes all public buildings in the City of Novi Sad that are directly under the jurisdiction of the City of Novi Sad, i.e. public buildings for which the City of Novi Sad pays energy and water costs from its budget. A narrow subject of research includes only those public buildings in the City of Novi Sad that have been subject to EE measures in the period 2014-2016.

In order for the achieved energy savings research results in the City of Novi Sad to gain significance, they were compared to the savings achieved in other cities in the country as well as in the neighbouring countries in the region. Criteria for selection of other cities depended on several characteristics, such as: climate, GDP, degree of country's development, public buildings construction etc. For the purposes of research comparison two cities from each country were selected, that is, from the Republics of Serbia, Montenegro and Croatia.

4.2. Working methods, research approach and models

Basic methodology used in this paper is the Bottom-Up methodology. The bottom-up (BU) methodology provides energy savings estimates for 12 individual EE measures that can be applied in building construction. This methodology is defined by the rulebook on the methodology for monitoring, verification and evaluation of the effects of the implementation of NEEAP RS *(Handbook, 2016: 461-462)*. The above mentioned measures include:

1. Replacement of light sources in public lighting (BU1);
2. Replacement or installation of lighting systems in new or existing residential buildings (BU2);

3. Replacement or improvement of the system or installation of a new lighting system or part of lighting components in new or existing commercial and public service buildings (BU3);
4. Reconstruction of thermal insulation of certain parts of the building envelope (walls, roofs, ceilings, foundations, etc.) and / or replacement of windows in existing residential, commercial and public service buildings (BU4);
5. Reconstruction of building envelope and heating system in existing residential, commercial and public service buildings (BU5);
6. Replacement of heating equipment in existing residential, commercial and public service buildings (BU6);
7. Introducing new building regulations for new residential, commercial and public service buildings (BU7);
8. Replacement or installation of new water heating equipment in existing residential, commercial and public service buildings (BU8);
9. Connection to a district heating system for new or existing residential, commercial and public service buildings (BU9);
10. Installation or replacement of air conditioning units with a nominal power of less than 12 kW in new and existing residential, commercial and public service buildings (BU10);
11. Installation of solar system for heating of sanitary hot water in new and existing residential, commercial and public service buildings (BU11);
12. Savings of primary energy from combined heat and power plants (BU12).

In the calculations themselves, depending on the EE measures applied on the observed objects, some of the BU measures / forms were applied. The BU forms were completed as follows:

- ✓ Each EE measure provided by the Rulebook complies with one electronic MS EXCEL energy savings calculation form, in which data on the applied measure is entered and
- ✓ the forms are filled out separately for each project and for each facility on which the EE measure has been applied.

The research within this paper had a theoretical and experimental approach.

Theoretical research included analysis of contemporary literature sources, scientific knowledge on global warming, on electricity in building construction, and analysis of energy consumption in building construction, of basic data on the City of Novi Sad, of the energy sector of the City, public buildings in the City, examples of good practice and the like.

The experimental studies were based on energy savings calculations and other parameters that could be obtained by implementing EE measures. The results obtained are shown for each object individually as well as collectively for all objects. The performed experimental research was carried out in accordance with national and international regulations (laws, rule books, standards and the like).

The obtained research values were systematized and processed, and the research results were presented appropriately, which enabled them to be adequately analyzed.

According to its functions, i.e. its purposes, presented models in the research are classified as descriptive given that they describe the system's past state. From the aspect of time dependence, the models are classified as dynamic because they are time-dependent. According to their generality in terms of the model application to different situations and phenomena, the observed models may be classified in the group of general models.

Basic descriptive characteristics of selected models are as follows:

- ✓ according to the form of existence – material models,
- ✓ according to the human role in formation of modeling subject – technical system models,
- ✓ according to the characteristic of modeling subject as a modeling system – behavioral models,
- ✓ according to the degree of perfection – technology models,
- ✓ according to the modeling subject's number of dimensions that constitute a model – complete models.

4.3. Description and discussion of the data used/collected, etc.

For the purpose of the research, 200 public objects (objects of educational institutions, objects of cultural institutions, objects of health institutions and administrative buildings) were observed in the territory of the City of Novi Sad, Tab.9. For the purpose of the research, the time period 2014-2016 was taken. This number does not include facilities under the jurisdiction of public utility companies, as these companies pay the stated costs for their facilities. The focus of the examination was on 27 different public buildings, (Tab.11-13).

Table 9: Public buildings that are the subject of research

Groups of public buildings by function	Types of public buildings	Number of buildings
CULTURAL INSTITUTIONS	Cultural centers	2
	Theaters	2
	Museums	2
	Other	8
HEALTH INSTITUTIONS	Health centers	6
	Medical centers	28
EDUCATIONAL INSTITUTIONS	Preschools	73
	Elementary schools	40
	High schools	16
COLLECTIVE ACCOMMODATION FACILITIES	Nursing homes	1
	Other	2
ADMINISTRATIVE BUILDINGS	Urban buildings	20

For the purposes of the research according to the "BU" methodology, a total of 35 calculations were performed, of which by pattern: BU1 - 2 calculations, BU3 - 1 calculation, BU4 - 25 calculations, BU6 - 4 calculations and BU11 - 3 calculations, Tab.10.

Table 10: Quantitative overview of applied EE measures

Applied EE measures	2014	2015	2016	Total
Measure (BU1)	-		2	2
Measure (BU3)	-	1	-	1
Measure (BU4)	6	10	9	25
Measure (BU6)	2	-	2	4
Measure (BU11)	1	1	1	3
Total number of energy interventions performed at facilities by years	9	12	14	35

The units of the experimental research:

- ✓ Public buildings in the City of Novi Sad and
- ✓ Energy agencies in the City of Novi Sad.

The scientific results of the research indicated:

- ✓ the achievement of total annual final energy savings - FES (kWh/year),
- ✓ the total investments made for the applied EE measures - (€),
- ✓ realized financial savings after the implemented EE measures - (€/year),
- ✓ CO_2 savings achieved - due to reduced CO_2 emissions (tCO_2/year).

The social results of the research indicated:

- ✓ reduced consumption of energy-generated products (heat and electricity),
- ✓ reduced level of emissions of CO_2 and other pollutants, directly affecting the environment and indirectly reducing global warming,
- ✓ reduction of energy costs which are paid from the city budget,
- ✓ realization of economically sustainable local energy,
- ✓ increase in the quality and comfort of housing in energy-renovated public buildings.

5. Presentation of the results, suggestions for solutions

5.1. Presentation of the results

After the calculations were performed, data of energy savings estimates for public buildings in the City of Novi Sad was processed. In order to better illustrate these savings estimates, in Tab.11-14 the following information is provided:

- ✓ the name of the object that has been subject to energy renovation,
- ✓ the name of the EE measure applied,
- ✓ classification of measures applied according to the BU methodology,
- ✓ total annual final energy savings - FES [kWh/year],
- ✓ total investments for EE measures applied [€],
- ✓ savings [€/year] and
- ✓ CO_2 savings [tCO_2/year].

The total summarized data of the research of total energy savings after the application of EE measures in public buildings in the territory of the City of Novi Sad are presented in Tab.14

According to the data from Tab.11 in 2014: total investments for applied EE measures amounted to € 132,747, total annual final energy savings amounted to 334,662 kWh/year, savings in finances due to energy savings amounted to 13,385 €/year and savings in reduced CO_2 emissions were 67 tCO_2/year.

According to the data from Tab.12 in 2015, total investments for applied EE measures amounted to € 197,062, total annual final energy savings amounted to 373,625 kWh/year, savings in finances due to energy savings amounted to 12,226 €/year and savings in reduced CO_2 emissions were 83 tCO_2/year.

According to the data from Tab.13 in 2016, total investments for applied EE measures amounted to € 540,801, total annual final energy savings amounted to 1,104,711 kWh/year, savings in finances due to energy savings amounted to 52,107 €/year and savings in reduced CO_2 emissions were 289 tCO_2/year.

In the observed time period, according to the data from Tab.14, a total of € 870,610 was invested in energy rehabilitation of public buildings in the City of Novi Sad, total annual final energy savings were 1,812,998 kWh/year, savings in finances on an annual basis due to energy savings were 77,718 €/year and savings in reduced CO_2 emissions were 439 tCO_2/year. An overview of these investments / savings by years is shown in Fig.9-12.

Table 11: Total energy savings after the application of EE measures in 2014

O.N.	The name of the object that was the subject of the energy renovation	The name of EE measure applied	Classification according to the BU methodology	Total investments for EE measures applied - [€]	Total annual final energy savings – FES [kWh/year]	Savings [€/year]	CO_2 savings - [tCO_2/year]
1.	ES "Vasa Stajić", Vojvode Knićanina 12b, Novi Sad	Replacement of joinery	BU 4	29,041	18,517	741	3.7
2.	ES "Jožef Atila", Šarplaninska 28, Novi Sad	Roof insulation	BU 4	51,690	158,197	6,328	31.6
3.	ES "Dušan Radović", Čenejska 61, Novi Sad	Installation of a new gas boiler	BU 6	3,685	12,668	507	2.5
4.	ES "Sveti Sava", Jovana Jovanovića Zmaja 24, Rumenka	Installation of solar collectors	BU 11	3,961	1,971	79	0.4
5.	Grammar School "Isidora Sekulić", Vladike Platona 2, Novi Sad	Replacement of joinery	BU 4	13,940	24,704	988	4.9
6.	ES "Jovan Dučić", Franje Malina 2a, Petrovaradin	Installation of a new gas	BU 6	3,980	9,428	377	1.9

		boiler					
7.	Novi Sad City Library, Dunavska 1, Novi Sad	Replacement of joinery	BU 4	1,400	6,995	280	1.4
8.	Health Center "Novi Sad" in Petrovaradin, Jože Vlahovića 8	Envelope insulation	BU 4	18,888	97,685	3,907	19.5
9.	Novi Sad Theater, Jovana Subotića 3-5, Novi Sad	Replacement of joinery	BU 4	6,162	4,457	178	0.9
			Total=	**132,662**	**334,747**	**13,385**	**67**

Table 12: Total energy savings after the application of EE measures in 2015

O.N.	The name of the object that was the subject of the energy renovation	The name of EE measure applied	Classification according to the BU methodology	Total investments for EE measures applied - [€]	Total annual final energy savings – FES [kWh/year]	Savings [€/year]	CO_2 savings - [tCO_2/year]
1.	Cultural Information Center "Mladost" Futog, Cara Lazara 22	Replacement of joinery	BU 4	19,023	2,878	89	0.6
2.	Youth Theater, Novi Sad, Ignjata Pavlasa 8	Roof insulation	BU 4	1,829	17,598	546	3.5
3.	Grammar School "Isidora Sekulić"	Replacement of	BU 4	20,033	21,959	659	4.4

	Vladike Platona 2, Novi Sad	joinery					
4.	ES "Vasa Stajić" Vojvode Knićanina 12b, Novi Sad	Replacement of joinery	BU 4	11,174	15,656	470	3.1
5.	ES "Veljko Petrović" Kralja Petra I 36, Begeč	Replacement of joinery	BU 4	20,300	29,938	898	6.0
6.	ES "Ivo Andrić" Školska 3, Budisava	Roof insulation	BU 4	7,395	144,798	4,344	29
7.	ES "Jovan Jovanović Zmaj" Školska 3, Sremska Kamenica	Replacement of joinery	BU 4	42,685	55,450	1,664	11.1
8.	SPSE "Milan Petrović" Braće Ribnikar 32, Novi Sad	Replacement of joinery	BU 4	8,351	14,326	430	2.9
9.	SPSE "Milan Petrović" Braće Ribnikar 32, Novi Sad	Installation of solar collectors	BU 11	13,998	19,433	952	3.9
10.	Health Center "Novi Sad", Bulevar Cara Lazara 75, Novi Sad	Lighting reconstruction	BU 3	9,811	23,935	1.316	12.7
11.	Health Center "Novi Sad", Bulevar Cara Lazara 75, Novi Sad	Replacement of joinery	BU 4	18,26	11,312	351	2.3
12.	Health Center "Zmaj Ognjena Vuka" Novi Sad, Zmaj Ognjena Vuka 19	Replacement of joinery	BU 4	23,537	16,342	507	3.3
			Total=	**197,062**	**373,625**	**12,226**	**83**

Table 13: Total energy savings after the application of EE measures in 2016

O.N.	The name of the object that was the subject of the energy renovation	The name of EE measure applied	Classification according to the BU methodology	Total investments for EE measures applied - [€]	Total annual final energy savings – FES [kWh/year]	Savings [€/year]	CO_2 savings - [tCO_2/year]
1.	Youth Theater, Ignjata Pavlasa 8, Novi Sad	Replacement of the light source	BU 1	50,822	57,108	6,282	30.27
2.	ES "Aleksa Šantić", Vojvode Putnika 6, Stepanovićevo	Envelope insulation / Replacement of joinery	BU 4	50,820	101,348	4,529	20.3
3.	ES "Desanka Maksimović", Carice Milice 1, Futog	Replacement of joinery	BU 4	77,928	67,732	2,371	13.5
4.	ES "Dušan Radović", school object located in Temerinska 133, Novi Sad	Replacement of joinery	BU 4	33,018	63,969	2,149	12.8
5.	ES "Dušan Radović", school object located in Čenejska 61, Novi Sad	Reconstruction of the boiler room	BU 6	13,128	56,606	1,896	11.3
6.	ES "Ivo Andrić", Školska 3, Budisava	Envelope	BU 4	17,678	30,031	1,036	6.0

		insulation / Replacement of joinery					
7.	ES "Miroslav Antić", Rade Končara 2 Futog	Replacement of joinery	BU 4	1,965	4,194	231	0.8
8.	ES "Miroslav Antić", Rade Končara 2 Futog	Replacement of the light source	BU 1	96,495	141,411	10,464	74.95
9.	ES "Sonja Marinković", Puškinova 28, Novi Sad	Envelope insulation / Roof insulation	BU 4	57,807	281,286	9,114	56.3
10.	ES "Veljko Vlahović", Street VIII no.2 Novi Sad – Šangaj settlement	Envelope insulation / Replacement of joinery	BU 4	52,701	206,793	7,772	41.4
11.	Health Center "Novi Sad" in Kisač, Slovačka 49, Kisač	Reconstruction of the heating system	BU 6	23,687	20,050	862	4
12.	Health Center "Novi Sad" Vase Stajića No. 5, Novi Sad	Ceiling insulation	BU 4	542	23,152	1,829	7.6
13.	Health Center in Veternik, Kralja	Replacement of	BU 4	5,836	8,645	346	1.7

	Aleksandra No.67, Veternik	joinery					
14.	Health Center "Novi Sad", Zmaj Ognjena Vuka No. 19, Novi Sad	Installation of solar collectors	BU 11	58,374	42,386	3,226	8.5
			Total=	**540,801**	**1,104,711**	**52,107**	**289**

Table 14: Total energy savings after the implementation of EE measures in public buildings in the territory of the City of Novi Sad

Parameters observed	**2014**	**2015**	**2016**	**Total**
Total investments for EE measures applied - (€)	132,747	197,062	540,801	**870,610**
Total annual final energy savings - FES (kWh/year)	343,662	373,625	1,104,711	**1,812,998**
Savings – (€/year)	13,385	12,226	52,107	**77,718**
CO_2 savings - (tCO_2/year)	67	83	289	**439**

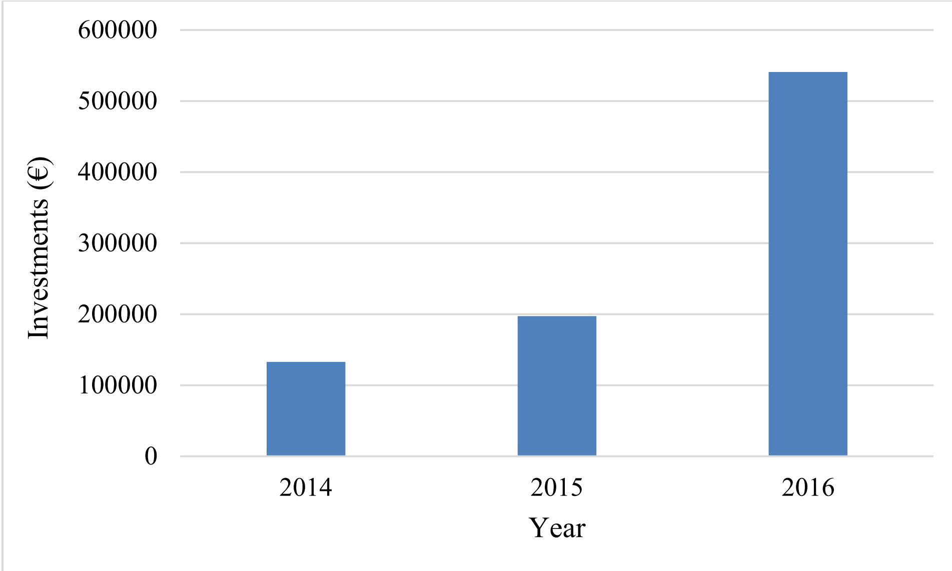

Figure 9: EE investments made

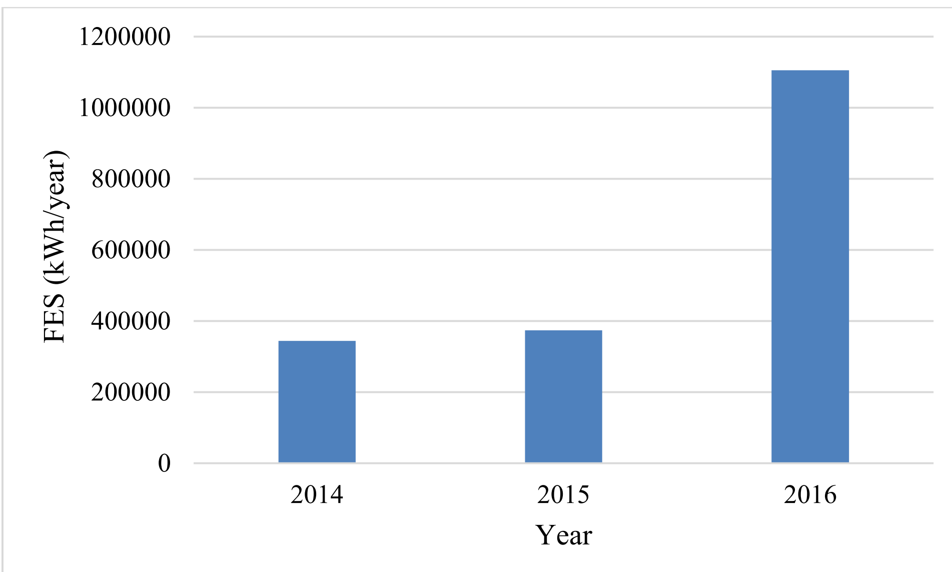

Figure 10: Total annual final energy savings

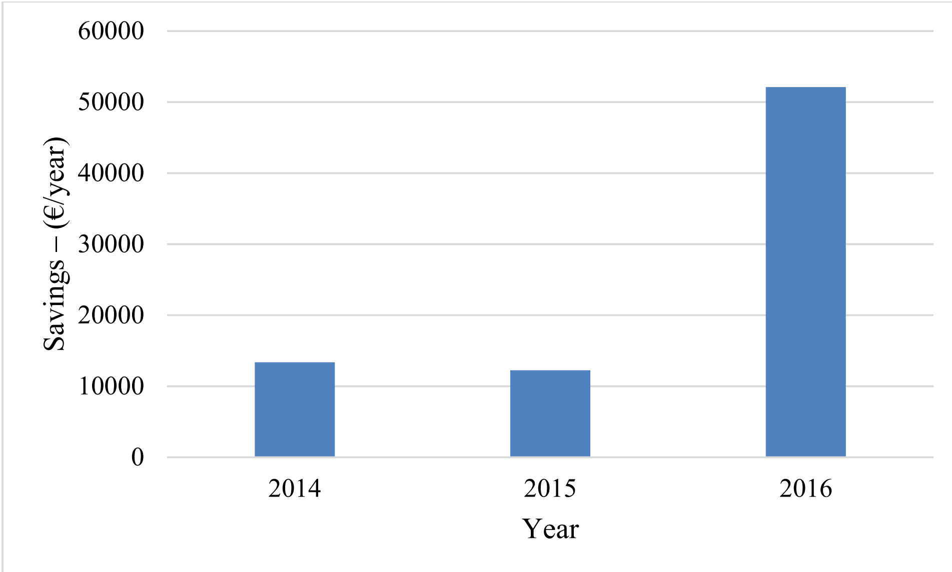

Figure 11: Total savings in finances on an annual basis

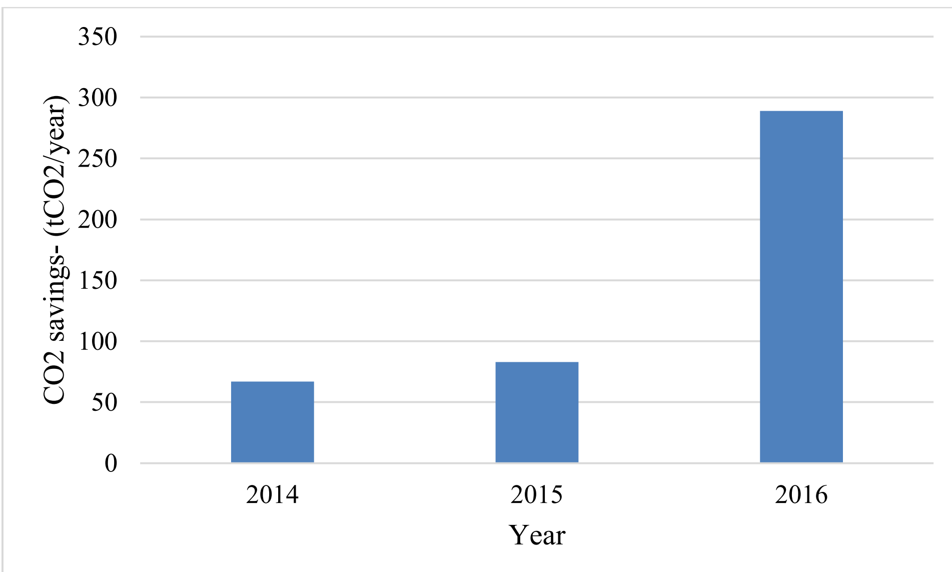

Figure 12: Total savings on reduced CO_2 emissions on an annual basis

5.2. Analysis of research results (hypotheses analysis)

If the savings achieved through the EE measures public buildings in 2015 in the City of Novi Sad are being analysed, and if those savings are compared to certain cities in the region, it can be concluded that the achieved energy savings in the City of Novi Sad are as follows:

- ✓ 13.2% higher than those in the City of Kragujevac, and 15.1% higher than those in the City of Bačka Palanka (Table 15),
- ✓ 46.4% lower compared to those in the City of Cetinje and 52.8% lower than in the City of Kotor (Table 15),
- ✓ 74.9%, lower compared to the City of Zagreb and 74.2% lower than in the City of Varaždin (Table 15).

Table 15: Comparative values of energy savings on public buildings in certain cities in 2015

Name of the City	Country	Total annual final energy savings - FES (kWh/year)
Novi Sad	Republic of Serbia	373,625
Kragujevac		324,276 *(Radojević, 2016: 14)*
Bačka Palanka		317,388 *(Fekete, 2016: 8)*
Cetinje	Republic of Montenegro	547,166 *(Project, 2016: 17)*
Kotor		571,110 *(Project, 2016: 17)*
Zagreb	Republic of Croatia	653,519 *(Annual Energy Efficiency Plan, 2015: 18)*
Varaždin		650,790 *(Annual Energy Efficiency Plan, 2015: 5)*

Comparing the research results to the certain cities in Western Europe and developed countries of the World would not be appropriate because of two reason, the first certainly lies in the fact that the measures of public building energy renewal were performed long time ago, and the second is that higher degree energy efficiency measures are being applied (solar panels, heating pumps, sources of geothermal energy etc.) which is not encompassed by the Bottom-Up methodology applied here.

In the pre-research works for the purpose of research on the topic "*Energy savings analysis of the city Novi Sad*", two hypotheses were set and their interpretations were confirmed.

By analyzing the results of the research, i.e. analyzing the applied EE measures in public buildings from 2014-2016, it can be concluded that the total final energy savings of more than 500,000 kWh (1,812,998 kWh) were achieved, thus confirming the first hypothesis.

By analyzing the results of the research, i.e. analyzing the applied EE measures in public buildings from 2014-2016, it can be concluded that the overall reductions in CO_2 emissions were greater than 150 tCO_2 (439 tCO_2), thus confirming the second hypothesis as well.

5.3. Suggestions for solutions

5.3.1. EE buildings

Energy efficiency means using less energy to perform a job or a specific activity. When we talk about EE buildings, we mean buildings that consume less energy to meet basic living needs, such as maintaining the optimum temperature, necessary lighting and other needs for staying and working indoors.

Saving usually means giving up certain goods or comforts, while EE measures should not diminish people's working and living conditions or impair the sense of comfort. Such a well-insulated building consumes less energy for heating in the winter and for cooling in the summer and staying in it is more comfortable and of better quality, in other words, an energy-efficient building conserves energy and its life span is extended.

In construction, EE involves the implementation of a set of measures aimed at reducing energy demand, the introduction of new environmental technologies and RES *(Adamović et al.,* *2013a: 102)*. It implies that energy, environmental and economic requirements are primarily met when selecting building installation components and technical systems.

In order for buildings to have satisfactory energy performance throughout their lifespan, both the facility itself and all the technical systems in it need to be regularly and properly maintained. Failure to implement all of the above will impair the functionality of the system, leading to irrational energy consumption.

Designing an energy efficient building involves optimizing all parameters that affect energy consumption, optimally positioning the building depending on local climatic conditions, designing the building's thermal load (heating, cooling, ventilation), selection of building materials, etc. The concept of an energy efficient building is defined in the design cycle of the building itself. First of all, the following points should be considered:

- ✓ requirements of future investors / users,
- ✓ building geometry,
- ✓ climatic factors of the given location,
- ✓ characteristics of heating and cooling systems,
- ✓ method of using and maintaining the building and technical systems,
- ✓ economics of consumption of energy-generated products.

5.3.2. Net zero energy buildings

With this in mind, as we transfer to EE, it is important not only to reduce the energy needed by one building but also to find ways to introduce new and cleaner sources of energy wherever possible. In order to fully implement the concept of EE, a new system must be created that will integrate multiple systems with RES. Switching energy sources from conventional to RES in construction, leads to the realization of the concept – net zero energy buildings.

Net zero energy building (NZEB) is a concept where the energy produced by one building can meet its overall energy demand, which means that it has to have zero energy grid consumption and zero gas emissions *(Pantong et. al., 2011: 75)*. This concept is no longer seen as merely a theoretical goal for a future but also as a realistic and achievable goal of today that would reduce the energy consumption of a building and eliminate CO_2 emissions from buildings. This implies that these buildings must have some RES facilities (solar panels, wind generators, heat pumps etc.). In addition to their own consumption of energy produced from RES, for example, energy plus buildings should provide energy for the start of electric cars to be supplemented with energy produced from buildings (solar panels).

Net zero energy buildings certainly require the elimination of fossil fuels and independence from electricity grids, but on the other hand require the application of all forms of RES from geothermal, solar energy, wind energy, etc.

Various terms have been found in the literature to express the EE building, such as *(Adamović et al., 2013b: 276)*:

- ✓ standard buildings,
- ✓ low energy buildings,
- ✓ passive houses,
- ✓ zero energy buildings,
- ✓ energy plus buildings,
- ✓ autonomous buildings,
- ✓ green buildings,
- ✓ zero carbon buildings, etc.

Zero energy building investors must be beneficiaries of incentive funds from state bodies. They also need legislations that will benefit them to be passed, a significant increase in energy prices on the market and so on. The positive effects that benefit the investors of these buildings are:

- ✓ safeness for building owners from future potential increases in energy prices,
- ✓ increased comfort and quality of life,
- ✓ reduction of total costs due to improved EE.

The biggest problem with net zero energy buildings is their technical solution in terms of solving the problems of balance between energy production, storage and distribution (produced from RES).

5.3.3. Smart buildings

In recent years, smart (intelligent) buildings have taken over the market. These buildings are characterized by the application of the world's current innovative technical systems and other solutions concerning the use and maintenance of facilities. Common to all these buildings we classify in this group is that they have an integrated approach to managing all the technologies installed in the facility. These buildings, for example, are characterized by the following solutions, automatic light switch when user enters the facility, automatic control of daylight intensity, automatic control of heating, cooling and ventilation systems, automatic sliding up and down of roller shutters and venetian blinds, depending on the intensity of outdoor lighting. For example, if no one is staying in the rooms, the heating and cooling mode is automatically set to the minimum operating and low power modes. These buildings are designed in such a way that they use all the need for technical water (washing, toilet, watering, etc.) from the rainwater falling on the roof of the building, and collecting it in a single tank from which it is used as needed.

Smart buildings have a system for reading energy consumption (electric, heat and gas) and water in real time *(Adamović, et al. 2013a: 124)*. All of these installations have impulse meters installed and are connected to the hardware and software themselves. Data is collected and stored in memory, and can also be analyzed, based on which real-time energy consumption optimization can be done.

One example of a modern smart building is shown in Fig.13, while an example of how energy consumption can be monitored is shown on a model of monitoring data on energy (district heating and electricity) and water consumption at the Technical School "Mileva Marić Ajnštajn" in Novi Sad, Fig.14.

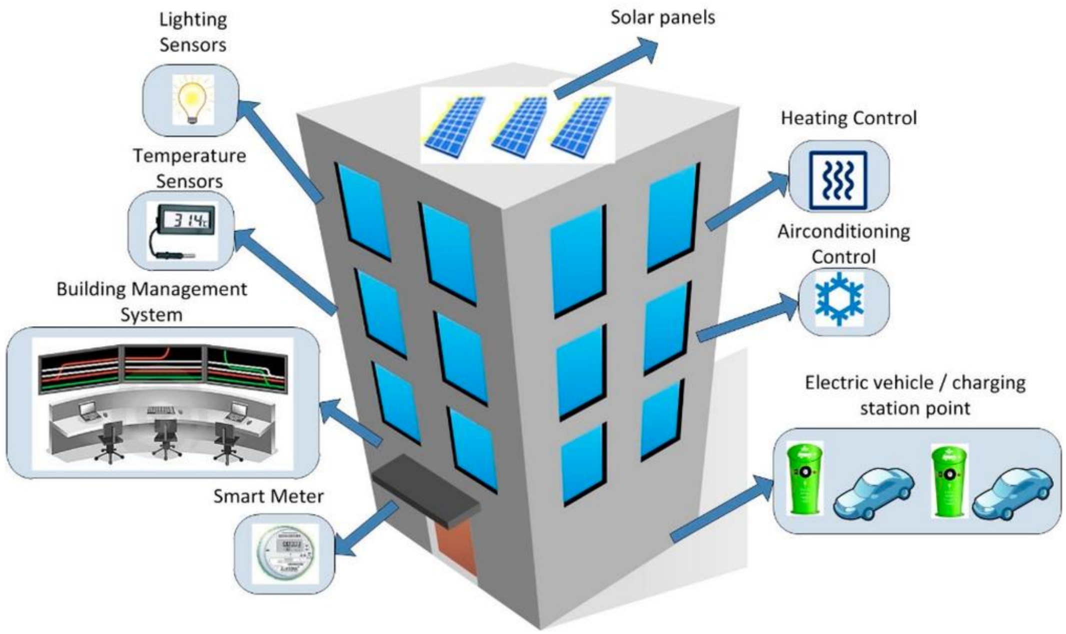

Figure 13: Schematic illustration of a modern smart building (Picture II, 2018)

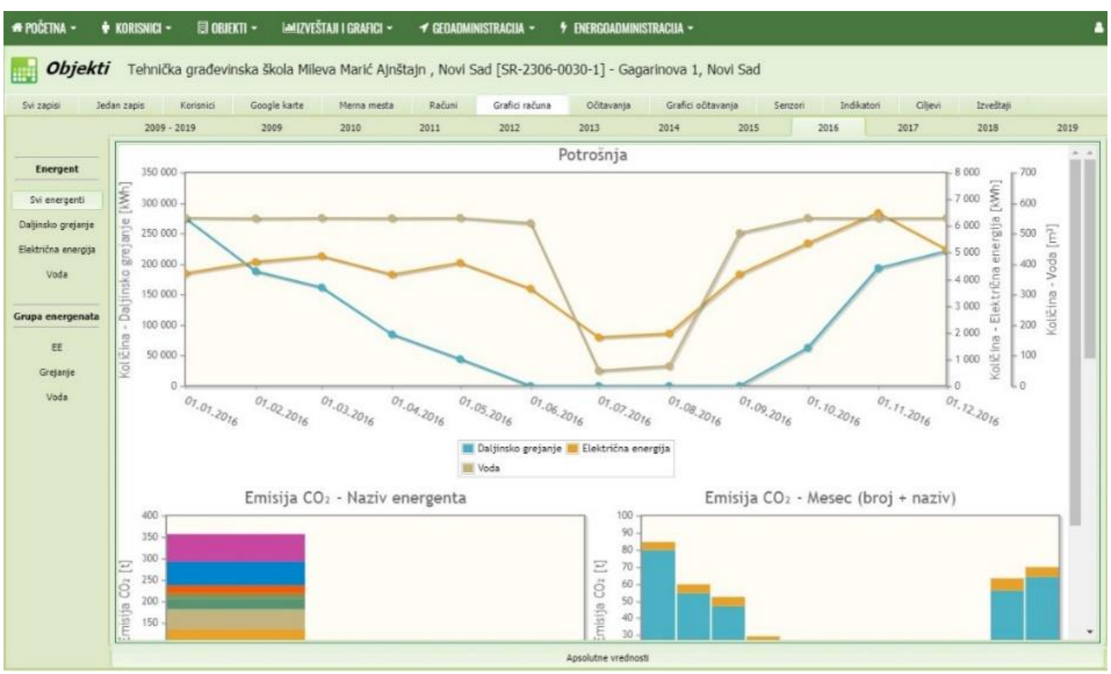

Figure 14: Active monitoring of energy and water consumption (data from the EMIS / ISEM information system)

5.3.4. Recommendation for the implementation of further EE measures

According to the benefit analysis based on the implemented EE measures, i.e. according to the analysis of already implemented EE measures to date, the following EE measures to be implemented in public buildings are proposed:

1. management of the system for heating, cooling, ventilation, preparation of sanitary hot water,
2. reconstruction of the lighting system,
3. reconstruction of heating and cooling systems,
4. reconstruction of thermal insulation (walls, roofs, ceilings, raft foundations) and replacement of joinery,
5. construction / erection of green roofs and green walls, etc.

Recommendations for the construction of future plants generating RES energy in public buildings are:

1. construction of solar power plants, with the tendency to have them become privileged producers of energy,
2. construction of plants with solar collectors for the preparation of hot water in facilities such as swimming pools, kitchens, sports facilities, childcare facilities etc. *(Djatkov et al., 2019: 39)*,
3. construction of heat pump plants.

In order to increase further EE, the following measures are suggested that should be implemented at the local level, regarding RES and waste:

- ✓ providing incentive prices for future producers of thermal energy from RES,
- ✓ making use of locally available resources as much as possible *(Van der Schoor and Scholtens 2015: 667)* like agricultural biomass, because they represent a significant raw material base in the city,
- ✓ significant use of cogeneration plants for combined heat and power generation.

6. Conclusion

The essence of the mentioned researches in this work was referring to the observation of mainly older public buildings that were constructed in an era when the energy consumption and EE of the objects were not taken into account. Some of the problems concerning the EE with the above-mentioned buildings are as follows: age of the bulding (there are buildings which are even 150 years old), many of the buildings are protected as the natural monuments and the most important EE measures cannot be conducted (setting-up the insulation to the envelope and window change), some of the buildings have a ceiling, even 6-meter tall, and a ground plane that cannot be insulated, etc. However the picture is completely different with new buildings constructed since 2010 until today. Since 2010 all public and other buildings must have an EE project i.e. must belong at least to the energetic class ”C” meaning that they will not consume more than 60 kWh/m^2 per year.

Research result analysis have shown that with an investment of 0.48 € an energy saving of 1 kWh/per year may be achieved. This data points to the fact that even with small investments the significant savings could be attained on an annual basis. Current problems concerning the investments in EE of public buildings in the City of Novi Sad are that those are mainly the investments from the City of Novi Sad’s own funds. Since the City of Novi Sad is one of the more developed cities in the Republic of Serbia it harder gets the funding for EE of public buldings awarded by the Provinicial and Republic institutions. Since 2016 a significant progress has been perceived in investing in the public buildings in the City of Novi Sad by various international projects. What is currently missing are the affordable subsidised loans from the commercial banks and other institutions.

Funds invested in the EE of public buildings in the City of Novi Sad have not been on a significant level, but certainly the encouraging fact is that the average annual growth of investments over the observed period (2014-2016) for the public buildings energy reconstruction in the City of Novi Sad was 211%. There are a lot of buildings that require an energy recovery and the same situation is with the other cities both in the Republic of Serbia and in the region. Good news for the EE in housing construction sector in the Republic of Serbia certainly is that from the beginning of 2019 started a collection of the EE fee payed for the consumed electrical energy, gas and petroleum products. This fee shall be used in the future for the needs of EE in the housing construction sector, and it will be available to the public and natural persons. Also, it is noticeable that year by year the number of international projects with the aim of energy renovation of public and residential buildings and construction of the RES facilities has been rising.

Analysis have also shown that the investment of 1 € in energy renovation of buildings achieves an emission reduction for $5.04 \cdot 10^{-4}$ tCO_2/per year. This data is very important because at the level of entire city there has been over than 85% buildings that require en energy renovation. In order to additionally reduce this percentage of CO_2 emissions it is necessary to, besides the measures of EE, conduct in the future the reforestation measures as well, i.e. construction of the additional green areas on the buildings' roofs. The afore-mentioned is very important given that the green area in the City of Novi Sad is around 10% and significantly lower than 20% as prescribed by the EU regulations. Currently, at the city level, new legal reglation is being prepared which could significantly affect the installation of green roofs with objects in construction, as well as the number of recommendations about the reconstruction of existing roofs. From the EE point of view the green roofs are very important and in the future a great attention should be dedicated given that the building insulation may lead the reduction of heating energy consumption (both during winter and summer), reduction of radiation intensity, better rainwater drainage etc.

Research results on the energy savings after the application of EE measures on the City of Novi Sad example, have shown that they are: 14.1% higher compared to the observed cities in the Republic of Serbia, 49.6% lower compared to the observed cities in Montenegro and 74.6% lower compared to the observed cities in the Republic of Croatia. Reason for these better energy-saving achievements in the cities of Republic of Montenegro and Croatia lies in fact of significantly higher investments in the energy recovery of its buildings (credit lines, EU funds etc.).

Regarding the EE in the housing construction sector, the Republic of Serbia is lagging significantly behind the developed EU countries. The following factors have contributed to this: delay in passing the necessary legislation that regulates this area, technological obsolence of the equipment, low purchasing power of citizens, lack of state subsidies, low environmental and energy-consumption awareness of the citizens etc. The biggest motivational problem today for saving energy with the Republic of Serbia's citizens lies in the low price of electrical energy (which is still a social policy instrument) compared to that in the EU.

Observed in the long run, by further harmonization of legislation with that at the EU level, by implementation of EE measures, by harmonization of energy prices with prices at the EU level, by raising awareness of the importance of energy saving in the population, by introducing incentive measures for energy renovation of buildings by the state, we can expect that in a few years the consumption of energy, primarily of thermal energy in the Republic of Serbia, can get close to the EU average.

In the future, the goal of constructing all buildings, including public buildings in the city, should be based on energy-sustainable buildings in order to minimize energy consumption while maintaining comfort at the same level. In order to build energy efficient buildings in the right way, care must be taken about the insulation, the way of lighting, the orientation of the building itself, urban details and all other factors that can affect the energy consumption itself.

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List of abbreviations

EE Energy efficiency
BU Bottom-up methodology
EU The European Union
GHG Greenhouse Gases
IEA International Energy Agency
PV Photovoltaic plants
FES Final energy savings
AENS Energy Agency of the City of Novi Sad
CHP Combined heat and power (Cogeneration)

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