DOI: 10.14621/tna.20140204

Energy Efficiency and Renewal of Residential Buildings Stock

Milica Jovanović Popović*, Jasna Kavran

Faculty of Architecture, University of Belgrade
Bulevar kralja Aleksandra 173, 11000 Belgrade, Serbia, milicajp@arh.bg.ac.rs

Abstract

The most part of national building stock of Serbia are residential buildings and more than 90% of them are single family houses. As construction and installation systems of these buildings are rather simple, compared to other types of buildings, it can be concluded that, through the process of rehabilitation and renewal of residential buildings, large savings in energy can be achieved. This process mainly consist of improvement of building thermal envelope in the first step and afterwards further energy savings are possible through heating and hot water systems improvement.

According to the national building typology, based on the Tabula project methodology, residential building stock in Serbia needs annually, only for heating, about 65 million MWh. About 76% of this consumption pertains to single family houses and 24%, for multifamily houses. Up to 70% of these buildings were built before the first "Regulations on thermal protection of buildings" were introduced in everyday practice, thus having no thermal insulation in the envelope. It is estimated that through a rehabilitation process (insulation of walls, roofs, and ceilings, installation of new windows), it is possible to reduce energy needed for heating by 65-70%. The remainder of energy needed for heating can be obtained from renewable energy sources (such as the biomass), significantly reducing the CO2 emission.

In this paper, the possibilities and ranges for reconstruction and renewal of residential building stock of Serbia are presented in order to achieve better energy efficiency in residential building stock as well as to prepare input data for development of road maps for the nZEB strategies.

Keywords:	National typology, Residential buildings, Energy efficiency, Energy renewal, Nearly zero energy buildings

Article history:	Received:	23 July 2014
	Revised:	
	Accepted:	19 September 2014

1. Introduction

After three years of research, based on previous R&D projects [1] [2] [3], and Tabula project [4], during which developed methodology for national typologies was approved as official for EU countries [5], research team from Faculty of architecture University of Belgrade published the National typology of residential buildings in Serbia [6]. Within the framework of typology, calculations of energy characteristics, energy needed for heating and CO_2 emission were calculated for chosen representative residential buildings giving the basis for development of possible road maps for energy efficiency improvement and national definitions for nearly zero energy houses. Two scenarios for energy efficiency improvement were suggested. Based on these calculations, different strategies for renewal of national residential building stock can be developed and long-term plans created. It is necessary to emphasize the importance of these plans, especially in the moment when Serbia has started the process of negotiations with EU, since they are obligatory part of various EU regulations concerning energy efficiency of buildings and nearly zero energy buildings (nZEB) [7].

2. National typology

For the purposes of national building typology development, field survey was conducted and almost 20 000 residential building were listed and assessed based on the specially prepared questioner and using software developed for these purposes. Basic principles for developing this typology were based on urban and architectural characteristics of residential buildings in Serbia but also on historical and socio-political national development. Those basic principles were:

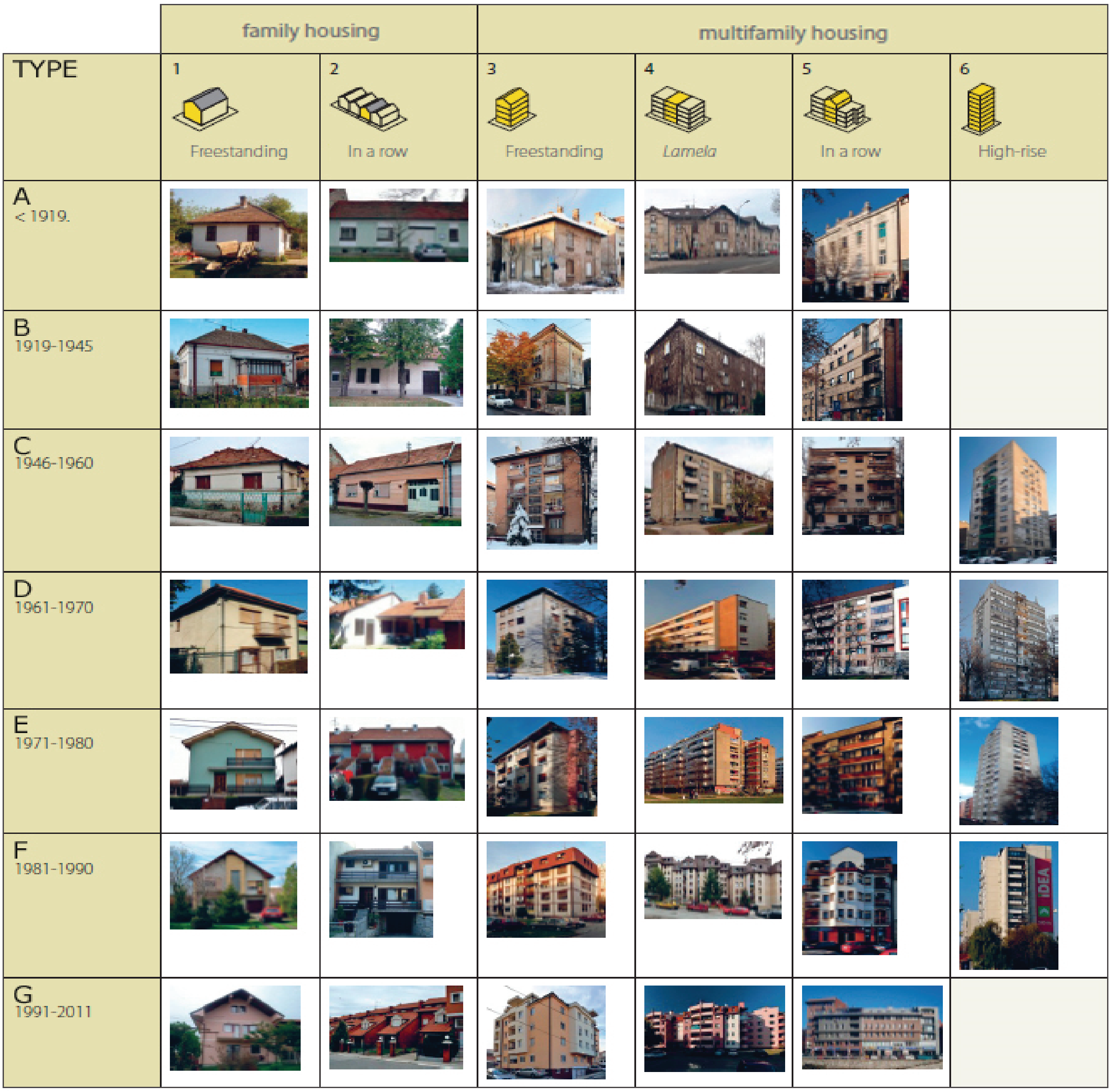
1. Year class defined according to historical and economic development, type of building construction technique, introduction of thermal protection regulations period,

2. Type of building according to their urban characteristics, position on the lot and position relative to other buildings, defining six typical types: two for family housing (detached and row house) and four types for multy-family housing (detached, row house, row house type „lamella", high rise),
3. Architectural characteristics, compact or jagged shape, percentage of windows in total facade area, use of attic or cellar,
4. Characteristics of envelope elements.

After cluster analysis was conducted, 40 buildings out of 20,000 were chosen as real representatives of model buildings (Table 1). For each adopted year class/building type the following items were defined:

– Typical elements of the thermal envelope and heat transfer coefficients (U values);
– Characteristics of the heating and domestic hot water systems;
– Frequency and area of the building type in the total national housing stock (Table 2, Table 3),
– Energy needed for heating, present state (Table 4).

Table1. National residential buildings typology



Two levels of refurbishment measures for reduced energy needed for heating: standard (Table 5) and advanced (Table 6) were proposed. Standard level is according to new regulations, when through the process of refurbishment energy class of the building must be raised for one class [8] and is mostly typical of our market in case of refurbishment, while the second level was defined as the maximum energy improvement that the building can reach depending mostly on the shape of building and its volumetric characteristics, requiring a rather large scope of investment.

3. Differences of architectural characteristics and characteristics of heating system

In Serbia there is significant difference in the architectural characteristics between family houses and residential buildings. Single family house are usually one to two stories high, with cellar and attic not used for living. They are usually built without building permissions based on everyday practice and knowledge. The construction system is usually with small spans, and

Table 2. National typology, type distribution by number of buildings (items)

		Family housing		Multi family housing					
		1	2	3	4	5	6	Σ items	%
A	< 1919	117 985	17 394	183	40	345		135 947	6.05
B	1919-1945	194 546	10 937	1 530	170	1 663		208 846	9.30
C	1946-1960	286 259	12 034	2 013	1 175	1 344	34	302 859	13.48
D	1961-1970	376 057	23 328	5 624	2 113	1 661	242	409 025	18.21
E	1971-1980	454 893	20 636	8 104	4 337	1 876	415	490 261	21.83
F	1981-1990	386 958	19 768	7 837	4 176	2 024	163	420 926	18.74
G	1991-2011	252 884	12 567	6 757	2 971	3 277		278 456	12.40
	Σ items	2 069 582	116 664	32 048	14 982	12 190	854	2 246 320	100
	%	92.13%	5.19%	1.43%	0.67%	0.54%	0.04%	100.00%	

Table 3. National typology, type distribution by area

		Family housing		Multi family housing					
		1	2	3	4	5	6	Σ m^2	%
A	< 1919	8 812 918	1 641 759	181 255	128 836	319 202		11 083 970	3.83
B	1919-1945	14 060 213	871 044	1 056 060	343 833	1 829 417		18 160 567	6.27
C	1946-1960	19 797 175	951 208	1 419 450	2 699 971	1 591 895	127 540	26 587 239	9.18
D	1961-1970	27 080 821	1 858 685	6 464 054	6 207 704	2 226 913	1 031 502	44 869 679	15.49
E	1971-1980	38 021 616	1 921 639	10 176 303	17 481 251	3 154 044	2 418 507	73 173 360	25.26
F	1981-1990	34 331 187	2 121 357	10 867 713	15 936 685	3 401 177	815 053	67 473 172	23.29
G	1991-2011	23 129 363	1 449 853	8 362 188	10 410 747	4 987 582		48 339 733	16.69
	Σ m^2	165 233 293	10 815 545	38 527 023	53 209 027	17 510 230	4 392 602	289 687 720	100
	%	57.04%	3.73%	13.30%	18.37%	6.04%	1.52%	100.00%	

Table 4. National typology, type distribution by energy needed for heating

		Family housing		Multy family housing				
		1	2	3	4	5	6	Σ MWh/a
A	< 1919	2 317 797	512 229	38 064	21 129	52 988		2 942 206
B	1919-1945	3 402 572	284 831	196 427	75 299	272 583		4 231 713
C	1946-1960	4 969 091	232 095	322 215	491 395	348 625	20 151	6 383 572
D	1961-1970	6 824 367	667 268	1 111 817	987 025	420 887	121 717	10 133 081
E	1971-1980	12 433 068	253 656	1 943 674	2 394 931	498 339	324 080	17 847 749
F	1981-1991	11 638 272	462 456	1 369 332	2 023 959	397 938	101 882	15 993 838
G	1991-2011	5 551 047	230 527	652 251	884 913	473 820		7 792 558
	Σ MWh/a	47 136 215	2 643 062	5 633 780	6 878 652	2 465 179	567 830	65 324 717
	%	72.16%	4.05%	8.62%	10.53%	3.77%	0.87%	100.00%

and the construction material used is as a rule brick or later brick block with slabs also with clay blocks. The use of thermal insulation in building envelope started approximately twenty years ago, its thickness does not exceed 5cm. lately, old wooden windows, which were used as a rule, are exchanged with plastic windows with insulating glass.

On the other hand, apartment buildings were built according to present regulations existing at that time they were designed, building techniques used were advanced, with application of concrete and very often prefabrication in the period 1960 to 1990. Average number of stories is 5 (cellar not included and by the law not used as a living space).

The characteristics of heating system used in single family houses also differ from those used in multi family houses.

Almost all single family houses have individual heating system, the number of units attached to district heating system is negligible. Single family houses are attached to district heating only in some settlements in suburban area of big towns, built in the period 1960-1970, were the investor was the state and flats were privatized later. In houses built in earlier periods, single stoves are installed using wood or single electrical stoves. In houses built in later periods, central hot water heating system is usually used with boilers on wood, gas or coal.

Multi family residential buildings are usually attached on district heating system. At the moment it is about 27% of total number of flats that are connected to district heating with the constant expansion net. In Serbia, existing heating plants are using gas (60% of the capacity), 20% is using oil fuel and 20% is still using coal. Because of the air pollution, as old heating plants that use coal are in the central part of towns due to its growth, it is planned that, through their modernization, switch from coal to gas.

4. Energy efficiency improvement measures

The suggested measures for improving energy efficiency and CO_2 emission reduction were given for each building in the typology. Those measures included:

- Construction interventions on the building thermal envelope;
- Improvement in the heat supply system; and
- Improvement in the domestic hot water supply system,

Although according to the existing regulations [9] it is obligatory to calculate only energy needed for heating and other types of energy are not included in definition of energy class of the building construction measures.

As mentioned before, two types of potential building renewal, in order to improve their energy efficiency and reduce CO_2 emission are suggested and defined: standard and advanced.

The aim of the first level of improvement was defined in accordance with the current regulations as improving building energy performance for at least one energy efficiency class. Thus, the first level of improvement includes:

Replacement of the existing windows with new packages, the characteristics of which comply with the current Regulations or are close to the given values. Despite their poorer performance, installation of wooden windows was suggested in order to preserve the visual identity of the buildings.

Improvement of thermal properties of walls and floor constructions by adding layers of insulation, usually 10cm thick, where applicable. The walls are typically refurbished using a contact façade system since this method of energy rehabilitation is common in our practice as the most economical and least technically demanding. An exception will be the buildings with façade brick cladding, which is technically difficult to re-apply; in this case it is possible to use special market ready systems in which ceramic cladding as the final façade layer has integrated thermal insulation.

Floor constructions, also have layers of insulation added either in subsequent interventions or integrated into the existing structure.

It is important to say that, when planning energy improvement; economical aspect was not taken into account. It means that, for high buildings, especially high rise, planned measures for the first level of improvement, sometimes are not economically justified. Scaffolding and the process of construction can be so expensive, that only second level of improvement can justify invested assets.

Table 5. National typology, savings in energy needed for heating after standard improvement MWh/a

		Family housing		Multy family housing				
		1	2	3	4	5	6	MWh/a
A	< 1919	1 427 693	270 890	19 757	11 209	21 067		1750 616
B	1919-1945	1 841 888	166 369	108 774	49 512	144 524		2 311 067
C	1946-1960	2 771 605	98 926	197 304	294 297	206 946	11 989	3 581 066
D	1961-1970	4 468 335	410 769	756 294	509 032	224 918	57 764	6 427 113
E	1971-1980	9 315296	117 220	1 210 980	1 031394	242861	198 318	12 116 069
F	1981-1990	7 964 835	305 475	521 650	653 404	91 832	54 609	9 445 432
G	1991-2011	3723827	71 043	234 141	176 983	99752		4 286 898
	Σ MWh/a	31 513479	1 275 471	3 048 900	2 725 830	1 031 901	322679	39 918 260

Table 6. National typology, savings in energy needed for heating after advanced improvement MWh/a

		Family housing		Multi family housing				
		1	2	3	4	5	6	MWh/a
A	< 1919	1 683 267	357 903	26 282	14 172	31 920		2 113 545
B	1919-1945	2 362 116	189 017	129 895	56 389	188 430		2 925 846
C	1946-1960	3 187 345	142 681	235 629	361 796	262 663	14 540	4 204 653
D	1961-1970	4 928 709	479 541	872 647	689 055	302 860	90 772	7 363 585
E	1971-1980	10 075 728	157 574	1 465 388	1 346 056	353 253	251 525	13 649 524
F	1981-1990	9 097 765	305 475	912 888	1 179 315	163 256	70 910	11 729 609
G	1991-2011	4 024 509	71 043	367 936	426 841	154 615		5 044 944
	Σ MWh/a	35 359 440	1 703 235	4 010 665	4 073 623	1 456 997	427 746	47 031 706

The second, advanced level of energy improvement includes specific measures to raise the building energy efficiency class to the maximum. Not typically used, these measures include installation of top quality windows available on the market and thick insulation layers in the thermal envelope.

4.1. Improvement in the heat supply system

For individual heat supply systems, the first level of improvement involves a change of fuel source (where applicable) or modernization of the heating system; the second level of improvement considers the use of the latest technology available on the market in each particular case, depending on the availability of fuel source. For systems with stoves using wood, coal, or electric power, either as single units or as part of the central (alternatively, independent per floor) radiator heating system, the improvement includes the shift to central heating with a wood gasification boiler with a buffer tank, a low temperature gas boiler, or a biomass boiler for pellets or logs.

The advanced level of improvement uses central heating with condensing gas boiler (alternatively biomass boiler for pellets or logs), or central heating with air/water heat pump.

In multi-family buildings with individual furnaces and radiator heating (regardless of fuel source), it is recommended to connect to district heating wherever possible, or otherwise switch to a more environmentally friendly fuel source.

In fossil fuel district heating systems, the first refurbishment measure involves improving control and efficiency of the existing system by installing thermostatic valves on radiators and upgrading the substation for heat supply control based on external air temperature. In accordance with the current legislation on energy efficiency, it is necessary to install equipment for heat supply metering in order to adopt consumption-based billing.

4.2. Improvement in the domestic hot water supply system

The survey found that most domestic hot water systems include individual electrical, storage and, occasionally, non-storage water heaters.

The first level of improvement measures involve central combined domestic hot water and heat supply connected either by the boiler itself or by the heat exchanger in the substation storage tank in case of district heating systems.

In addition, the second level of improvement also includes the use of an auxiliary solar hot water system.

5. Nearly zero energy buildings

During 2013, Ministry of energy, development and environmental protection of Republic of Serbia prepared the Action plan, Strategy for development of energy of republic of Serbia by 2015 with projections by 2030 [10]. It is stated that, among other obligations, Serbia is accepting all the obligations from Energy community treaty and Directive 2009/28/EU as its basis. In this document national energy sector was analysed in details and requirements and goals concerning energy are defined including energy efficiency of buildings. As one of the principles and goals for the development of Serbia, further harmonization with EU regulations was established.

When renewable energy sources are in question, it is planned, according to the scenario that takes into account the measures of energy efficiency, that by 2018 in housing, public and commercial sector, transportation and industry could save up to 9% final energy. It is estimated that the participation of renewable energy sources in gross final energy consumption can reach 27% by 2020 and that, by full applications of energy efficiency measures in new buildings and in major rehabilitation of building stock, up to 16% of final energy consumption can be saved. Although in National typology, the use of renewable energy in buildings was not calculated, it gives sufficient data as the basis for nZeB scenarios.

5.1. National definitions of nZEB

As there is no unique definition for highly energy efficient buildings, generally it is considered that the term indicates the buildings with higher performances than standard buildings built according to national codes and regulations. In order to make the national definition of nZEB and prepare sustainable road map for Serbia, it is necessary to identify several parameters that can be classified in following groups: location, calculation methodology, building stock characteristics, technical possibilities and economy.

Parameters deriving from the location itself are climate and renewable energy sources. Introducing the Regulations on energy efficient buildings, the old standard JUS.U.J5.600 which defined climatic zones, is not any more in effect. According to new Regulations, all calculations are taking into account the exact values for the location of the building for: HDD, insolation, external temperatures. For nZEB definition only one set of climatic data should be calculated representing the whole country. For RES, based on the present investigations, the estimation or mean values for whole country should be prepared taking into account solar, wind, geothermal and biomass energy.

Calculation methodology in Regulations on energy efficient buildings is already based on EU standards and EPBD Directive (2002). As our present regulations give the method for calculating final and primary energy and CO2 emission, it is necessary to upgrade those standards to EPBD recast (2010) and include calculations for other types of energy spent in the buildings as obligatory. Further tightening of benchmarks and allowed levels of needed energy as well as allowed levels of CO_2 emissions are necessary in a very short period of time.

The quantity and quality of building stock has been evaluated to some extent through the National Census, but more information is available in National building typology elaborated in accordance with principles of TABULA project.

Technical possibilities depend on existing state of knowledge and systems applied in everyday practice. While the first is absolutely up to date and is possible to develop and implement all the new products available on the world market, the second is mostly developed in the past century and rehabilitated to a small extent.

According to the EBBD (recast) every EU member state has to make its own definition of nZEB, according to the local economy status and to make calculations that prove that initiatives are sustainable, and that industry is possible to produce new materials and elements that could lead to energy efficiency and nearly zero CO2 emission in buildings. For Serbia, the moment for introducing those standards is very difficult because of the economy crises, and it can influence the position of the benchmarks to lower standards.

6. Discussion of the results and conclusion

From the tables presenting characteristics of residential building stock and total energy demand for heating it can be concluded that:

- The net area of apartments in single family houses is 61% from total net area of Serbian residential building stock while the rest of 39% is in multi family houses,
- 97% of number of residential buildings are single family houses,
- From total number of apartments in Serbia, approximately 73% is in single family houses,
- More than 76% of energy demand for heating of residential building stock is needed for singly family houses heating.
- Through standard level of improvement is possible to reach more than 60% savings of energy needed for heating and up to 50% by renewal of single family houses stock
- Through standard level of improvement is possible to reach more than 72% savings of energy needed for heating and up to 57% by renewal of single family houses stock.

Although the calculated values are theoretical and do not include the fact that energy consumption is different from calculated energy needed due to different behaviour and habits of residents, it gives enough space and potential to reach defined national strategies of 16% saving in building sector. Especially if RES are included in energy efficiency improvement.

It can be concluded that the first rational step in residential building stock energy rehabilitation planning is to start the process with single family houses. The process should include:

- Formulation of strategy
- Preparing architectural designs and descriptions as well as bill of quantities and estimation of the rehabilitation costs
- User friendly software, publicly available and free, based on typical buildings from national typology that will enable the owners to calculate energy potential savings and costs for their own buildings and find the best and feasible solution
- Prepare financial support and lawns, including state support and commercial banks,
- Promote the use of RES especially for preparing domestic hot water and use of heat pumps for heating and cooling process.

For this conclusion the argumentation can be found in following reasons:

- Single family houses are rather small, with small number of floors what gives the advantages in simple construction process and use of scaffolding,
- Legally, the process is also simple: there is no need for agreement of assembly of tenants or long and tiresome procedures for getting of building permit, the owner decides by himself when and what to do and usually they can do that by themselves. It must be stressed that financial support through the banking system must be solved on national level.

References

[1] Jovanović Popović Milica et all, Energy building optimisation in the context of sustainable architecture - part 1: Analysis of building stock

structure, ed Jovanović Popović Milica (in Serbian: Енергетска оптимизација зграда у контексту одрживе архитектуре -део 1: Анализа структуре грађевинског фонда, ур. Милица Јовановић Поповић (Београд: Архитектонски факултет Универзитета у Београду, 2003).

[2] Milica Jovanović Popović, Ana Radivojević, Dušan Ignjatović and Martin Elezović, “ Attic extension and thermal renovation of the residential building -case study“, Spatium No 13-14 (2006): 41-6.

[3] Milica Jovanović Popović, Dušan Ignjatović, Nataša Ćuković and Ana Radivojević, “Rehabilitation project of an appartment building in Belgrade, Serbia”, Spatium No 15-16, (2008): 60-6.

[4] www.building-typology.eu

[5] European Commission, “Notices from European union institutions, bodies, offices and agencies. Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of building by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements”, Official Journal of the European Union, C 115 (2012): 1-28.

[6] Jovanović Popović Milica, Ignjatović Dušan et all, National typology of residential buildings in Serbia, Belgrade, Faculty of architecture, University of Belgrade, GIZ- Deutche Gesellschaft fur Internationale Zusammenarbeit, Belgrade, 2013.

[7] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of building (recast), Official Journal of the European Union, L 153/13, 13-35.

[8] Republika Srbija, Ministarstvo životne sredine, rudarstva i prostornog planiranja, „Pravilnik o energetskoj efikasnosti zgrada“(Regulations on energy efficiency of buildings), Službeni glasnik Rešpublike Srbije br. 61, 2011.

[9] Republika Srbija, Ministarstvo životne sredine, rudarstva i prostornog planiranja „Pravilnik o uslovima, sadržini i načinima izdavanja sertifikata o energetskim svojstvima zgrade“ Službeni glasnik Republike Srbije br. 61, 2011.

[10] Ministry of energy, development and environmental protection of Republic of Serbia, Strategy of energy development of Serbia by 2015 with projection by 2030, Draft version.