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# Renovation of existing glass facade in order to implement energy efficiency and media facade

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## Abstract

Modern cities and their architectural structures undergo significant functional and physical changes. In recent years, the interventions on building envelopes have increased. Therefore, it is necessary to analyze potential remodeling of glass facades, along with applying the concept of smart technologies, in order to increase energy efficiency of the existing buildings. This paper analyzes the modernization process of devastated glass façade of the tall Slavija hotel, built in 1960s in Belgrade, Serbia, taking into consideration some positive examples of transformation and reskinning of buildings, where the aspect of medialization is an active part of urban renewal. The subject of this paper is the analysis of research findings about the improved thermal comfort of this building, after performing the replacement of its glass façade and converting the hotel building into a office building. Special attention was paid to the implementation of media technologies and final effects on energy balance of the newly designed facade.

The proposed solution is supposed to evaluate the improved thermal comfort that was achieved by a radical renovation of the facade and by replacing the existing facade with a new single façade (double and triple glazed units), with media elements as well as without them. The research results are presented as proposals for improving EE public buildings by implementing the latest system of curtain walls in order to increase the value of the buildings. One of the most important criteria included in the process of energy refurbishment is technological improvement of the existing buildings, along with the presentation of media facades. The case study is based on EnergyPlus simulations.

**Keywords:** media technologies, façade modernization, energy efficiency increase, energy refurbishment, energy simulation

## 1. Introduction

Reduction of energy requirements for heating, cooling and lighting is the key indicator of a city's energy consumption and environmental protection.

This led to demanding design and construction requirements and standards for new buildings, along with holistic transformation of the old buildings. Facade remodeling is one of major element in transforming the appearance of old structures, in order to improve the level of attractiveness, change their function and/or add completely new values. The topic of this paper is the analysis of the most effective ways for increasing energy efficiency of glass facades, illustrated by the example of the tall landmark structure, built 1960s in Belgrade. The process of facade medialization is supposed to enable the building to replace its static quality with a more dynamic medium. The main objective is to transform the existing structure and its facade into an interactive urban media architecture space, the one that stimulates cognitive and perceptive abilities of beholders.

The basic hypothesis of this paper is that building envelope restoration, carried out in accordance with adequate energy efficiency standards, leads to the planned reduction in energy consumption, preservation of original appearance, incorporation of new technologies into the facade system and a more intensified presence of the building in its urban surroundings, without negatively affecting energy balance of the building itself. The research objectives:

- provide adequate solutions for building envelope refurbishment,
- find out whether or not the functional change of existing structures affects energy performance certification and whether or not the glass facade modernization is able to meet the most demanding and complex Energy efficiency requirements,
- find out whether or not the building integration abilities of media elements included in glass facade modernization affect energy consumption,
- define what construction measures are to be carried out in glass facade restorations, in order to increase energy efficiency.

Refurbishment methods for building envelope systems include: modernization of the existing glass facade in order to meet the following requirements (enhanced thermal insulation, solar protection, safety, sound protection), refurbishment of other building envelope elements (roof, overhang space, wall facade parts), application of media elements to the south-west glass facade.

Energy consumption calculation was applied to estimate the improved building envelope model and the values showed that the overall energy consumption for heating the primary part of the building would be reduced from 115.37 kWh/m<sup>2</sup> to 26.52 kWh/m<sup>2</sup>, which means that energy consumption decreased by 77 %, representing a good result leading to decreasing negative effects of global warming.

## 2. Literature review

"Energy efficiency is the balance between heat loss and solar heat gain" [1].

Climate changes, reduced energy consumption and compliance with the latest energy efficiency requirements are inevitable issues of refurbishment process. Pursue deep renovation as part of normal building refurbishment, initiated with incentives with the goal of 75% to 80% reduction in energy consumption [2]. "Deep renovation is considered here to mean refurbishment that reduces energy consumption and limits energy consumption for heating, cooling, ventilation, hot water and lighting to 60 kWh/m<sup>2</sup>/yr." (GBPN, 2013) [3].

Different dynamics of improving the energy efficiency of historic buildings in Europe depends on location and significance of the building itself. The importance of speeding it up is indisputable. About 1% of buildings are renovated each year (BPIE, 2011)<sup>1</sup>, but the overwhelming majority of these renovations do not lead to deep energy-use reduction. Policy makers should also aim to double the renovation rate to at least 2% per year (IEA model assumptions); many organizations are calling for an increase to 3% per year (European Voice, 2013). The European Union has already instituted requirements for a public building renovation rate of 3% per year (EU, 2012) [2].

In 2013 the International Energy Agency (IEA) defined the scope of its mission regarding the transition to sustainable buildings: high levels of insulation in walls and roofs, high-performance windows with low thermal transmittance and appropriate solar heat gain coefficients, highly reflective surfaces in hot climates, controlled ventilation and thermal bridges neutralization.

The buildings from 1950s, 1960s and 1970s still occupy the major part of building stock in Serbia and Europe. Also, they are the biggest energy consumers – the calculated energy consumption is five to six times higher than the energy consumption values of the buildings built in accordance with the current energy efficiency requirements [2]. The structures with glass facades are regarded as specific problems to be dealt with. The buildings of the 1970s usually have low cultural values, but in specific cases they can be landmark structures that add significant value to their cities. Given the physical nature of the built environment, visual dominance is crucial, just like K. Lynch provides a definition for *landmark* (1960). Tall structures - significant landmarks that visually shape the silhouette of their city, are seen as priorities of urban and energy transformation. According to Jana Temelova [4], significant architectural structures of a city are employed in external marketing and promotion of a city identity. Modern materials, advanced technologies and distinctive shapes of buildings make them noticed and recognized within different groups (local residents, tourists, etc.).

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<sup>1</sup> BPIE (Building Performance Institute Europe) (2013), *Implementing the Cost-Optimal Methodology in EU Countries, Lessons Learned from Three Case Studies*, BPIE, Brussels, [http://bpie.eu/cost\\_optimal\\_methodology.html](http://bpie.eu/cost_optimal_methodology.html).  
BPIE (2011), *Europe's Buildings Under the Microscope – A Country-by-Country Review of the Energy Performance of Buildings*, BPIE, Brussels.

According to some authors [5], restoration of old buildings is more complex than new construction and the design of a new building, considering a number of requirements and standards that are to be met, not only in terms of energy efficiency but also in terms of fire protection, static stability and functional values.

The facade of a building is a crucial segment of refurbishment of the existing building. ” *The objective of retrofitting actions is to optimize the energy performance of the building, while maintaining thermal and visual comfort as well as acceptable air quality for the occupants* ”[6]. Stephan Messner [5] sees the process of facade modernization as a possibility to achieve the following goals: meet the current energy efficiency standards, reduce the overall energy consumption, reduce CO<sub>2</sub> emission, improve comfort conditions (thermal, visual, air, sound and light comfort), change the function of a building and maximize the value of investment.

However, it is not the only prerequisite. There are many other causes: the owner's changed requirements regarding the comfort issues; physical and visual disrepair; changes in the function of a building; incorporation of new technologies into facade systems, in accordance with changes in urban and global context and strengthening the visual presence of the building itself within its urban surroundings.

Restoration and adaptation of building envelopes, as reuse methods, have been widely used to increase architectural, functional and economic potentials as well as to improve energy efficiency, as optimization techniques. Certain authors [7] state that adaptive reuse of old buildings and changes in the function of buildings need to be in balance between the surrounding changes and preservation of buildings, in accordance with the current trend development. Urban areas can transform themselves into new areas by revitalizing dilapidated and neglected parts, thus offering new functions to the city itself. Not only is there a need for a functional design, but also for intensified visual presence of existing structures, which can be accomplished by facade modernization.

After several decades, some buildings undergo significant changes – completely different surrounding, along with increased external noise due to intensified traffic. Therefore, various possibilities are to be considered in order to improve sound comfort in buildings.

According to Marradi and Overend [8], the extent of facade modification depends on the following:

- the significance of the existing building – it has to be determined if it is a historic or local landmark,
- categories, extent and scope of construction works (selective reconstruction, recladding, overglazing).

Marradi and Overend divide the existing structures into the following categories: architectural monuments, listed buildings, the existing structures of minor historic values. The previous classification is important for: preservation of the existing facade style, dimensions of profiles and glass types (light transmission, reflection and color).

In a selective reconstruction, only the glass panes that are defective would be removed and replaced with identical or similar ones. Recladding is the removal of an existing curtain wall system and replacing it with a new one, due to

"water/moisture damage, upgrade or replacement of improperly installed system". Overcladding is the installation of a completely new facade system, but the original one is left in place [8].

The main problem in relation to the structures and glass facades, designed and built in the previously mentioned period, is the application of outdated systems consisting of metal profiles without thermal breaks and of thermal insulating glass with poor thermal performance. The current capacities have been significantly improved. It includes metal profiles equipped with thermal breaks, improved performance and new generations of low-e glass, with or without noble gas. In accordance with the current EE standards, the following thermal performance is required: glass  $U_g \leq 1.1 \text{ W/m}^2 \text{ K}$ , aluminum profile  $U_f \leq 1.8 \text{ W/m}^2 \text{ K}$  [2].

Marradi and Overend [8] noticed the absence of legal obligations at the level of the European framework for monitoring and control of building envelope for designing tall buildings (over six floors), and presented some useful American architectural experience. The restoration of building envelopes made of glass can facilitate the illustration of the process map of the facade design and construction process of glass facade renovations, in order to "provide an overview on design process, the related main issues and best practice" [5]. The map suggested by the authors represents an extended algorithm that had previously been provided by Voss and Overend [5].

According to some authors [9], renovation of the glass elements included in the facade cladding system enables the following possibilities:

- replacement of the existing windows with the new ones, which have better thermal capacities, with or without improving the thermal characteristics of the whole facade parts,
- transformation of the window strip facades into glass facades,
- replacement of the existing glass facade with a new, single skin glass facade,
- transforming the existing glass facade into a double skin facade,
- modernization achieved by installing the brise solei solar shading system, automatically controlled,
- integration of photovoltaic modules into elements of single skin or double skin glass facade.

Generally speaking, renovation of glass facade is achieved by replacing the existing elements with new ones, which are characterized by: improved physical, mechanical, chemical and visual qualities of glass; improved thermal and visual facade framing; improved mechanical and visual qualities of solar shading systems; implementation of the smart control system integrated with the control system for glass cladding; integration of passive or active ventilation, heating, artificial lighting, solar protection and safety systems into the facade system.

Marradi and Overend [8] think that the renovation of glass facades is a complex process that consists of a few different aspects – statics of structural supports, building service, building physics and architecture, i.e. design. When it comes to the process of glass facade modernization, the main issue to be dealt with is the existing original structure and

appearance of the facade itself – whether to keep it or change it.

Media facades are often included in the so-called re-skinning methods. Along with the energy refurbishment it is possible to develop the social sphere and increase the aesthetic quality of structures by applying smart technologies of media architecture [10]. Therefore, it is very important to choose an adequate media facade technology, in accordance with a multiple criteria evaluation, especially focusing on energy efficiency aspect.

There are only few case studies of media facades in literature, and they mostly deal with a framework for designing media facades [10] [11]. Therefore, it is important to analyse the way in which media facades affect the energy consumption for a building as well as the solar loads of a facade during summer and winter periods, and it also has to be pointed out that there is an evident lack of similar investigations.

There are numerous useful and motivational cases of restoration, transformation and reconstruction of building envelopes, the ones where the aspect of medialization was an active aspect of urban renewal, such as *City Hall*, Hong Kong, 1956, arch. A. Fitch, *Nexus Building*, Hong Kong, AEDAS, arch. R. Phillip or University of Technology in Sidney (UTS), arch. C. Bosse.

Energy losses are one of the major challenges in LED lighting and design of laminated glass [12] for media facades. Energy losses increase when current is increased or the surface path in coating is decreased. In conjunction with Glassiled, AGC offers a new range of power supply units, that are able to deliver voltages between 36V DC and 160V DC to power LEDs through the coating. Such radical reduction of losses in coating is achieved by this new, safe and certified technology. Applications with high-power LEDs are also enabled. A transparent conductive coating, which consists of a thin layer of metallic oxide or metal deposited on one of the glasses or on a flexible film, is used to power LEDs.

Controlling all individual LED power sources is the main prerequisite for video displays. Each glazing unit in the facade is a fully-fledged video display. The power consumption of the entire system is 100 watts/m<sup>2</sup> maximum (and typically about 35 watts/m<sup>2</sup> in practice), depending on the resolution and content of the displayed images [13].

A thorough analysis of energy demands is calculated on the basis of the studies containing energy simulations estimating total annual consumption. The current literature contains a great number of research papers on energy simulations in hot and wet climate. The researches conducted in moderate continental climate in Europe are important for this paper. There are some case studies on energy optimization of office buildings in Europe [6] [14] [15] [16] [17].

As for the case studies realized in Serbia, there is a case study on energy efficiency optimization and cost optimal solutions for a office building [15]. The author points out the significance of cooling demands in relation to total energy consumption. Since the climate in Belgrade is known for its hot summers, the author writes about the importance of glazing types, shading, and points out that the lack of shading in cost optimal solutions implies close to minimal

window-to-wall ratio on the south facade as well as significantly large window-to wall ratio on the north facade. The findings of the same case study reveal that cost-optimal glazing is achieved by the windows with lower U value and medium solar heat gain coefficient.

Current researches on solar design in Serbia [18] mainly suggest the design of large windows on the southern façade with exterior shading, small windows on the northern façade and the use of thermal mass. As for the case studies on retrofitting in Serbia, Todorović [19] favors a holistic approach.

Boyano et al. [14] points out thicker thermal insulation is suitable for cold and moderate climate zones. As for warmer climate zones, thermal insulation should be designed with great care since heat gains are not easily released from a well-insulated building. The same author suggests four solutions for increasing energy efficiency of a building: energy saving by light control systems, windows replacement, better insulation of other cladding element, optimal orientation of a building. Windows replacement has two benefits: heat loss decreases and reduction of energy requirements for heating during the heating season (solar heat gains).

The authors [16] present their findings revealing that the orientation of a building does not significantly affect energy consumption if the building has two identical longitudinal and lateral facades. Low thermal transmittance values are crucial for heating energy demands and total energy consumption. A great percentage of glazed surfaces does not necessarily mean the reduction of energy requirements for illumination. The glare issues negatively affect the quality of visual comfort. Therefore, solar control systems must be implemented in buildings with large glazed surface. " *The further to the inside the shading is placed, the poorer it reduced solar gains and thereby the higher the cooling demand is*". Low thermal transmittance of windows is significant for heating demands but irrelevant for cooling demands. Low g-value (solar factor) is crucial for cooling demands. According to the same authors, unlike the cell type, the open plan increases cooling demands and decreases heating demands.

Eskin and Türkmen [17] investigated the impact of double and triple glazed low-E glass on total energy consumption in a building and confirmed that shading coefficient has linear impact on energy requirements.

Dasclaki and Santamouris [6] have analyzed the energy demands of office buildings, classified into five categories in retrofitting procedures. The investigated building included in this study belongs to category D (Free standing/light structure/skin dependent/open plan). " *These buildings have significant solar gains, which also means increased cooling demands in summers. This type has little or no shading from surroundings*". Total annual energy consumption is from 183 kWh/m<sup>2</sup> in the Southern Mediterranean climate to 307 kWh/m<sup>2</sup> in the North Coastal climate. Distribution of energy requirements: -67 % for heating, 23 % for cooling and 10% for illumination. According to these authors, retrofitting strategies include several scenarios: improvement of building envelope, use of passive systems (solar gain in winters and reduction of solar penetration in summers), optimization of illumination system, maximum use of



daylight, improvement of cooling, heating and ventilation systems. Effective retrofitting means energy saving from 47% in Mediterranean climate to 77% in North Coastal climate.

Based on the studies on energy saving potentials, some authors [14] point out the importance of energy savings potentials (18-36%) for lighting by replacing conventional lamps with more energy efficiency or by lighting control. Reinhart and Wienold [20] defined a well illuminated space – qualitative and quantities aspects of a well illuminated space must also be taken into consideration when dealing with disruptive thermal comfort and total energy requirements for the entire building. Franayetti et al. [21] emphasize the fact that lighting consumption in office buildings accounts for 30% and in the best-case scenario, it could result in a reduction of 65 % by using energy saving lighting system. This could be of crucial importance, especially in relation to the impact on HVAC system.

The case studies on Double Skin Facade (DSF), as one of potential alternatives in modernization of glass facades in moderate climate conditions of surrounding countries of Serbia, e.g. Hungary [22], confirm that outdoor curtain mode DSFs could lead to the reduction of energy consumption in comparison to alternative solutions of single skin facades, but the reduction percentage is not significant. On sunny days in the winter period, the daily heat balance is only positive for south-oriented facades. Also, various experimental analyses showed that during short, extreme seasonal periods (high external temperatures, intensive solar radiation, strong winds) energy consumption could increase [23]. Taking into consideration previous researches and significant initial investments, DSFs were not included in further analyses in this paper.

### **3. Methodology**

#### 3.1. Methods

This paper contains the following research methods:

- in-situ observation – on site analysis of the structure,
- analysis of the Project Documentation,
- case- study as the research method used for reconstruction and energy refurbishment of the Hotel Slavija,
- structural analysis for testing the stability of glass (using the calculation program *AGC calculator*)
- building 3D modeling in OpenStudio u okviru SketchUp,
- software energy simulatin (BES) of the current situation and newly designed model in EnergyPlus,
- data analysis and findings,
- analysis of improvement potentials that are to be achieved by various construction methods.

The performed in-situ observation led to the following findings:

- the presence of cold perimeter structures, roofs and floors and the lack of thermal insulation in these areas, or poor thermal insulation caused numerous deformations due to harmful effects of condensation in structural elements and overheating in the summer;
- defected structural components, dampness and mold growth are the result of harmful effects of condensation. Not only does condensation reduce the life span of the building, it also endangers the lives of its occupants by causing mold and allergens.

The software package that was used in this research for the purpose of evaluating building physics, is based on the following directives: The 2011 Energy Performance of Buildings Directive [24] and The 2011 Rulebook on the conditions, content and manner of issuance of certificates of energy performance of buildings [25] in compliance with the European energy efficiency standards and requirements<sup>2</sup>.

An **EnergyPlus** Version 8.7.0-78a111df4a, simulation program was used for modeling. EnergyPlus is a modular software tool linked to ANSI/ASHRE Standards. The objective of simulations is comparative analysis of current conditions and new design solutions for improved building envelopes, along with repurposing of a building. The software is used for predicting heating/cooling loads, total energy consumption, thermal comfort, lighting consumption, in accordance with alternative use of buildings. Also, Energy Simulator enables 3D geometrical modeling as well as additional modeling potentials: selection of materials properties and characteristics, climate conditions, cooling and heating temperature parameters, building occupancy arrangement, lighting operational schedule, use of household appliances, etc.

The evaluation of the energy performance of the Hotel Slavija was carried out by comparing the calculated values of total energy consumption in three cases:

- current condition, prior to reconstruction (Fig. 1. a, b),
- proposed new design - Solution 1,
- proposed new design - Solution 2.

This research deals with a sixteen-story hotel tower, as a technical – technological and functional structure and heated area. It is separated from the lower floor by unheated crawl space.

It should be pointed out that the proposal includes the improvements to the entire building envelope (facade, flat roof, overhang space, floors toward the unheated technical area), enhancement HVAC system efficiency and lighting improvements. Total building area is 8251.93 m<sup>2</sup>, net conditioned building area is 7351.91 m<sup>2</sup>. The shape factor of the

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<sup>2</sup> Energy Performance of Building Directive – EPBD No 2002/91/EC - Directive of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings [26], Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast) [27].

building is 0.22 m<sup>-1</sup>. Values gathered over 8760.00 hour.

### 3.2. Weather data

The climate in Belgrade (44°49'N, 20°27'E) is moderate continental, with mild transitions between seasons. Due to global warming, there is no transitions between the seasons. Summers are getting warmer and winters are getting colder. The number of heating degree days (HDD) in Belgrade is 175. The climate data included in the analysis are for Belgrade and TMY (typical meteorological year) for dynamic simulations (dynamic study on building performance). External temperatures and wind speed for sizing period days are presented in Table 1.

## 4. Case study- The hotel Slavija, Belgrade

4.1. Based on the comparative analysis of several strategic development projects in Belgrade, it is evident that a much intensive promotion of Belgrade cultural identity is necessary, as well as the regeneration of the main transport nodes within the public space in order to revitalize the existing units, and restoration of capital landmark structures along with the modernization or repurposing of the existing city hotels.

Urban renewal led to recognizing the need for revitalizing one of the most important tall buildings of Belgrade urban matrix – the Hotel Slavija located at Slavija Square. It would be the revival of an old but still outstanding structure achieved by energy refurbishment and changeable facade.

The Hotel Slavija, the subject of this study, is one of the three major structures – towers at the very center of the Serbian capital city – Belgrade. The Slavija square can be reached by seven different routes. It is located at the intersection of the Belgrade diagonale of the main urban route Kalemegdan-Plato, the Temple of Saint Sava, and another important area between the Temple of Saint Sava and the bank of the river Sava (future *Belgrade Waterfront*), along Nemanjina street (Fig. 1).

The hotel was built in the 1960s and designed by architect Bogdan Ignjatović. This state-owned hotel is in the middle of the restructuring process. As soon as it is taken over by a strategic partner, it will undergo significant structural changes. At the moment, the south-west facade is both functionally and visually disturbed by enormous commercial billboards.

The proposed building was chosen to be the model for implementing the latest technologies through media facades, in accordance with the following criteria:

- location near important city areas, visual dominance;
- technical modernization of decades-old buildings' facades, incorporation of new technologies into facade systems, in accordance with urban and global changes;

- the Hotel Slavija is surrounded with numerous office buildings; however, since these buildings are relatively far away from the hotel itself, it is possible to present media contents properly, without negatively affecting any surrounding building by excessive lighting;
- evident aggressive marketing, the so-called "visual pollution" of urban space, and facade designs that are not in harmony with buildings themselves,
- roundabouts – since they prolong the perception of media contents.

#### 4.2. Description of building

It is a pronouncedly vertically designed building – 18 floors with glazed facades. The building consists of two basement levels, a ground floor, a mezzanine, a crawl space, 16 hotel floors and one attic. There is a terrace on the ground floor, oriented toward the square [28].

Approximate dimension of the foundations is 28.90 m x 16.25 m. There are two wings with hotel rooms (single and double rooms) along the facade walls and at the center of vertical communication (stairs and elevators) (Fig. 2).

The building was designed and built as a reinforced concrete skeleton structure, 5.70m x 5.05m raster (two external tracts) and 5.75m x 5.75m raster (tract is in the middle). Standard story height is 3.10 m.

The existing facade is the combination of the curtain wall and full parts without openings, with mosaic tiles as the finish coat. The glass facade is made of anodized aluminum profiles, and is vertically divided into windows (177 cm) and parapet line (88+15 cm). The surface of the facade is 85 cm wide. The windows of the hotel rooms are the same size. They are fixed or they open around the horizontal axis, with venetian blind systems. Parapets with thermal insulation and non-transparent safety glass are external to the wall.<sup>3</sup> The part of the facade covered in canvas wall art is made of giter blocks, 20 cm thick, with mosaic tiles 2/2 cm.

The roof is flat, passable around the elevator core. The Hotel Slavija has its own boiler-room and radiator heating system fueled by oil. Set point is 21°C. Cooling of the ground and first floor requires the chiller plant with an air-cooled chiller. The tower of the building does not have its own cooling system. Hot water is provided by oil heating and 60 kW solar power.

Spatial 3 D model of the building is presented in Fig.3.

#### **Fig. 3. 3 - Model**

#### 4.3. Refurbishment objectives

The following structural and functional imperfections were identified: insufficient floor height, position of the columns

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<sup>3</sup> Source: Technical report of the Project

and reinforced concrete walls that limit the recommended width of vertical and horizontal communications. Since it is not possible to have the expected category of hotel contents, the process of reconstruction requires repurposing of the building. The proposed changes will convert the existing building into an office building (proposed new design 1 and 2), having an open space office on each floor. The building envelope is planned to undergo a complete modernization. The process of building envelope renovation should bring an appropriate balance between architectural, commercial and cultural requirements, and preservation of original values of the building itself, in order to optimize energy efficiency and implement media facade elements.

The facade modernization strives to achieve the following goals:

- to create landmark and urban identity through media architecture of the building,
- to create attractive elements of urban space,
- to meet both private and public requirements by presenting important and useful contents and events (culture events, promoting city tourism, public service, etc.) and brand marketing,
- comfort improvements (thermal, visual, air, sound and light<sup>4</sup>),
- heat loss reduction,
- implementation of cooling system in order to fight global warming,
- solar gain and glare effect management in urban space,
- strategies for increasing profits by facade advertising,
- improvements of aesthetic potentials of the building,
- strategies for increasing investment value of the building.

## 5. Results

### 5.1. Current condition

The most important features of current condition are presented in the following Table 2.

The Building Physics survey provided the calculation of thermal transmittance coefficient for all buildings. All potential positions of building envelope and its layers are presented in Table 10. The main indicator of poor performance of the existing glass facade is its  $U_w$  value of 3.25 W/m<sup>2</sup> K, which is far from the required value. These are the calculated values for other structures: flat roof- 1.56 W/m<sup>2</sup> K, masonry walls of the facade - 1.61 W/m<sup>2</sup> K.

Annual energy demands for the analyzed building are calculated per m<sup>2</sup> of the conditioned interior space of the existing building, as presented in Table 3.

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<sup>4</sup> Proposal for a criterion on 'daylight availability' for the EU Ecolabel for office buildings

Total energy consumption of the existing building is 230.68 kWh/m<sup>2</sup>. The Study on Energy Efficiency reveals that the total annual heat loss, is 555.28 kW, and specific annual heat demand is 115.37 kWh/m<sup>2</sup> (Table 10. and 11, the current condition). Based on energy simulation ("as design") this building fall into energy class "D" and does not meet the requirements of the Energy Performance of Building Directive.

## 5.2. Proposed new design – Solution 1

The first phase of modernization consists of analyzing all facade cladding elements in terms of performed changes: replacement of glass facade, improvement of thermal insulation of flat roof and walls. Insulation thickness meets the Serbian regulatory standards.

The design of this model implies the optimized cooling/heating systems (Ideal Loads Air System), along with a partial lighting control system (50 % activity). The main features are presented in Table 4.

The most significant change is replacement of glass façade with a new one. The main criteria used in selecting a new facade: panel dimension (2.8x0.85 and 1.77x0.85m), as transparent effect as possible (LT >50%), low light-reflection range, middle solar factor (≤40%), proper thermal performance of glass (U≤1.1 W/m<sup>2</sup> K) and aluminum structure (≤ 1.8 W/m<sup>2</sup> K), safety (the height of the last floor 54.15 m), proper acoustic performances (Rw minimum 35 dB).

Structural analysis for testing the stability of glass (using the calculation program *AGC calculator* version 2.0-01/2005) indicates that the following thermal insulation glass systems meet the minimum requirements: 6mm+6mm, 8mm+6mm, 6mm+Lami44 and Lami33+Lami55. Laminated glass should be installed as external glass. Since the glass 6mm+16mm+6mm does not meet the acoustic requirements, it is eliminated. The glass 8mm+16mm+6mm provides the acoustic protection of 38 dB, and the glass 6mm+15mm+44.1<sup>5</sup> provides the insulation protection of 41dB. The PVB laminated glass provides the best results and options.

Since the solar control is more important in summer conditions and thermal insulation performance is better in winter conditions, with lower U coefficient, it requires double glazing and solar control glass with low E film on position 2 in order to reduce solar radiation in summers. Visual aspects, low light reflection (LR) and neutral appearance do not permit the use of coating for the position. The interspace is 90% filled with a noble gas – argon (90/100)<sup>6</sup>.

Solar and other performances of potential installations are presented in Table 5 (based on the software Calumen SGG and AGC Glass Configurator<sup>7</sup>).

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<sup>5</sup> Double glazing unit with laminated PVB: glass tickness (mm)+cavity width (mm)+ laminated glass with PVB film. For example structure 44.1 = laminated glass 2x4 mm panes of glass separated by 1 PVB (~0.38mm PVB film)

<sup>6</sup> Argon gas is commonly used and is affordable. Krypton gas performs better but is expensive and generally not cost-effective in locations with moderate energy prices. Research is under way to reduce its extraction cost. Different inert gases have different minimum glass glaze gap width for optimal reduction of convection (Selkowitz, 2012).

<sup>7</sup> The data are calculated using spectral measurements that are conform to standards EN 410, ISO 9050 (1990) and WIS/WINDAT. The U<sub>g</sub>-value is calculated according to standard EN 673. The emissivity measurement complies with standards EN 673 (Annex A) and EN 12898.

The calculation of the proposed reconstruction design implies the implementation of double glazing windows and low-emissivity glass (6mm+16mm+44.2) filled with argon,  $U_g=1.0 \text{ W/m}^2 \text{ K}$ . The aluminum structure consists of the improved profiles for optimal sealing, air tightness, maximum class 4 (EN 12 207) and wind resistance capacity of Class C4/B4 (EN 12 210), in accordance with the height of the building.

The overall thermal transmittance coefficient of the facade is  $U_w=1.356 \text{ W/m}^2 \text{ K}$  (in accordance with EN 10 077). The adopted coefficient value for thermal transmittance in aluminum structures is  $U_f=1.8 \text{ W/m}^2 \text{ K}$ , and the linear coefficient of warm edge spacer in insulated windows is  $\psi_g=0.06 \text{ W/m K}$ .

Solar protection systems are provided by aluminum interior venetian blinds. The windows are not openable.

Annual energy demands for heating, cooling and lighting, calculated per  $\text{m}^2$  of the conditioned space, are presented in Table 6. Improved inter-relationships are presented in Model 1a+, which is an optimized system of energy demands for lighting and equipment.

Based on specific annual heat demand  $Q_h$  ( $31.76 \text{ kWh/m}^2$ ) and if the building is converted into an office building, it will fall into the energy class B, meeting the requirements of Energy Performance of Buildings Directive, in the sector of commercial buildings (Table 11).

Further evaluation of energy performance, carried out in order to check the possibility of improving the proposed reconstruction, enabled the analysis of the designed facade with triple low-emissivity glass (44.2+16Ar+4+16Ar+33.2),  $U_g = 0.5 \text{ W/m}^2 \text{ K}$ , aluminum structure  $U_f=1.4 \text{ W/m}^2 \text{ K}$ , and the overall  $U_w=0.85 \text{ W/m}^2 \text{ K}$ . The analysis research revealed that the specific annual heat demand is  $Q_{h, nd} = 26.52 \text{ kWh/m}^2$ , which means that the building remains in energy class B, in accordance with the Energy Performance of Building Directive for commercial buildings (Table 11).

Annual energy demands for heating, cooling and lighting, calculated per  $\text{m}^2$  of the conditioned space, are presented in Table 7. Improved inter-relationships are given in Model 1b+, which is an optimized system of energy consumption for lighting and equipment.

Monthly energy consumption for cooling and heating in newly designed models is presented in **Proposed new design- Solution 2 (media façade)**

The future scenario 2 includes the improvement presented as Solution 1, and suggests that the southwest facade, oriented toward Slavija square is to be converted into LED media façade.<sup>8</sup> The basic parameters of required-technologies of media facades are given in Table 8.

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<sup>8</sup> Considering the concept of media facade technology and on-site observation, the optimal perception distance is approximately 150 m, maximal perception distance is up to 2500 m and the angle of perception is  $75^\circ$ . Taking into consideration the calculated optimal perception distance (100-150 m), it can be concluded that the optimal perception of high-resolution facades requires that the distance between pixels should not exceed 50-75 mm.

Aside from the main function, LED strips technology, integrated into glazing unit, also provides an adequate and integrated solar protection. Therefore, it is regarded as a better solution.

Such media facade concept is a mixture of a low-resolution media facade and a higher-resolution facade oriented toward Slavija square, with an 18-hour operating mode, without negatively affecting the transparency and operating of the building. LED installation could be active during the day and night. The application of this technology enables the presentation of numerous visual contents, from videos to graphic contents. Such media facade design offers the presentation of much complex and different contents, unlike the current option of commercial contents only (Fig.5).

The energy demand for electronic media facade with double/triple glazed insulating glass (6+16+44)/, chosen in accordance with EN 410 and energy consumption of 100 W/m<sup>2</sup> is:

$$Q_{disp} = n \times P = 175 \times 18 \times 50 \text{ kW} = 157500 \text{ kWh/a,}$$

in which: n – number of operating hours of electronic media facade (175 days during the heating season+ 175 days during the cooling season, 18 hours a day)

P<sub>disp</sub> - el. power of media facade 50.0 kW (500 m<sup>2</sup> x 100 W/m<sup>2</sup>=50000 W=50.0 kW),

The implementation of the chosen technology of media elements, where the consumption ranges from 50 to 100 kW/m on the south-west facade (about 500m<sup>2</sup>), would increase the coefficient of specific annual heat demand, due to solar gain reductions.

The specific annual heat demand is Q<sub>h,nd</sub> = 32.25 kWh/m<sup>2</sup> (double glazed insulating glass), and Q<sub>h,nd</sub> = 26.97 kWh/m<sup>2</sup> (triple glazed insulating glass) including media elements during heating days.

The comparative view of the research findings, achieved by the method of calculation applied to the current condition of the Hotel Slavija, and the reconstruction and conversion into an office building (proposed new design) is presented in the Table 11. It is now possible to determine if and how much the proposed reconstruction is able to reduce the total annual energy consumption in the building, overall heat loss and specific annual heat demands, thus upgrading the energy class as well.

## 6. Discussion

In order to create a high-quality and optimal energy efficient building design, the process of modernization of glass tower Slavija hotel relies on the following criteria:



- location, orientation and form of the building,
- high level of thermal insulation for the entire building envelope, with the focus on avoiding thermal bridges,
- maximum solar gains in the winter period and protection from excessive solar exposure in summer.

The suggested scenarios imply the implementation of numerous measures in order to enhance energy efficiency of the building in order to enhance energy efficiency of the building, revitalize, reuse and visual intensity of a building located at the very heart of this significant urban area. Based on previously defined levels (Marradi) of glass envelope renovation, the proposed model belongs to the category of curtain wall recladding.

Total energy reduction, implementation of construction measures in order to change the envelop, optimization of HVAC system, implementation of cooling and light control system for 47% (new design 1a+) and for 46.3% (new design 1b+), can be defined as successful retrofitting scenarios, also in accordance with other results (Dascalaki and Santamouris). Comparison with other studies (Dascalaki and Santamouris-type D) shows that additional improvement measures can be performed (" global retrofit scenario"), primarily cooling, in order to achieve desired energy savings for office buildings – approximately 80 % of energy saving.

Based on the analysis of the research findings that were achieved through performed calculation and modeling, the authors reached the results and potential values in favor of energy saving, in relation to the glass building in Belgrade, which is of great significance for numerous similar 1960s buildings and their future energy refurbishment measures. The obtained results confirm the hypothesis regarding the planned energy reduction for heating of 72-77 %, which is carried out by implementing innovation systems, such as the integration of media facade elements into the building envelope. The specific annual heating energy demand for the existing building is 115.37 kWh/m<sup>2</sup> while for the reconstructed building with a double- glazed insulating glass would be 26.52 kWh/m<sup>2</sup>, (Table 10, case 2a), that is – 27.61 kWh/m<sup>2</sup> is the triple glazed glass is included in curtain walling.

The following results could be achieved, in comparison to the original design of the building, carried out in 1960s:

- the overall heat losses would be reduced by 57.18% (double glazed units), or by 65.75% (triple glazed units);
- the specific annual heat energy demand would be reduced by 72 %, (double glazed units), or by 77% (triple glazed units), in accordance with the recommended 75-80 %, provided by the European Agency for Energy;
- the existing building – the tower of the Hotel Slavija, falls into energy class D. It is possible to upgrade the current energy class to energy class B by carrying out the proposed reconstruction and converting the existing building into an office building. The glass should be double glazed, low-E (8+16+6), filled with 90% of argon ( $U_g=1.0 \text{ W/m}^2 \text{ K}$ ) and used in the curtain walling  $U_w = 1.35 \text{ W/m}^2 \text{ K}$ . In accordance with this model,

the building could upgrade its energy class for two energy classes, in comparison to the previous one (depending on the glass used for curtain walling), if the reuse measures are implemented, converting the building into an office building;

- the implementation of media facade elements on the south-west facade and a 15% shading system, which reduces the solar gains in winter months, the annual heating energy demand is increased by 1.55% (double glazed insulating glass), and by 1.72% (triple glazed insulating glass) and cannot be regarded as a significant improvement in relation to the entire building.

Significant energy savings for heating reveal positive effects of heat loss reduction achieved by envelope improvements. G-value is crucial for energy consumption for cooling, whereas heating energy depends on Uf coefficient. The suggested glass envelope replacement resulted in heat loss reduction and significant energy savings, which is consistent with other studies [14].

The analysis of the findings shows that there is a great compatibility with the results provided by other authors investigating the issues on energy efficiency of buildings in Serbia. It can be concluded that more energy savings could be achieved by further optimization of solar control in summers, which means higher solar factors (g-value).

Well-insulated building and lower U coefficient of its roof and other facade elements was not favorable for energy demands for cooling (especially during three the warmest months), which is in accordance with other studies [16].

Boyano's theory was confirmed in this way - heat gains in wamer climate regions cannot be easily released from well insulated buildings in summers.

Selection of triple glazed insulating glass does not significantly affect total annual energy consumption of the building, which is in accordance with the facts stated by Eskin and Türkmen, but it does reduce heating energy demand (implementation of double glazed insulating glass increases the heating energy consumption for 16.50 % in comparison to triple glazed glass).

In addition to this, the open plan increased energy consumption for cooling, which is in accordance with the facts provided by other authors [16].

Enormous glass surfaces do not necessarily have positive effects on energy demands for illumination, considering the energy percentage needed for lighting, which can also be found in various analyses conducted by other authors [16].

However, lighting improvements through energy saving systems can significantly reduce total energy demands for lighting for 32%, which reduces the percentage of energy demands for lighting for 5%, which is in accordance with the statements provided by Boyano at all.

Lighting system optimization significantly reduces energy demands for cooling, for 25%-double glazed units and 26%-triple glazed units, but it increases energy demands for heating for 32-34%.

The findings on total annual energy demands of existing building can be compared to D type of office buildings, as defined by Dascalaki and Santamouris, having the characteristics of Mediterranean and continental climate and significant energy demands for cooling. Additional retrofit improvements can be achieved by following the suggestions given by the mentioned authors.

In addition to thermal and visual comfort, another important criterion for selecting glass types within curtain walls is sound insulation, in accordance with the office buildings standards in urban environment and in accordance with the recommendations given by other investigators (Mesner).

Orientation of the building does not affect energy demands since the building is a simple, cubic structure.

The implemented media elements in the form of louvers between the glazed units, can be considered as fixed curtains. Such feature of the façade cladding affects three factors: daylight availability, visual comfort improvement and energy demands of a space depending on daylight utilization. Also, this system positively influences the light comfort control. Continuous reductions of LT% (do 85%) glass surfaces of the southwest media façade led to the reduction of heat losses in winter months, minor increase of energy demands for heating and reduction of energy demands for cooling in summers.

Based on the proposed design for improving a part of the Hotel Slavija, the authentic appearance was supposed to be preserved as much as possible (the type of the facade would be kept – a typical curtain wall, the authentic landmark of the past), thus preserving the symbol and ambiental value of Slavija square itself.

The implementation of media elements as well as the improvements of this landmark building, located in the middle of one of Belgrade squares, would certainly turn this square as well as the whole area of the city into a more attractive and appealing one. Since the office buildings is not open at night, active media facade would not disturb the users of the building at night. During the day, the light comfort would be provided by interior curtain systems.

The integration of media elements into the process of envelope reconstruction is a valuable and required element, according to other authors (Lefèvre, A.Fitch, R. Philips, C. Bosse). Current technologies provide enormous possibilities for both investors and local communities, without negatively affecting the energy balance of a building, which is in accordance with the already presented opinions of other authors (Lefevre). Although the LED technology, integrated into the system of multilayered/insulating glass, has been used for a long time, it could be increasingly used in the coming period if the energy loss issues in conductive transparent coatings are dealt with.

Based on the presented findings, the following energy efficiency measures are to be implemented, in order to achieve the planned energy refurbishment of the building with primarily glass facade:

- thermal insulation of the building envelope, whenever it is possible to be carried out,
- replacement of the glass curtain wall,

- heat loss reduction and solar gain management – enabled by adequate choice of glass,
- focus on the integrative approach to facade design through additional elements in curtain wall systems (media elements), which represents an additional function of facades,
- thermal insulation of the floor structure toward the unheated crawl space and the flat roof layers,
- new heating and cooling systems,
- energy demand management.

All the presented construction methods aim to increase the level of energy performance to at least one higher energy efficiency class, in accordance with thermal regulations. This study proved that it is possible and achievable to carry out the improvements to the existing building by increasing the level of its energy efficiency for three energy classes, in accordance with the current regulations on energy performance.

## **Conclusion**

The analysis of the potential for renovating glass facades is a part of the complex refurbishment process of building envelopes, primarily the ones built in 1960s in Serbia. This is a valuable research, since only few dilapidated glass facades of the public building in Serbia, from this period of time, have undergone renovation. Therefore, this research could initiate decision-making process for further renovations.

More often than not, the refurbishment of the existing facade turns out to be more complex than carrying out a newly designed facade. This paper emphasizes the importance of the holistic approach to refurbishment, which includes a few different aspects – structural analysis of load bearing structures, building service, building physics and architecture, taking into account the historic value of a building. Modern technological solutions and performances of insulating glass, aluminum structures of facades and spacers significantly increase the level of energy efficiency of transparent facades. It is possible to achieve the required values, ranging from 72% to 77% reduction in heating energy consumption and for approximately 47 % of total annual energy consumption along with additional implementation of cooling in the building, in accordance with the IEA.

The proposed refurbishment of the building envelope requires implementing a few the energy efficiency measures, meeting the authenticity and uniqueness demands, and preserving the original appearance of the building but changing its function. The obtained results revealed that an energy class could be significantly upgraded, following the most important criterion of the curtain wall type and its two basic elements – glass and aluminum structure.

Heat gains in warmer climate regions cannot be easily released from a well-insulated building in summers. Selection of glass and appropriate balance between U coefficient and solar factor significantly affect energy demands for cooling/heating.

Lighting system optimization significantly reduces energy demands for cooling - for 25-26%.

Along with renovation works, aimed at increasing the level of energy efficiency of a building, it is also possible to implement modern technologies in curtain wall systems and achieve energy efficient refurbishment, comfort improvements and additional values. The integration of media elements into the facade system provides numerous possibilities for the owners of those buildings as well as for local communities. Therefore, the reduction of energy consumption cannot be separated from other potential achievements enabled by building envelope refurbishment (physical aspect, additional functions of facades).

It can be concluded that the design phase of renovation and revitalization, in accordance with adequate energy efficient measures, requires an individual approach to each building.

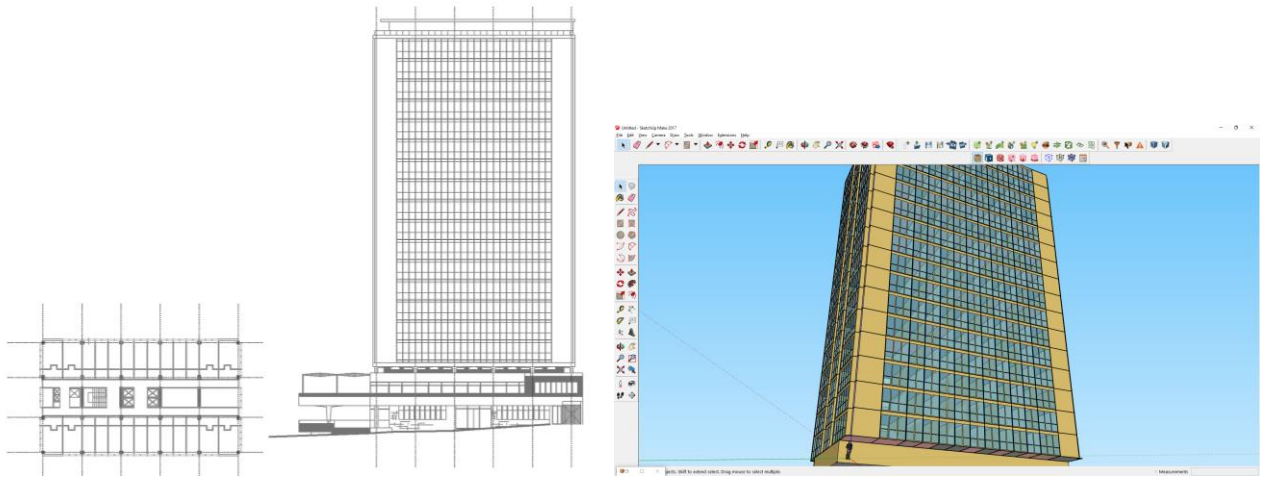
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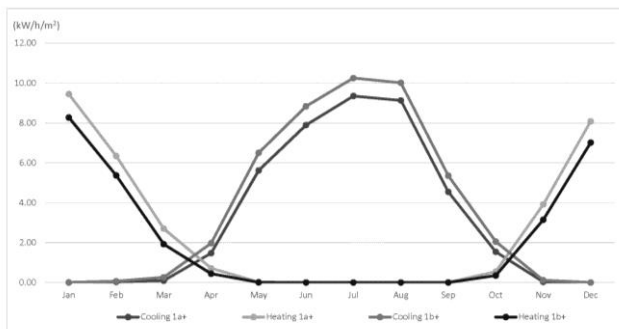
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**Fig.1. The Hotel Slavija – current condition a. b. south-west façade (the photos taken by the author)**



**Fig. 2. The Hotel Slavija: floor plan and elevation**



**Fig. 4. Monthly energy consumption for heating and cooling in newly proposed designs, 1a+,1b+**



**Fig. 5. The Hotel Slavija, Slavija (3D model)- active media facade, different programming models: a) graphics b,c) video**

**Table 1. Climatic Data Summary for Belgrade, sizing period days**

BELGRADE - SRB IWEC Data WMO#=132720





Sun Gard SN 51/28 (Lami 44.2-16 Ar(90/10)-Lami Extra clear 33.2)	50.2	12.2	26.6	23.7	0.31	43(-1;-6)	1.0
Sun Gard Sn 62/34(Lami 44.2-16mm Ar (90/10)-4 mm extra clear float-18mm Ar (90/10)-Clima Guard Premium Lami 33.2 SR	54.9	16.0	29.4	25	0.34	44(-2;-7)	0.5
AGC Stopray Vision 6mm-16mm Ar (90/10)-44.2 Stratobel	60	13	33	29	0.38	39 (-3;-7)	1.0
AGC 44.2 Stratobel Stopray Vision-15 mm Ar (90/10) -4 Planibel Clear Vision- 15mm Ar (90/10)-44.4 Stratophone Low-E Planibel Top N+Planibel Clear	52	17	30	24	0.34	43(-2;-7)	0.6

**Table 6. Energy consumption for a newly designed model and total consumption percentage (double glazed units)**

End Use	Consumption (kWh/m <sup>2</sup> ) 1a	Consumption (kWh/m <sup>2</sup> ) for improved system lighting control and equip. 1a+	<span style="color:red">■</span> Heating <span style="color:blue">■</span> Cooling <span style="color:yellow">■</span> Interior Lighting <span style="color:grey">■</span> Interior Equipment <span style="color:lightblue">■</span> Pumps <span style="color:orange">■</span> Water Systems					
heating	21.65	31.76						
cooling	54.20	39.69						
lighting	36.56	20.83						
interior equipment	32.78	20.84						
pumps	0.012	0.012						
water system	9.56	9.56						
<b>TOTAL end use</b>	<b>154.76</b>	<b>122.69</b>						

**Table 7. Energy consumption for a newly designed model and total consumption percentage (triple glazed units)**

End Use	Consumption (kWh/m <sup>2</sup> ) 1b	Consumption (kWh/m <sup>2</sup> ) for improved system lighting control and equip. 1b+	<span style="color:red">■</span> Heating <span style="color:blue">■</span> Cooling <span style="color:yellow">■</span> Interior Lighting <span style="color:grey">■</span> Interior Equipment <span style="color:lightblue">■</span> Pumps <span style="color:orange">■</span> Water Systems					
heating	17.30	26.52						
cooling	60.77	45.42						
lighting	36.56	20.83						
interior equipment	32.78	20.84						
pumps	0.012	0.012						
water system	9.56	9.56						
<b>TOTAL end use</b>	<b>156.981</b>	<b>123.82</b>						

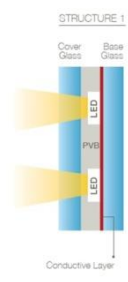
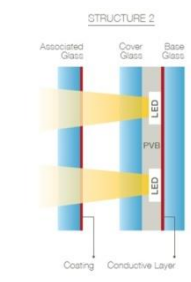
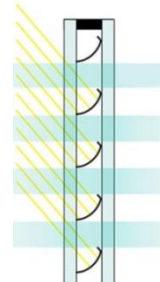
The overall heat loss is 237.80 kW (glass facade – double glazed insulating glass), and 190.13 kW (glass facade -triple glazed insulating glass) (Table 11).

**Table 8. Parameters of media facade technologies**

Media facade of the Hotel Slavija - technology	<b>Lighting system</b>	LED RGB lighting
	<b>Programming Model</b>	Autoactive and interactive
	<b>Resolution</b>	High
	<b>Media content category</b>	Art, commercial, service
	<b>Media content presentation forms</b>	Dynamic lighting, text/graphics, video
	<b>Operation mode</b>	Day and night, a total of 16 hours
	<b>Facade surface</b>	740 m <sup>2</sup>

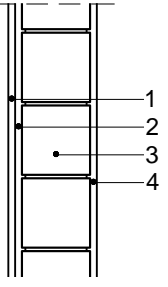
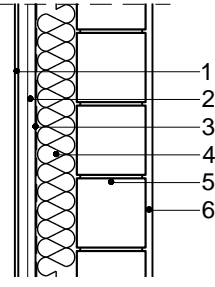
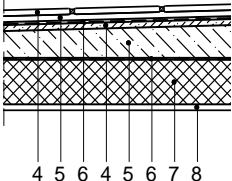
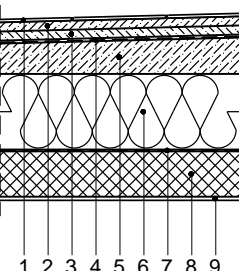
Two technologies were taken into consideration: LED light integrated into laminated glass and LED strip technology integrated into glazing units (Table 9).

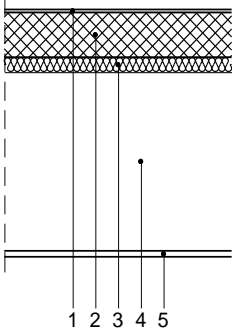
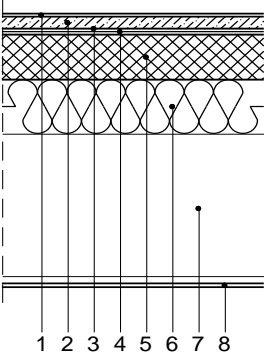
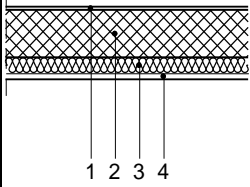
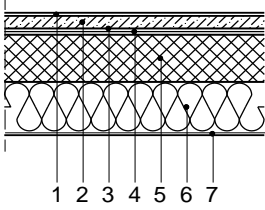
**Table 9. Media facade technologies (www.glassiled.com, www.onlyglass.com)**

Media facade technologies	1 RGB LED lighting integrated into laminated glass	2 LED strip technology integrated into thermal package	
			
Max. Dimensions	2700 x 3500 mm	1500 x 2700 mm	
Intensity LED	1.500 nits night and twilight 3.000 nits daylight 6.000 nits direct sunlight	235 cd/m <sup>2</sup>	
Transparency	98-99%	≥80%	
Number of LEDs	250 LED / m <sup>2</sup> for 60 mm pitch	100 LED / m <sup>2</sup> (max.)	
Min. distance between LEDs (pitch)	20 mm	50 mm	
Elec. properties	50 W/m <sup>2</sup> (for pich 60mm) 0.12– 0.15 W/pixel	100 W/m <sup>2</sup> 12 VDC to 160 VDC	

**Table 10. U values (W/m<sup>2</sup>K), current condition, proposed new design 1**

	The current condition	Proposed new designs -solution 1	
		Double glazed glass - a	Triple glazed glass - b

	<ol style="list-style-type: none"> <li>1. Aluminum frame</li> <li>2. Double glazed insulating glass (4+12+4)</li> <li>3. Aluminum structure</li> </ol>	<ol style="list-style-type: none"> <li>1. Aluminum frame</li> <li>2. Double glazed, low-E glass with argon (6+16Ar+44.2)</li> <li>3. Aluminum structure with interrupted thermal bridge</li> </ol>	<ol style="list-style-type: none"> <li>1. Aluminum frame</li> <li>2. Triple, low-E glass, with argon (44.2+16Ar+4+16Ar+33.2)</li> <li>3. Aluminum structure with interrupted thermal bridge</li> </ol>
U (W/m <sup>2</sup> K)	3.25	1.36	0.85
Masonry facade wall			
	<ol style="list-style-type: none"> <li>1. Ceramic mosaic 2.00 cm</li> <li>2. Mortar 2.00 cm</li> <li>3. Gitter block 20.00 cm</li> <li>4. Mortar 2.00 cm</li> </ol>	<ol style="list-style-type: none"> <li>1. Ceramic tiles 1.00 cm</li> <li>2. Air (substructure for tiles) 5.00 cm</li> <li>3. Steam permeable foil 0.02 cm</li> <li>4. Stone wool 12.00 cm</li> <li>5. Gitter block 20.00 cm</li> <li>6. Mortar 2.00 cm</li> </ol>	
U (W/m <sup>2</sup> K)	1.61	0.25	0.25
Flat roof			
	<ol style="list-style-type: none"> <li>1. Terrazzo tiles 2.00 cm</li> <li>2. Sand 2.00 cm</li> <li>3. Waterproofing 0.50 cm</li> <li>4. Cement set 2.00 cm</li> <li>5. Foam concrete 6-17.00 cm</li> <li>6. Bituminous strips with aluminum foil 0.40 cm</li> <li>7. Reinforced concrete 15.00 cm</li> <li>8. Plaster cardboard panels 2.00 cm</li> </ol>	<ol style="list-style-type: none"> <li>1. Ceramic tiles 1.00 cm</li> <li>2. Cement mortar 3.00 cm</li> <li>3. Cement set 3.00 cm</li> <li>4. Waterproofing 0.50 cm</li> <li>5. Incline 6-17.00 cm</li> <li>6. Extruded polystyrene 25.00 cm</li> <li>7. Bituminous strips with aluminum foil 0.40 cm</li> <li>8. Reinforced concrete 15.00 cm</li> <li>9. Plaster cardboard panels 1.25 cm</li> </ol>	
U (W/m <sup>2</sup> K)	1.56	0.13	0.13

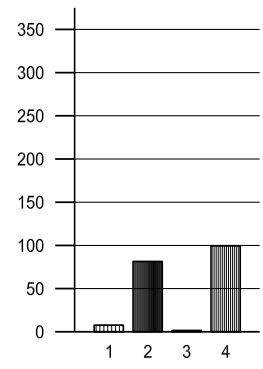
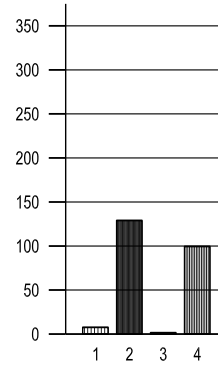
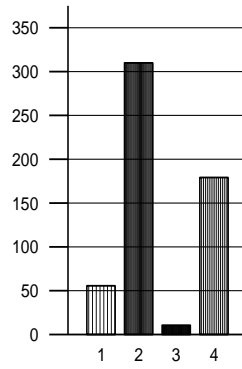
Overhang space			
	<ol style="list-style-type: none"> <li>1. Linoleum 0.60 cm</li> <li>2. Reinforced concrete 15.00 cm</li> <li>3. Durisol 5.00 cm</li> <li>4. Air 60 cm</li> <li>5. Wire-mesh mortar 2.00 cm</li> </ol>	<ol style="list-style-type: none"> <li>1. Carpet 0.60 cm</li> <li>2. Cement set 4.00 cm</li> <li>3. PVC foil 0.01 cm</li> <li>4. Stone wool TR 2.00 cm</li> <li>5. Reinforced concrete 15.00 cm</li> <li>6. Stone wool 18.00 cm</li> <li>7. Air 50.0 cm</li> <li>8. Drop ceiling of the substructure 1.25 cm</li> </ol>	
U (W/m <sup>2</sup> K)	1.15	0.17	0.17
The area toward the crawl space			
	<ol style="list-style-type: none"> <li>1. Linoleum 0.60 cm</li> <li>2. Reinforced concrete 15.00 cm</li> <li>3. Durisol 5.00 cm</li> <li>4. Mortar 2.00 cm</li> </ol>	<ol style="list-style-type: none"> <li>1. Carpet 0.60 cm</li> <li>2. Cement set 4.00 cm</li> <li>3. PVC foil 0.01 cm</li> <li>4. Stone wool TR 2.00 cm</li> <li>5. Reinforced concrete 15.00 cm</li> <li>6. Stone wool 16.00 cm</li> <li>7. Mortar 1.00 cm</li> </ol>	
U (W/m <sup>2</sup> K)	1.15	0.18	0.18

**Table 11. Comparative view of improving the building envelope elements: total energy demands, heat loss and reduction of annual heat demands, the case studies of the Hotel Slavija (current condition - Hotel Slavija, proposed new design solutions - converting into an office building)**

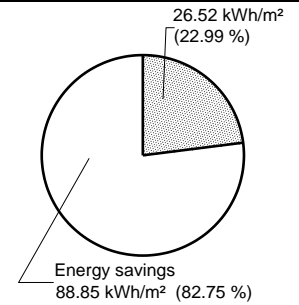
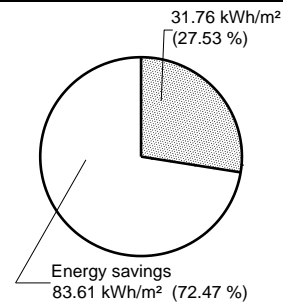
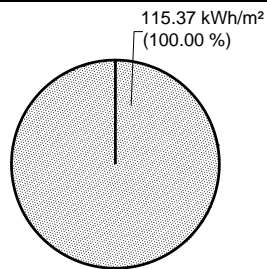
The current condition	Proposed new design - Solution 1	
	Double glazed insulating glass - 1a	Triple glazed insulating glass - 1b

Heat loss (kW)

1. transmission losses through the opaque cladding
2. transmission losses through windows and doors
3. transmission losses through thermal cladding above unheated areas
4. ventilation losses due to transmission through windows and doors



Specific annual heat demand/energy savings [(kWh/m<sup>2</sup>/year) (%)]



Energy class	<b>D</b>	<b>B</b>	<b>B</b>
Total annual energy demands (kWh/m <sup>2</sup> )	230.68	154.76 (1a) 122.69 (1a+)	156.981 (1b) 123.82 (1b+)