ENERGY REFURBISHMENT OF PUBLIC BUILDINGS UNDER CULTURAL HERITAGE PROTECTION IN SERBIA
Constraints and Potentials

by

Milica Dj. JOVANOVIĆ POPOVIĆ, Ljiljana S. DJUKANOVIĆ, and Miloš R. NEDIĆ *

Faculty of Architecture, University of Belgrade, Belgrade, Serbia

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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-therm process of applying energy efficiency regulations at national level. Initial steps in implementation of adopted energy efficiency principles were made in Serbia during 2015, when first energy certificates for three most valuable buildings of national authorities (Government building, The National Assembly, and the Palace of Serbia) were issued. 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.

Key words: *public buildings, energy efficiency, energy refurbishment*

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 favorable for conduction of continuous and progressive energy efficiency increasing measures. 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.

Harmonizing national to EU legislation, Directive 2012/27/EU targets has been adopted, which enforced national governments introduce favorable energy efficiency principles, through energy refurbishment of its own building stock [1]. This directive stipulates all EU members to conduct energy refurbishment of public buildings, counting 3% of used building area each year. 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.

* Corresponding author, e-mail: nedicmilos@gmail.com

During 2010-2014 assessment of existing residential building stock has been made, resulting with *National typology of residential buildings in Serbia* [2]. During 2015, in cooperation of Faculty of Architecture from Belgrade University and German society for international cooperation (GIZ), work has started on assessment and energy certification of public buildings. 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), fig. 1. Finally, aiming to perceive further energy refurbishment possibilities of selected buildings, bilingual brochures have been prepared, representing possible refurbishment scenarios [3].

Figure 1. National Assembly, Building of the Serbian Government, the Palace of Serbia

Scopes

Energy refurbishment of public buildings along with refurbishment of buildings with respected historical values, as two up-to-date topics that lately preoccupy national expert public, are discussed within paper. If observed at the same time, they require specific metodological approach during energy refurbishment process. Considering highest historical, monumental as well as cultural heritage values of inspected buildings, whose energy efficiency survey has never been conducted, obtained results are found very important in assessment of amount of heating energy needs of this type of buildings, potential savings after refurbishment, as well as of environmental impact. During energy refurbishment of regular buildings, one can target maximum energy savings as common goal, while refurbishing this type of highly protected buildings, conserving it is authentical existing appearance must be found as priority. This often leads to very modest set of criteria and tools used for energy refurbishment, while whole process requires interdisciplinary approach when choosing appropriate methodology [4, 5].

Considering the lack of energy refurbishment of this type of protected building within national previous practice, this research shows brief overview of potential savings that can be made, targeting at the same time specific measures and guidelines that needs to be followed. In that respect, choosing appropriate refurbishment methodology which search for maximum energy savings while conserving authenticity of subject building, inspection of potential levels of improvement/savings, as well as setting out specific guidelines that needs to be followed during refurbishment of this type of building are found as final goal of this research.

Methodology

Methodological approach used in this research is based on up-to-date national energy efficiency legislative framework, which target only heating energy needs, while other type of energy consumption like cooling energy, domestic hot water, ventilation or general lightning are left out of the scope [6]. This inconsistency is caused by absence of National software for calculation of all kind of energy consumed within the buildings. Until setting out compatible National software (it is expected to be delivered until the end of 2018), energy consumption calculation, and energy certification process is based only on calculation of heating energy demand.

Buildings were put through energy efficiency calculation, which results in defining its energy class according to energy performance certificate. Using KNAUF TERM2 PRO software, which is set in line with national legislation on energy efficiency [7], assessment of the specific heating energy demand per year $QH_{,nd}$, as well as CO_2 emission for each of selected buildings has been conducted within research. Moreover, their thermal envelope heat losses have been assessed as well, in order to define appropriate refurbishment strategy that search for maximum savings of primary energy needs and CO_2 emission. Focus is put on thermal envelope improvement, which energy refurbishment leads to significant energy savings and reducement of environmental impact both directly or sideways.

Significant architectural, cultural and historical value of selected buildings was a predominant factor when deciding on the scope and level of the proposed interventions. Suggested improvements are three-level based, according to their scope and complexity. First level implies minimum refurbishment measures, in order to improve the energy performance by at least one class, according to the Rulebook on the Energy Efficiency in Buildings [6]. Second level encompasses optimum measures, targeting particular envelope parts with the highest thermal losses. This includes the set of easily implementable measures, but without major interventions. Third level strives to achieve the highest possible energy class, retaining at the same time protected building status.

Basic features of selected buildings

Overall age was found as basic feature of selected building. As with majority of Serbian public buildings (authorities real estate, educational institutions, healthcare centers, *etc.*) selected ones were built long before first thermal-protection regulations. Buildings were made using traditional technique, without thermal protection layers, which further implicates significant divergence from current regulation concerning energy performance. In terms of specific parts of thermal envelope, all three are far beyond maximum heat transfer coefficient values required, *U*-value. Moreover, selected buildings belong to monumental ones, which results in complex floor plans, with unfavorable building shape and large surface and volume of thermal envelope. Finally, thanks to their significant architectural, cultural and historical values, they are all found protected, which to a large extension directed approach during energy refurbishment proposal. Basic features of the selected building are shown in tab. 1.

Table 1. Basic features of selected buildings

	National Assembly	Serbian Government	The Palace of Serbia
Year of construction	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
Façade openings	Wooden, double frame, single glazed	Wooden, double frame, single glazed	Aluminum, single frame, double glazed

The National Assembly building represents the first monumental building of the former Kingdom of Serbia. Constructed during 1907-1936 period, building has orthogonal structure and symmetrical, relatively complex layout. It was constructed as a massive masonry structure, with old size solid brick as basic construction material, and reinforced concrete floor structures. Wall thickness vary from 45 cm to 180 cm. Most frequent are the 60 cm thick façade walls, finally finished in artificial stone with a lavish decoration and moldings. The building has wooden pitched roof covered with metal sheet. Windows are wooden, double frame, double sash with single glazing. Walls are abundantly finished on the interior side with natural stone lining, wooden oak and walnut paneling, silk wallpapers, and stucco ornaments. Floors are with marble covering and intarsia pattern parquet.

Building of the Serbian Government, was built in the period between two World Wars. The four store building has a square atrium layout (with atrium annex added afterwards), with offices and cabinets for administrative services. It was constructed as a massive masonry structure, with brick as basic structure material, and reinforced concrete floor structures. Wall thickness decrease from the basement upwards and vary from 180 cm to 38 cm. Exterior walls are finished in artificial stone. Loft floor, originally designed as unoccupied attic, was subsequently reconstructed and converted into offices. Pitched roof is thermally insulated, however insufficiently to meet up-to-date thermal regulations. Three types of windows were installed namely: wooden double frame-double sash windows (old part of the building), wooden single frame-double glazed windows (added annex), and roof windows with a double glass unit (in the refurbished loft).

The Palace of Serbia represents one of the first structures to be built during post-war renewal on New Belgrade. Construction during 1947-1959 period, it was built as a free-standing monumental administration building, with number of ceremonial spaces, and almost 1000 standard administrative offices distributed on five floors. Building`s symmetrical H letter figure, consist of dominant central corpse and two lateral wings with slightly rounded sides. It was constructed in a skeleton reinforced concrete system, with the brick and concrete façade walls. Floor structures are made of reinforced concrete, as corrugated structures or hollow concrete panels. Glazed parts of the facade are of aluminum frames, with double-glazed flat glass, except the entrance portal where single-glazed tempered glass is installed. Ceiling lanterns are calotte-shaped, made of glass prisms. Façade walls are covered by 4 cm thick stone panels. Flat roofs are covered with the bituminous hydro-insulation with gravel, or concrete tiles protective layer.

Existing energy performance assessment

In terms of thermal properties, none of the buildings implies to up-to-date energy efficiency requirements, either on the thermal envelope elements level, either on the level of a building as a system [6, 8]. It has been noticed that majority of their thermal envelope elements have significantly higher *U*-values than current regulation proposed. Comparative review of basic energy performance data of the selected buildings is shown in tab. 2.

National Assembly Building belongs to G energy class, with specific heating energy demand per year, $QH,_{nd}$, which is three times higher than requested [8]. 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 losses are found on ground floor structures. External walls *U*-values reach three times higher values than requested, while floor structures are far beyond requested with seven times higher values. Windows are with almost three times higher *U*-values [6].

Table 2. Selected buildings – existing energy performance

	National Assembly	Serbian Government	The Palace of Serbia
Energy class	G	F	F
Specific heating energy demand $Q_{H,nd}$ [$kWhm^{-2}a^{-1}$]	180	145	140
Primary energy [Mwh]	5160	4792	12376
CO_2 emission [t]	1703	1582	3465
Walls [$Wm^{-2}K^{-1}$]	0.32-1.19	0.38-1.37	0.72-2.58
Roof/floor structure to unheated area [$Wm^{-2}K^{-1}$]	2.9	0.24-0.29	0.38-0.46
Ground floor [$Wm^{-2}K^{-1}$]	0.194	0.30	0.37
Windows [$Wm^{-2}K^{-1}$]	3.5-4.95	3.0-3.5	4.0

Building of the Serbian Government belongs to F energy class, with two times higher specific heating energy demand per year, $Q_{H,nd}$, than requested [8]. 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. This happens due to recently conducted building reconstruction, when roof attic area was thermally insulated and converted for general use. External walls *U*-values are almost 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 are still beyond current standards. Windows are also beyond requested, with almost three times higher *U*-values [6].

The Palace of Serbia belongs to F energy class, with also two times higher specific heating energy demand per year, $Q_{H,nd}$, [8]. 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 with two to six times higher *U*-values than current standard requested. In spite of thermal insulation used (cork panels 3 cm), flat roof structure also does not meet current standards having *U*-value three times higher. As with other two buildings, windows are with extremely high *U*-value way beyond requested maximum [6].

Energy refurbishment – improvement possibilities

National Assembly building – improvement possibilities

The first level of improvement covered the glazed parts of the façade envelope showing poor thermal features and air-tightness on a thermographic imaging, all leading to increased ventilation losses. In regard to the aforesaid, instead of the wooden, double frame, double sash windows, proposed were the single frame wooden windows with double-glazed, low-E glass unit filled with krypton. Manufacturing of such windows would require thoroughness and precision in capturing the authentic molding, division and proportion of individual parts against the whole, in order not to tamper with the original design. The first proposed intervention has upgraded the building from G to F energy class, accompanied by reduction in the total heating energy demand by 18% annually compared to the baseline situation. Obtained results are shown in tab. 3.

Second level of improvement represents an upgrade to interventions proposed in the previous step. Besides replacing the façade doors and windows, the proposed energy refurbishment encompassed the floor structure towards the unheated attic space, demonstrating the highest energy losses by far. It was constructed as a 20 cm thick reinforced concrete slab with the finishing layer made of cement screed. Thermal insulation of this item represents the least possible investment, while showing best results in terms of reducing the overall heating energy demand. The advantages of intervening on this item are seen in the facilitated access to the attic (without potential obstruction of the building operation during the works), simple works' execution, same as in the fact that this would not in any way affect the overall appearance of the building. The proposed intervention implies insulating the floor structure with 15 cm thick stone wool on the attic side, with the cement screed installed over it in order to enable the unhindered use of the space. This level of improvement considerably contributed to reduced heating energy consumption in comparison with the baseline situation (42%), which was sufficient to upgrade the energy class (from F to E energy class). Obtained results are shown in tab. 3.

The third level of improvement includes proposed energy refurbishment architectural and civil engineering measures contributing to a maximum increase in the building's energy efficiency, aiming to reach the energy class C. Wooden windows of the exquisite thermal characteristics were installed, with triple-glazed, low-E glass unit filled with krypton. In addition, aiming to achieve a higher energy class, interventions were proposed on all façade walls not being part of the representative space and not having the luxurious interior finishing, but only rendered and painted surfaces. Any intervention on a building from the past could raise the question of authenticity and this especially refers to the buildings that are recognized by law as protected monuments. In such cases, preservation of the historic value of the façade might be one of the priorities of any intervention on the building [9]. Thermal insulation was

Table 3. National Assembly – energy balance

<table>
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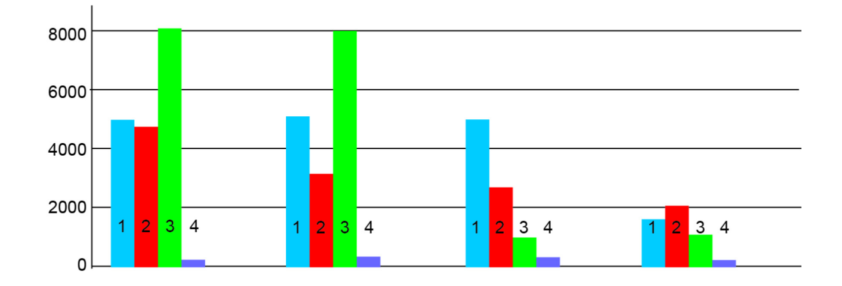
<tr><td rowspan="2">Heat loss through the thermal envelope [WK^{–1}]</td><td colspan="4">
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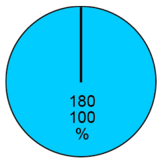
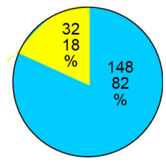
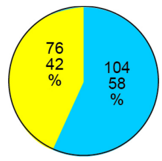
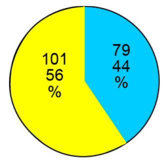
<tr><td>Specific heating energy demand per year [kWhm^{–2}a^{–1}] [%]</td><td>
</td><td>
</td><td>
</td><td>
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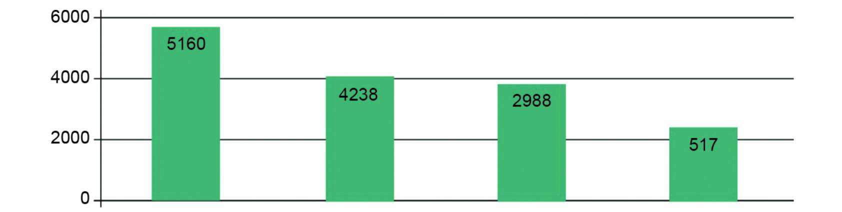
<tr><td>Energy class</td><td>G</td><td>F</td><td>E</td><td>D</td></tr>
<tr><td>Primary energy [MWh]</td><td colspan="4">
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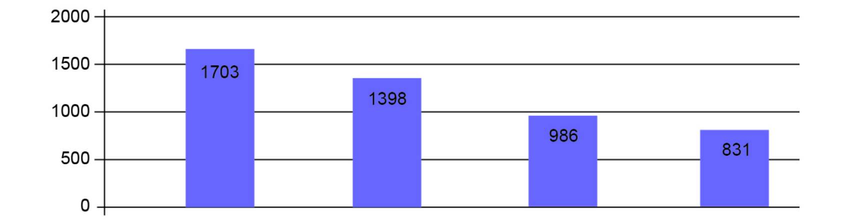
<tr><td>CO_2 emission [t]</td><td colspan="4">
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</table>

also installed on the interior side to preserve the authentic look of the building, by applying the 10 cm thick stone wool, with plasterboard being installed over it. Taking into consideration large wall surfaces covered by this intervention, heating energy demand was significantly reduced: by 56% compared to the baseline situation, with the building being upgraded only to energy class D. Obtained results are shown in tab. 3.

The conducted interventions did not exhaust all possibilities for energy refurbishment of the National Assembly building. Apart from the proposed measures, additional savings could be made by transforming the atrium of the building into a closed space. That kind of refurbishment could further improve the energy efficiency of the building, especially in terms of significant heating energy savings. Installation of low-emissivity glass units on top of the atrium space, will convert open atrium into ventilation controllable space, which could be used to *operate* indoor climate, in terms of indoor temperature, ventilation needs, *etc.*

Building of the Serbian Government – improvement possibilities

The first level of improvement is focused solely on the glazed parts of the façade envelope, although the façade walls represent the somewhat larger heat loss sources. Such a decision was substantiated by the space users' statements, who have stressed the windows draught issue, confirmed by the expert forensics on the ground. Instead of the wooden double frame, double sash (wide box) windows located on the façade of the oldest part of the building, and wooden, single frame, double-glazed windows in the additionally built part of the annex, wooden double-glazed low-E glass unit with krypton were proposed. In this was the authenticity of the building was preserved, through application of the wooden frame as in the original design, with the glass performance being significantly improved for this window to meet the current thermal requirements. Roof windows are of a later date. Quality elements of a prominent manufacturer were installed, that are in excellent condition, and thereby they were excluded from the energy refurbishment. This procedure helped improve the energy class F to energy class E, with the reduced energy consumption by 30% compared to the baseline situation. Obtained results are shown in tab. 4.

Second level of improvement is an upgrade to interventions performed in the previous step. Namely, besides replacing the windows, which was taken over from the first improvement level, the energy refurbishment was focused on the annex space (not visible from the street), having neither the stylistic plastics, nor artificial stone on its façade. This enabled interventions on the external part of the structures. The annex walls were insulated with the 15 cm thick stone wool, with façade rendering finishing. Additionally, the interventions included the flat roof above the top annex floor, presently insulated with the 5 cm thick thermal insulation. In scope of this level of improvement, the existing bituminous hydro-insulation of the flat roof was upgraded by the 20 cm stone wool thermal insulation, and new synthetic hydro-insulation membrane. This level of improvement slightly contributed to reduced energy consumption in comparison to the previous intervention (only 2%). However, this was sufficient to improve the energy class (from E to D class). The proposed energy refurbishment was focused on the single segment of the building, *i. e.* the annex, which is spatially separated from the street exposed corpses, thus affecting improvements in the energy performance in this part of the building only, while the remaining spaces were included in the next step. Obtained results are shown in tab. 4.

The third level of improvement includes proposed energy refurbishment architectural and civil engineering measures further contributing to additional increase in the building's energy efficiency, aiming to reach the energy class C. Wooden windows of the exquisite thermal properties were installed, with triple-glazed, low-E glass unit filled with krypton. Besides this, interventions were undertaken on all façade walls of the street exposed corpses, which were insulated on the interior side in order to preserve the authenticity, lavish the façade plastics and the protected status of the building as the culture monument. Stone wool 10 cm thick was applied, with the plasterboard covering. Having in mind large wall surfaces covered by this intervention, heating energy consumption was significantly reduced (by 58% against the baseline), thereby shifting the building to energy class C. Obtained results are shown in tab. 4.

Apart from the proposed measures, additional energy savings could be made by transforming the atrium of the building into a closed space. That kind of refurbishment could

Table 4. Building of the Serbian Government – energy balance

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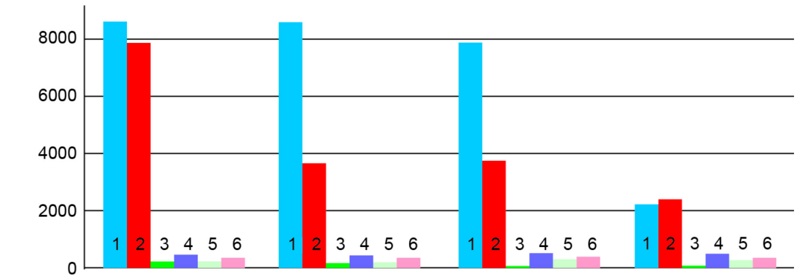
<tr><td rowspan="2">Heat loss through the thermal envelope [WK^{-1}]</td><td colspan="4">
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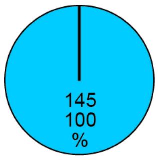
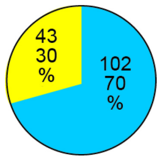
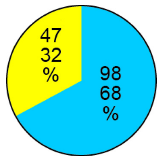
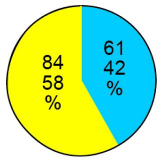
<tr><td>Specific heating energy demand per year [kWhm^{-2}a^{-1}] [%]</td><td>
</td><td>
</td><td>
</td><td>
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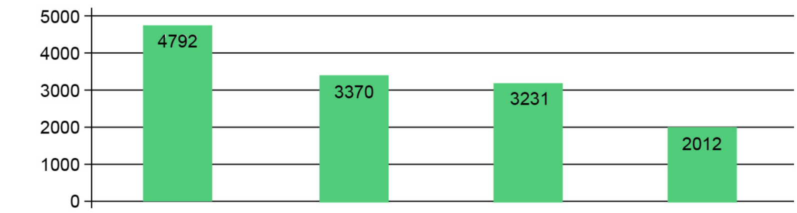
<tr><td>Primary energy [MWh]</td><td colspan="4">
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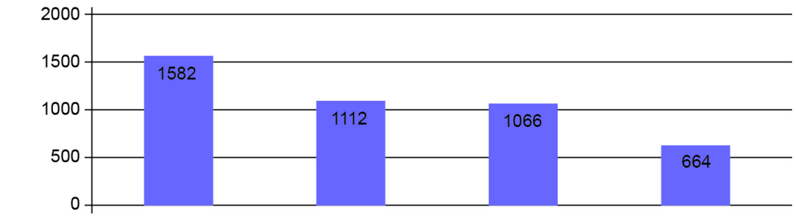
<tr><td>CO_2 emission [t]</td><td colspan="4">
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further improve the energy efficiency of the building, especially in terms of significant heating energy savings. Like National Assembly, building of the Serbian Government could also be energy refurbished by installing low-emissivity glass units on top of the atrium space. That intervention will convert open atrium into ventilation controllable space, which could be used to *operate* indoor climate, in terms of indoor temperature, ventilation needs, *etc.*

On the other hand, additional improvement measures can be made on pitched roof, by adding additional layer of thermal insulation into roof structure. Although roof part of the building was recently refurbished (after NATO bombing in 1999), when roof attic area was thermally insulated on the internal side, overall energy performance of the roof structure are beyond current standards requirements. Adding additional layer of thermal insulation between roof rafters can be easily done, resulting in overall energy balance improvement.

Palace of Serbia – improvement possibilities

The first level of improvement is focused on the glazed parts of the façade envelope representing the major heat loss sources. Replacement of the existing windows and façade doors would not jeopardize the protected building status, with the overall energy performance being significantly improved. In this respect, installation of new aluminum windows and doors with thermal breaks was proposed, with double-glazed, low-E glass unit filled with krypton. In this way, heat losses in the segment of windows and doors were reduced by 50%, with the building being upgraded from F to D energy class, accompanied by the reduction in the total heating energy demand by 39% annually compared to the baseline situation.

Energy refurbishment of the transparent parts of the building did not take into account the glass lanterns and the dome in the central part of the building. Their glazing with the thermal insulation glass packages could additionally contribute to further reduction in the heating energy demand. However, this intervention would require dismantling the inner interior finishing of exceptional artistic value, of primary concern for the overall appearance of the building. Obtained results are shown in tab. 5.

The second level of improvement, in addition to the windows' replacement, encompassed the floor structures, bordering external or internal non-heated areas. Flat roofs were insulated by removing the final coverings (gravel and concrete tiles), with the 15 cm stone wool covered with a new synthetic hydro-insulation membrane. In addition, floor structures above the passages (gangways-pedestrian bridges and a part above the central front corpse) were insulated with the 8 cm stone wool, with the suspended ceilings being installed. Reed ceilings were removed from the ceiling between the basement and ground level. The structure is insulated with 10 cm thick stone wool layer, and a new plasterboard ceiling being installed. Although these procedures did not improve the energy class of the building, heating energy demand was reduced by an additional 6% in comparison to the previous improvement level. Obtained results are shown in tab. 5.

Although the external walls' heat losses are much higher than in floor structures, their energy refurbishment would require either dismantling facade stone panels, or interventions on the internal side which is limited by the representative interior finishing, taking up the large part of the interior walls' surfaces.

The third level of improvement aims for the maximum level of energy efficiency increase, targeting at achieving the energy class C. Envisaged was the installation of high-performance aluminum windows namely: frames with thermal breaks and low-E glass unit with krypton filling. Floor structures were insulated same as in the previous procedure (level 2), with additional insulation of suspended ceilings surrounding the lanterns. Moreover, aiming to achieve the higher energy class, façade parapet walls, without a special interior finishing, were insulated, without threatening the protected status of the building. Stone wool 10 cm thick was installed on the interior part of the walls, with the plasterboard covering. In order to avoid damages to the interior wall finishing, a special refurbishment measure was applied reflecting in filling of the hollow spaces in specific façade walls by blowing-in the thermal insulation granules or threads. These measures have raised the building to energy class C with achieving energy savings of 56% compared to the baseline situation. Obtained results are shown in tab. 5.

It is to be noted that the building allows broad application of the alternative energy sources (photovoltaic panels and geothermal energy), although according to the valid legislation, their application does not affect the energy class of the building.

Table 5. The Palace of Serbia – energy balance

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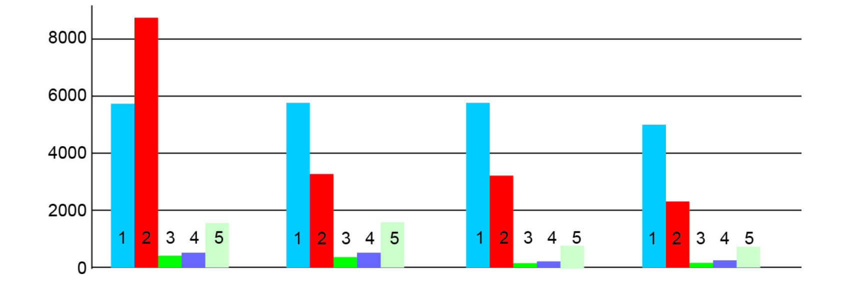
<tr><td rowspan="2">Heat loss through the thermal envelope [WK^{-1}]</td><td colspan="4">
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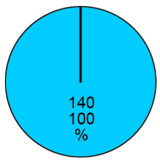
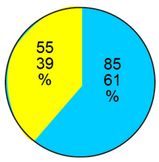
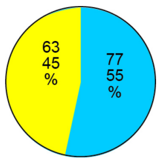
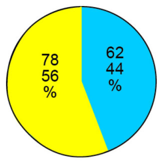
<tr><td>Specific heating energy demand per year [kWhm^{-2}a^{-1}] [%]</td><td>
</td><td>
</td><td>
</td><td>
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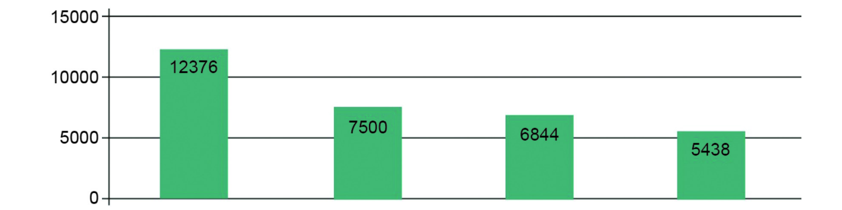
<tr><td>Primary energy [MWh]</td><td colspan="4">
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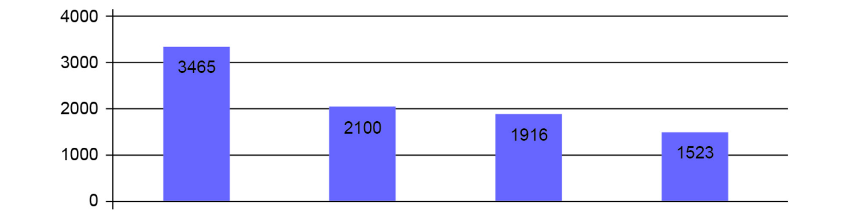
<tr><td>CO_2 emission [t]</td><td colspan="4">
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Conclusions

In spite of significant cultural values and protected status of selected buildings, conducted research indicates numerous possibilities for improving their energy performance and environmental impact, by reducing energy demand and CO_2 emission. Having in mind that they are all built long before thermal protection regulation enforcement, overall absence of thermal insulation layer is found very suitable. 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. It should be noted that greatest share in energy savings are made by replacing the windows and external doors, which was common in the first level of improvement for all three buildings. Due to great restriction issues of analyzed building, both on internal and external side of thermal envelope, this turns out to be the first choice when selecting energy improvement measures.

Proposing windows and external doors replacement for National Assembly building, as well as for The Palace of Serbia, heating energy demand was reduced by almost 40% already in the first level of improvement. Similar thing happens with Building of the Serbian Government, where reduction of 30% was reached with the same measures. This fact is found very important, because we can expect generous improvement only by improving one or two building elements. Second and third level of improvement made additional energy savings on all three buildings by adding thermal insulation layer. Thermal envelope elements like façade walls (on the interior side), flat roofs, ceilings and floors to unheated areas, are improved by adding thermal insulation up to 20 cm thickness. Energy refurbishment of those elements lead to additional reduction of up to 20% of energy demand, which was found very successful, concerning stringent cultural protection status of selected buildings.

Finally, although proposed energy refurbishment measures results in significant reduction of energy demand, 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. However, it has to be noted that this type of buildings has to be approached separately, since their specific architectural and technical features, along with specific heritage status are of great importance when selecting possible options for energy refurbishment.

Nomenclature

$QH_{,nd}$ – specific heating energy demand per year, [$\mathrm{kWhm^{-2}a^{-1}}$]
U-values – thermal transmittance value, [$\mathrm{Wm^{-2}K^{-1}}$]

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