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Glass and Media Facades - Energy Refurbishment

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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 facades 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 Energy Plus simulations.

Keywords: Glass, Media facades, Refurbishment

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. Media architecture is a part of creative-cultural revival of cities. 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. Various interpretations deal with basic prerequisite to be met so that a facade could be considered as media facade. As for Hank Hasler (2009), dynamism and variability in the appearance of façade are regarded to be the most important. Some other theorists, such as Alexander Val (2005) see the possibility of transposing messages (communicability) as the sole prerequisite.

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^2 to 26.52 kWh/m^2, which means that energy consumption decreased by 77 %, representing a significant result leading to decreasing negative effects of global warming.

1. Literature review

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 (2014). 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. Linch 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 (2004), 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.).

According to some authors (Englhardt, O. 2012), 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"(* E. Dascalaki, E, M. Santamouris 2002). Stephan Messner (2012) 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_2 emission, improve comfort conditions (thermal, visual, air, sound and light comfort), change the function of a building and maximize the value of investment.

Dasclaki and Santamouris (2002) have analyzed the energy demands of office buildings, classified into five categories in retrofitting procedures.

2. Methodology

2.1. 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 in 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 Energy Performance of Buildings Directive (2011) and The Rulebook on the conditions, content and manner of issuance of certificates of energy performance of buildings (2011) in compliance with the European energy efficiency standards and requirements[1].

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^2, net conditioned building area is 7351.91 m^2. The shape factor of the building is 0.22 m^{-1}. Values gathered over 8760.00 hour.

2.2. Weather data

The climate in Belgrade ($44^0$49'N, $20^0$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.

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

BELGRADE - SRB IWEC Data WMO#=132720		
Latitude	$44^0$49'N	
Longitude	$20^0$27'E	
Elevation	99 m	
Source of processed climate data:	ASHRAE Climate Zone	
Sizing period days	Maximum Dry Bulb [C°]	Wind Speed [m/s]
ANN CLG .4% CONDNS DB=>MWB	33.80	3.00
ANN CLG .4% CONDNS DP=>MDB	26.60	3.00
ANN CLG .4% CONDNS ENTH=>MDB	30.90	3.00
ANN CLG .4% CONDNS WB=>MDB	30.90	3.00
ANN CLG .4% CONDNS WB=>MDB	-11.00	2.20
HTG WIND 99.6% CONDNS WS=>MCDB	0.70	11.50
ANN HUM_N 99.6% CONDNS DP=>MCDB	-9.90	2.20

[1] 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].

3. Case study- The hotel Slavija, Belgrade

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. 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. Fig. 1.

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).

Spatial 3 D model of the building is presented in Fig.2.

Fig.1. The Hotel Slavija – current condition. south-west façade (the photo taken by the author)

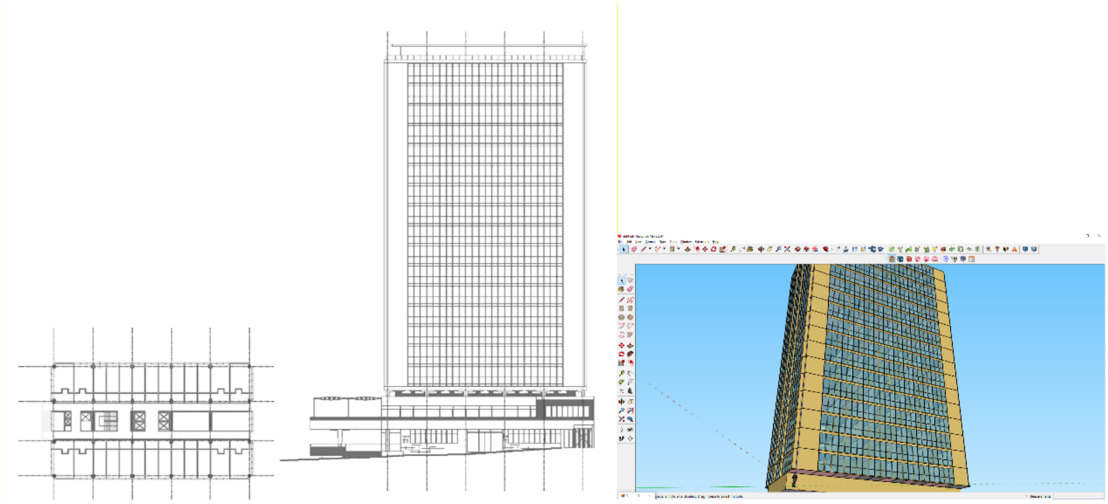


Fig. 2. 3-D model of the building

4. Results

4.1. Current condition

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

Table 2. Internal heat loads-current condition

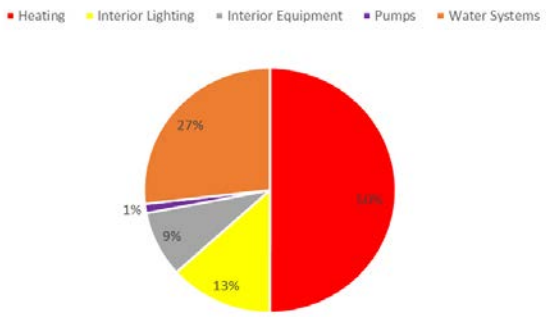
Source	Properties	Heat loads	Schedule
Occupants	1-2 person/per room	100W	Large hotel guest room occ. 0.03842 people /m2
Room equipment	TV	8.3W/m2	Large hotel guest room equip.
Lighting	4x60W+1fluo (18W)	258W/room	Large hotel bldg. light

The Building Physics survey provided the calculation of thermal transmittance coefficient for all buildings. The main indicator of poor performance of the existing glass facade is its U_w value of 3.25 W/m^2 K, which is far from the required value. These are the calculated values for other structures: flat roof- 1.56 W/m^2 K, masonry walls of the facade - 1.61W/m^2 K.

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

Table 3. Energy consumption for the existing building and percentage of total consumption

End Use	Consumption (kWh/m^2)
heating	115.37
cooling	-
lighting	30.72
interior equipment	20.00
pumps	2.83
water system	61.76
TOTAL end use	**230.68**



Total energy consumption of the existing building is 230.68 kWh/m^2. 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^2. 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.

4.2 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.

Table 4. Internal heat loads-office building

Source	Properties	Heat loads	Schedule
Occupants	13 m^2/occupant.	130W/person	Office Work Occ.
Office equipment	1 computer/person	7.64W/m^2	Office Bldg. Equip.
Lighting	12W/m^2 -work space	12W/ m^2	Office Bldg. Light.

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^2 K) and aluminum structure (≤ 1.8 W/m^2 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[2] provides the insulation protection of 41dB. The PVB laminated glass provides the best results and options.

[2] 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 separeted by 1 PVB (~0.38mm PVB film)

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)[3].

Solar and other performances of potential installations are presented in Table 5 (based on the software Calumen SGG and AGC Glass Configurator[4]).

Table 5. Glass performances

glass	Light Transmission LT (%)	Light Reflection LR (%)	Solar factor g (%)	Direct Energy Transmission DET (%)	Shading coefficient - SC	Acoustic properties (dB)	Ug (W/m² K)
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

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 W/m^2 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 ClassC4/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 W/m^2 K (in accordance with EN 10 077). The adopted coefficient value for thermal transmittance in aluminum structures is U_f=1.8 W/m^2 K, and the linear coefficient of warm edge spacer in insulated windows is ψ_g =0.06W/m K.

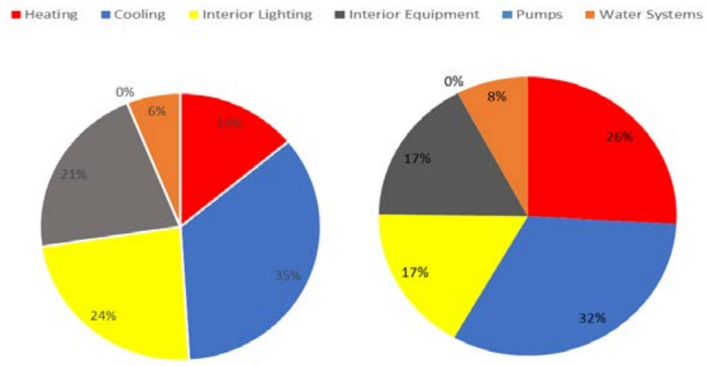
Solar protection systems are provided by aluminum interior venetian blinds. The windows are not openable.

Annual energy demands for heating, cooling and lighting, calculated per 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.

3 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).
4 The data are calculated using spectral measurements that are conform to standards EN 410, ISO 9050 (1990) and WIS/WINDAT. The U_g-value is calculated according to standard EN 673. The emissivity measurement complies with standards EN 673 (Annex A) and EN 12898.

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

End Use	Consumption (kWh/m^2) 1a	Consumption (kWh/m^2) for improved system lighting control and equip. 1a+
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
TOTALL	**154.76**	**122.69**



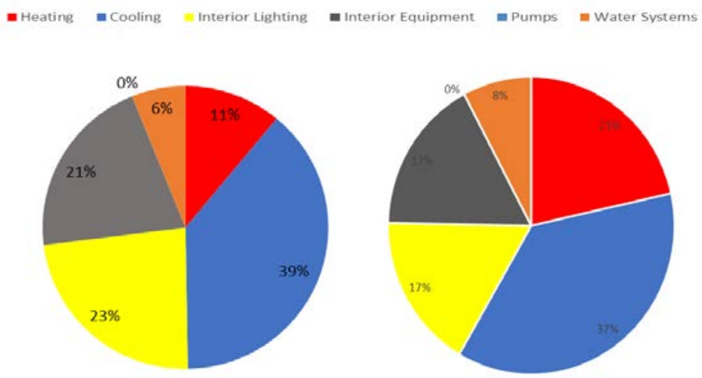
1a 1a+

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 W/m^2 K, aluminum structure U_f =1.4 W/m^2 K, and the overall U_w =0.85~~W~~ W/m^2 K. The analysis research revealed that the specific annual heat demand is Qh, nd = 26.52 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 .

Annual energy demands for heating, cooling and lighting, calculated per 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.

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

End Use	Consumption (kWh/m^2) 1b	Consumption (kWh/m^2) for improved system lighting control and equip. 1b+
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.
TOTAL	**156.981**	**123.82**



1b 1b+

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

Monthly energy consumption for cooling and heating in newly designed models is presented in Fig.3.

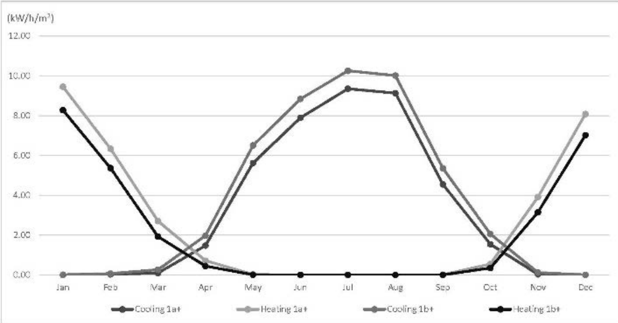


Fig. 3. Monthly energy consumption for heating and cooling in newly proposed designs, 1a+,1b+

4.3 Proposed new design- Solution 2 (media façade)

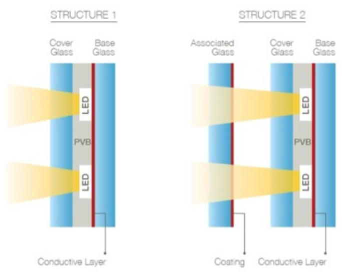
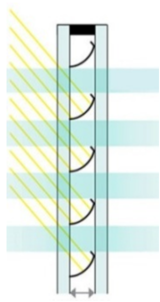
The future scenario 2 includes the improvement presented as Solution 1, and suggests that the southwest facade, oriented toward Slavija square is to be converted into LED media façade.[5] The basic parameters of required technologies of media facades are given in Table 8.

Table 8. Parameters of media facade technologies

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

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 nits (cd/m²)	235 cd/m²

[5] 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 75º. 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.

Transparency	98-99%	≥80%
Number of LEDs	250 LED / m^2 for 60 mm pitch	100 LED / m^2 (max.)
Min. distance between LEDs (pitch)	20 mm	50 mm
Elec. properties	50 W/m^2 (for pich 60mm) 0.12– 0.15 W/pixel	100 W/m^2 12 VDC to 160 VDC

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^2 is:

Qdisp=n x P=175x18x 50kW=157500 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)

Pdisp - el. power of media facade 50.0 kW (500 m^2 x 100 W/m^2=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^2), would increase the coefficient of specific annual heat demand, due to solar gain reductions.

The specific annual heat demand is Qh,nd = 32.25 kWh/m^2 (double glazed insulating glass), and Qh,nd = 26.97 kWh/m^2 (triple glazed insulating glass) including media elements during heating days.

5. 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, 2002). 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^2 while for the reconstructed building with a double- glazed insulating glass would be 26.52 kWh/m^2, (Table 10, case 2a), that is – 27.61 kWh/m^2 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 W/m^2 K) and used in the curtain walling U_w =1.35 W/m^2 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 façade elements was not favorable for energy demands for cooling (especially during three the warmest months), which is in accordance with other studies (H. Poirazis, A. Blomsterberg, 2008). Boyano’s (2013) 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, (2007) 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 (H. Poirazis, A. Blomsterberg, 2008).

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, (2002) 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 lovers 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, 2012). 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.

6. 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 coefficinet and solar factor significantly affect energy demands for cooling/heating.

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

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