CONFERENCE PROCEEDINGS

3RD INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

EDITORS
EVA VANIŠTA LAZAREVIĆ
MILENA VUKMIROVIĆ
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
AND ALEKSANDRA ĐUKIĆ

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PLACES AND TECHNOLOGIES 2016

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ENERGY REFURBISHMENT OF PUBLIC BUILDINGS IN SERBIA

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ABSTRACT

By harmonizing national legislation to European codes concerning energy efficiency in building sector, Serbia took commitment to improve energy efficiency of national government buildings. Following the Directive 2012/27/EU principles, refurbishment of this part of building stock is recognized as a leading example in long-term process of applying energy efficiency regulations at national level. In this respect, both national and local authorities are expected to perform systematization and current state assessment of respected building stock, followed by a proposal for their energy refurbishment. Basic feature of this part of Serbian building stock is represented by the fact that almost all buildings (from one occupied by central government, through local-scale administration buildings, to educational and medical care institutions) are made long before thermal-protection regulations were introduced. That indicates overall divergence from adopted codes and predefined standards in energy efficiency. On the other hand, these buildings are often founded of high architectural value and protected as building heritage, what significantly reduces possible options and energy refurbishment scenarios. Initial steps in implementation of adopted energy efficiency principles were made in Serbia during 2015, when in cooperation of German international cooperation organisation – GIZ and Faculty of Architecture from Belgrade, work has started on assessment and energy certification of public buildings. First energy certificates (energy passports) for public buildings in Serbia were issued, starting from three most valuable buildings of national authorities: Government building, The National Assembly, and The Palace of Serbia. At the same time, aiming to investigate their energy refurbishment potentials, technical brochures are prepared, showing possible, code-related, options for further energy improvement of buildings thermal envelope. This paper will present results obtained during energy-assessment and energy-certification process of this particular buildings, showing at the same time their specificity, that pretty much traces possible category and range of proposed energy refurbishment scenarios.

Keywords: energy efficiency, public buildings, energy refurbishment

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INTRODUCTION

Targeting overall environmental protection, Serbia has been formalized to enforce continuous measures aimed to increase overall energy efficiency on global level, followed by national legislation development according to European regulations. Besides global activities targeting national energy resources efficiency, building sector has been recognized as very important and favourable for conduction of continuous and progressive energy efficiency increasing measures. Along with development of national legislation concerning energy efficiency in buildings[2], first steps were made in Serbia aimed to inspect energy performance of existing building stock, as well as to create legal framework targeting energy efficiency of new buildings. During 2010-2014 assessment of existing residential building stock has been made, resulting with "National typology of residential buildings in Serbia" [3]. Furthermore, additional activities have started on arranging energy efficiency of public buildings. Harmonizing national to European Union legislation, Directive 2012/27/EU targets has been adopted, which enforced national government introduce favourable energy efficiency principles, through energy refurbishment of its own building stock. This directive stipulate all EU members to conduct energy refurbishment of public buildings, counting 3% of used building area each year [1]. Initial steps in long-term process of public buildings energy efficiency refurbishment, were found in current-state assessment of that part of a building stock, along with introducing possible energy refurbishment options. During 2015 in cooperation of Faculty of Architecture and GIZ (German society for international cooperation), initial research of selected governmental buildings has been made, concerning energy efficiency assessment followed by energy performance certificate. First energy passports were issued for selected buildings, namely for the National Assembly building, Building of the Serbian Government, and for The Palace of Serbia (former Federation Palace). Finally, aiming to perceive further energy refurbishment possibilities of selected buildings, bilingual brochures have been prepared, representing possible refurbishment scenarios [2].

Figure 1: Selected buildings (from left): National Assembly building, Building of the Serbian Government, The Palace of Serbia

BASIC FEATURES OF SELECTED BUILDINGS

Overall age was found as basic feature of selected building, with further implications on their energy performance. As with majority of other Serbian public buildings that hosts national institutions (local authorities, educational institutions, healthcare and medical centers, etc.) selected building belongs to part of the national building stock that was built long before first thermal-protection regulations were introduced. Selected buildings were built using traditional technique, without thermal protection layers, which further implicates significant divergence from current regulation concerning energy performance of buildings. In terms of individual parts of buildings thermal envelope, all three buildings are represented by significant divergence from maximum heat transfer coefficient values required (U-value). On the other hand, selected buildings belongs to monumental ones, with highest significance on national level, which results in large, complex floor plans, with unfavourable building shape and large surface and volume of

[2] First Serbian regulations concerning energy efficiency in buildings were enforced in 2011.

thermal envelope. Finally, thanks to their significant architectural, cultural and historical values, they are all are included in the opus of cultural and historical monuments of Serbia, which to a large extension directed approach during energy refurbishment proposal.

National Assembly Building and Building of the Serbian Government

Both representative and monumental, with lavish stylistic ornamental features, significant facade decoration, and historical significance, buildings are found as architectural and cultural monuments. Both of them were constructed using traditional techniques, as masonry built structures with solid brick walls of great thickness, which varies depending on their position within a structure. Both buildings have walls 40-180 cm thick, with majority of them in thickness of 60 cm. Floor structures are made of reinforced concrete. External walls are covered in decorative plaster, with lavish facade decoration. Windows are wooden, double frame, double sash (wide box) with single glazing.[3] Buildings have traditionally organized attic area over entire floor layout. It should be noticed that in case of building of Serbian Government, attic space was recently converted and adjoined to the rest of occupied area. Both buildings are with orthogonal, complex layout, which results in large surface and volume of heated thermal envelope.

The Palace of Serbia

Represents one of the first structures to be built during post-war renewal on New Belgrade. Concerning historical issue, The Palace of Serbia is a symbol of new, post-war social system creation. Thanks to its tempestuous and politically rich past, significant architectural qualities, along with numerous paintings and sculptures of the most prominent Yugoslav artists of that time, building was recently being awarded the cultural monument status.

The building is constructed in a skeleton reinforced concrete system, with the brick and concrete façade infills. Floor structures are made of reinforced concrete, as ribbed structures or hollow concrete slabs. External walls are covered in stone panels. Glazed parts of the facade are made of aluminium frames, with double-glazed flat glass. Building have large, complex layout, which results in large surface and volume of thermal envelope.

Table 1: Basic features of selected buildings

	National Assembly building	Building of the Serbian Government	Palace of Serbia
Year of construct.	1907-1936	1926-1928	1947-1959
Number of floors	B+Gr+2	B+Gr+4+At	B+Gr+5
Heated area	12147 m^2	13971 m^2	55179 m^2
Heated Volume	67438 m^3	51495 m^3	187836 m^3
Structure	Masonry	Masonry	Skeleton frame
Walls	Solid brick	Solid brick	Solid brick / Concrete
Floor structures	Reinforced concrete	Reinforced concrete	Reinforced concrete
Facade openings	Wooden, double frame, single glazed	Wooden, double frame, single glazed	Aluminium, single frame, double glazed

EXISTING ENERGY PERFORMANCE ASSESSMENT

Selected buildings were put through energy efficiency calculation, which results in defining its energy class. I terms of thermal properties, none of them implies to up-to-date energy efficiency requirements, either on the thermal envelope elements level, either on the level of a building as a

[3] Exceptions are found on some parts of Building of the Serbian Government, whose windows on additionally built annex, and recently converted loft floor, have been made according to up-to-date standards as single- frame, double-glazed windows.

system [4]. It has been noticed that majority of their thermal envelope elements have significantly higher U-values than current regulation proposed. Finally, energy efficiency calculation shows, concerning specific heating energy demand per year, primary energy needs, as well as CO2 emission.

National Assembly Building belongs to "G" energy class according to energy performance certificate. Specific heating energy demand per year (QH,nd) reaches 180 [kWh/(m^2a)], which is three times higher than requested [5]. Diagram of the building thermal envelope elements' heat losses illustrates the highest heat loss in floor structure to unheated attic, followed by external walls and glazed parts whose heat loss values almost matches. Lowest heat loss is found on ground floor structures. External walls U-values reaches almost 1.2 W/m^2K which is three times higher than current standard requested. In case of floor structures, same coefficient reaches 2.9 W/m^2K (seven times higher than requested), while windows are with U-values of 3.5-4.95 W/m^2K (maximum 1.5 is requested)

Building of the Serbian Government belongs to "F" energy class according to energy performance certificate. Specific heating energy demand per year (QH,nd) reaches 145 [kWh/(m^2a)], which is two times higher than requested [5]. Diagram of the building thermal envelope elements' heat losses illustrates the highest heat loss in external walls and facade openings, while other elements of the thermal envelope have negligible heat losses. [4] External walls U-values reaches almost 1.37 W/m^2K which is three times higher than current standard requested. Despite recently conducted refurbishment of attic space, when thermal protection layers are added to a pitched roof structure, U-values of 0.25-0.35 W/m^2K are still beyond current standards. Windows are with U-values of 3.0-3.5 W/m^2K (maximum 1.5 is requested)

Palace of Serbia belongs to "F" energy class according to energy performance certificate. Specific heating energy demand per year (QH,nd) reaches 140 [kWh/(m^2a)], which is two times higher than requested [5]. In spite of partially insulated thermal envelope, which was found very prosperous for building construction period, building is far away from up-to-date energy efficiency standards. Diagram of the building thermal envelope elements' heat losses illustrates the highest heat loss in windows, which takes largest share of building`s thermal envelope. Significant heat losses are found in external walls also (despite thermal protection layers used), while other elements of the thermal envelope have negligible heat losses. External walls U-values are in range of 0.70-2.50 W/m^2K, which is two to six times higher than current standard requested. In spite of thermal protection layer (cork panels 3cm thick), flat roof structure also doesn't meet current standards having U-value of 0.38-0.48 W/m^2K. Windows are with extremely high U-value of 4.0 W/m^2K, way beyond requested.

Table 2: Existing energy performance

	National Assembly building	Building of the Serbian Government	Palace of Serbia
Energy class	G	F	F
Specific heating energy demand QH,nd [kWh/(m^2a)]	180	145	140
Primary energy (MWh/a)	5160	4792	12376
CO_2 emission (t)	1703	1582	3465
Walls (W/ m^2K)	0.32-1.19	0.38-1.37	0.72-2.58
Roof / Floor structure to unheated area (W/ m^2K)	2.9	0.24-0.29	0.38-0.46
Groundfloor (W/ m^2K)	0.194	0.30	0.37
Windows (W/ m^2K)	3.5-4.95	3.0-3.5	4.0

[4] This happens due to recently conducted building reconstruction, when roof attic area was thermally insulated and converted for use.

ENERGY REFURBISHMENT – IMPROVEMENT POSSIBILITIES

After energy certification process, based on current state of buildings thermal envelope, has been conducted, further proposal are made for possible energy refurbishment of selected buildings.[5] Their significant architectural, cultural and historical values, along with its protected status as a cultural monuments, was a predominant factor in deciding on the manner and level of the proposed interventions aimed to improve their energy efficiency. Suggested improvements are three-level based, according to their scope and complexity. First level of improvement implies minimum refurbishment measures, in a single element of the building, in order to improve the energy class by at least one class, according to the Rulebook on the Energy Efficiency in Buildings [4]. Second level of improvement encompasses optimum measures of interventions on the thermal envelope elements with the highest thermal losses. This includes the set of easily implementable measures, not requiring major interventions. Third level of improvement strive to achieve the highest possible energy class, including energy refurbishment measures not threatening the protected building status.

National Assembly building – improvement possibilities

First level of improvement encompassed glazed part of thermal envelope, which will lead to its thermal properties improvement, without effecting overall appearance of a building. Windows replacements are suggested, using new wooden windows of high energy performance (low-E double glazed unit with krypton infill). Suggested measures improve building energy class to "F", with energy consumption reduced by 18% compared to the baseline level. Second level of improvement, besides windows replacement, encompassed the floor structure to the unheated attic, using rock wool 15 cm thick. This simple and low-value investment will significantly reduce overall energy consumption. Suggested measures improve building energy class to "E", with energy consumption reduced by 42% compared to the baseline level. Third level of improvement, alongside previously proposed measures, encompassed more extensive interventions on external walls without luxurious interior finishing. Applying of the 10 cm thick rock wool, with plasterboard finish has been proposed. This "pushes" building to energy class "D", with energy consumption reduced by 56% compared to the baseline level.

Table 3: National Assembly building – energy performance after refurbishment measures

	Improvement 1	Improvement 2	Improvement 3
Energy class	F	E	D
Specific heating energy demand QH,nd [kWh/(m^2a)]	148	104	79
Primary energy (MWh/a)	4268	2988	517
CO_2 emission(t)	1398	986	831
Walls(W/ m^2K)	-	-	0.17-0.28
Roof / Floor structure to unheated area (W/ m^2K)	-	0.23	0.23
Groundfloor (W/ m^2K)	-	-	-
Windows (W/ m^2K)	1.5	1.5	1.5

[5] The proposed improvements cover solely the thermal envelope of the building, while the heating and hot water systems were not included in the respective interventions.

Building of the Serbian Government – improvement possibilities

First level of improvement encompassed glazed part of thermal envelope, although external walls are found as a little bit higher heat loss sources. This will lead to energy efficiency improvement, keeping at the same time protected exterior appearance of the building. Windows replacement are suggested, using new wooden windows of high energy performance (low-E double glazed unit with krypton infill). Suggested measures improve building energy class to "E", with energy consumption reduced by 30% compared to the baseline level. Second level of improvement, besides windows replacement, encompassed external walls and flat roof thermal protection using rock wool 15 cm- 20 cm thick. This measures targeted single parts of thermal envelope positioned inside building atrium, without having significant monumental values. Suggested measures improve building energy class to "D", with energy consumption reduced by 32% compared to the baseline level. Third level of improvement, alongside previously proposed measures, encompassed more extensive refurbishment measures on all external walls. Applying of the 10 cm thick rock wool on the internal side of the walls has been proposed, in order to preserve the authenticity of the building as the culture monument. This measures improved building energy class to "C", with energy consumption reduced by 58% compared to the baseline level.

Table 4: Building of the Serbian Government – energy performance after refurbishment measures

	Improvement 1	Improvement 2	Improvement 3
Energy class	E	D	C
Specific heating energy demand QH,nd [kWh/(m^2a)]	102	98	61
Primary energy (MWh/a)	3370	3231	2012
CO_2 emission(t)	1112	1066	664
Walls(W/ m^2K)	-	0.14-0.18	0.14-0.29
Roof / Floor structure to unheated area (W/ m^2K)	-	0.14	0.14
Groundfloor (W/ m^2K)	-	-	-
Windows (W/ m^2K)	1.5	1.5	1.5

Palace of Serbia – improvement possibilities

First level of improvement encompassed glazed part of thermal envelope, which are found as highest heat loss sources. This will lead to significant energy efficiency improvement, keeping at the same time protected exterior appearance of the building. Windows replacement are suggested, using new aluminium windows of high energy performance (thermal-brake frame, low-E double glazed unit with krypton infill).[6] Suggested measures improve building energy class to "D", with energy consumption reduced by 39% compared to the baseline level. Second level of improvement, besides windows replacement, encompassed insulation of floor structures to unheated spaces, i.e. flat roofs, structure to open corridors and to unheated basement. As insulating layer, rock wool of various thickness was proposed. Although proposed measures didn't improve energy class, energy consumption were further reduced to 45% compared to the baseline level. Third level of improvement, alongside previously proposed measures, encompassed more extensive refurbishment measures on external walls. Applying 10cm thick rock wool, with plasterboard covering, were proposed on the internal side of the walls (part of the walls below windows). Furthermore, blowing-in the thermal insulation granules or threads into

[6] Proposed measures doesn't include glarge glass dome and lanterns, which replacement would cause extensive work on protected parts of a building

specific external walls cavity are also proposed. This measure improve building energy class to "C", with energy consumption reduced by 56% compared to the baseline level.

Table 5: Palace of Serbia - energy performance after refurbishment measures

	Improvement 1	Improvement 2	Improvement 3
Energy class	D	D	C
Specific heating energy demand QH,nd [kWh/(m^{2}a)]	85	77	62
Primary energy (MWh/a)	7500	6844	5438
CO_2 emission(t)	2100	1916	1523
Walls(W/ m^{2}K)	-	-	0.03-0.24
Roof / Floor structure to unheated area (W/ m^{2}K)	-	0.15-0.30	0.15-0.30
Goundfloor (W/ m^{2}K)	-	-	-
Windows (W/ m^{2}K)	1.5	1.5	1.5

CONCLUSIONS

In spite of significant cultural values and protected status of selected buildings, conducted research indicates numerous possibilities for improving their energy efficiency, through reducing energy demand and CO2 emission. At the first place, refurbishment measures are possible on specific part of thermal envelope, where desired activities are allowed, without affecting overall appearance and status of protected building. On the other hand, although proposed energy refurbishment measures results in significant reduction of energy consumption, it should be stated that not all of possibilities are employed. Thanks to overall absence of insulation layers in buildings structure, further energy performance improvement options are possible.

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