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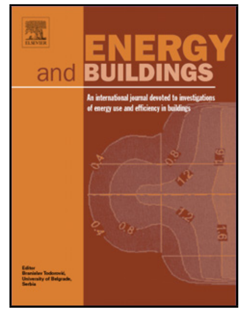

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APPLICATION OF SUNSPACES IN FOSTERING ENERGY EFFICENCY AND ECONOMICAL VIABILITY OF RESIDENTIAL BUILDINGS IN SERBIA

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ABSTRACT

Residential building sector in Serbia has changed dramatically over the last two decades. Large scale projects have given way to individual, private initiative resulting in smaller interventions rarely exceeding one lot. For this reason architectural concepts, building types, scopes and construction technology have been marginalized and fallen under the influence of market mechanisms and stringent local planning procedures.

New regulations on energy efficiency have risen the standards for thermal insulation therefore increasing the thickness of building enclosure. This actually means that construction costs are increased and net built area, therefore expected profit, reduced. In order to provide the viable ground for both implementation of new regulations and economic benefits for investors, authors of energy efficiency regulations in Serbia have noted a whole set of solar systems, among which

sunspaces that would not count as a part of gross area, provided that they contribute to the increase of energy performance of the building.

This paper describes the case of a typical residential new construction in Belgrade that has applied the prescribed solutions and became the first building that has obtained the building permit by applying a sunspace as an efficient strategy for energy saving.

Keywords: Residential buildings, sunspaces, energy efficiency, economical sustainability

1 SERBIAN BUILDING STOCK

Structure of the Serbian building stock has been influenced by the turbulent history and great devastations resulting in the fact that more than 95% of all multifamily buildings originate from the period after II World War, or, more precisely, 8.53% were constructed before 1960. These data present some of the results of the vast research of residential building stock, conducted by a team from Faculty of Architecture University of Belgrade, which resulted in formulation of National typology of residential buildings in Serbia [1]. Also, by evaluation of more recent types of construction we can say that the whole doctrine of construction process has changed in post socialist period and is today characterised by simplification of construction technologies, reduction of building types and smaller scale activities commonly driven by the individual initiative and financing schemes of private investors. Some very common building types which were representatives of socialist prosperity and industrial progress, like high-rise (approx. 7% in the period 1960-1980), are not being constructed at all anymore. Others, like lamella[1] type buildings represented with more than 50% in period 1970-1990 to around 40% in the period after the 1990, decreased in numbers, while representation in the overall building stock of some types has risen (buildings constructed as part of the city block, from around 10% in the 1970-1990 to more than 20% after the 1990). This tendency is likely to continue and will gradually change the whole structure of the residential building stock. For the purpose of this work buildings constructed within the city block, as a fastest growing portion of construction activity have been analysed, especially since the restrictions of possible solar design elements are highest for this type. Other building types, like free standing or lamella types, have free (less obstructed) facades and therefore more possibilities for application of various solar systems.

Bettering the overall performance of this type of buildings from the perspective of their energy efficiency is limited mainly by the urban layout. This is illustrated in the study Catalogue of energy characteristics of typical residential buildings in Belgrade [2]. By analyzing the behaviour of typical representatives of Belgrade building stock and investigating their thermal envelope performance by the means of Infrared inspection a set of standardized improvement methods have been proposed and their impact on energy performance and payback period of investment calculated. By *standardized improvements* are defined those focused onlly on composition of the building envelope and materialized mainly thorugh addition of layers of thermal insulation and facade finishings or by replacing the wihdows, without including any passive or active solar design elements. If we analyze only the segment of the building stock that has been designed and constructed according to the latest regulations on thermal protection of envelope elements, before the introduction of

[1] Lamella building is defined as the composition of several visually and technologically identical segments combined in certain spatial order

procedures for determination and certification of energy consumption, we can see that improvements of buildings belonging to the type built within a closed city block are ranging from 5 to 20% of energy savings with payback period from twenty to almost hundred years. This leads to the conclusion that a different approach has to be applied if we were to improve the energy performance of buildings built in last twenty years. Newly constructed buildings, designed and constructed upon the more stringent regulations, have envelopes that are already improved compared to the analyzed models, therefore principles of alternative ways of bettering their overall performance is even more complex and calls for inovative ways of design thinking and use of renewable technologies.

2 CURRENT URBAN PLANNING AND ARCHITECTURE DESIGN PRACTICE

In order to investigate the possible ways of achieving superior energy performance of the new types of residential constructions we have to understand the principles that are driving the construction process. It has to be said before any preliminary analysis of the procedures that in Serbia construction activity is determined by the number of laws, bylaws and urban planning regulations which, depending on the region, often have postulates that are not mutually harmonized and can result in different interpretations for each different case.

At the state level, the Law on Planning and Construction [3] presents a framework which regulates construction and defines general procedures for the preparation of required documentation and for the procurement of necessary permits. Urban planning regulations are enacted for cities and municipalities and they are generally based on spatial planning at the level of the state and of a particular region. The general and detailed regulation plans precisely determine the use of space, the types of buildings which can be built on particular lots, and a number of parameters that determine the precise shape and size of the building. These parameters are:

- The **regulation line**, defining the boundaries of the buildable lot;
- The **construction line**, defining the position of the building;
- The **occupancy index**, defining the maximum buildable area of the lot, including bay windows, canopies, balconies, etc.;
- The **construction index**, defining the maximum gross buildable area above the ground, where gross area is defined as the unfolded building floor area encompassing all building structures, insulation, railings, etc.;
- The number of floors;
- The height of the building, the height of the atica or of the roof ridge;
- Various distances between the front and the rear boundaries of the lot, between the side boundaries of the lot, between the adjoining buildings, etc.

These parameters determine the shape and the size of the building, while maximum allowed values cannot be exceeded. In addition to these parameters, the **net floor area** of the building, i.e. its usable floor area, is directly affected by the quality of the design, the selected construction technology and all other elements of the building structure: its envelope, partition walls, installations, etc. The legislation and the current practice have shown that the net floor area ranges from 75% to 80% of the gross floor area. This area also determines the profit in the real estate market.

3 REAL ESTATE MARKET CONDITIONS

Contemporary residential construction activity nowadays usually takes place in the centre parts of the cities rather than in the outskirts. These developments are taking place in densely built urban structures, replacing old and often devastated buildings, upon newly formed “free” lots. Resulting urban matrix is following the pattern of existing city blocks with minor adaptations of grid in order to meet the planning regulations. No major changes of the matrix are being executed and majority of the lots are preserved in original state apart from adaptations to the planned building and regulation lines. Also, there is no planning mechanism which would encompass merging of several lots and providing guidelines and incentives for creation of more sustainable and energy efficient designs on the block level, since usual residential blocks are inefficient from the solar energy utilisation point of view [4]. Relationship between urban texture and energy consumption of buildings has been investigated by several researches [5,6,7] all concluding that urban design has a great impact on the overall energy performance of buildings and that it has to be addressed if we are to utilize maximum of the available natural resources. However, in domestic practice, design parameters which derive from planning regulations are seldom adjusted to the potentials for a more sustainable design. Also, since there is no rule that urges the owner to comply to the envisioned urban structure the process is left to the individual initiative and is often subject to various speculative actions.

Practice has shown that development either starts with acquirement of the lot by the investor, or, more frequently, by setting up of joint investment with the owners of the lots. In later, the investors would finance the entire construction of the building and the owners, instead of compensation in currency, would be given a certain percentage of the built floor area of the building. The amount is largely depending on the location and the expected price that could be achieved per m^2 of the living area on market. With downtown locations, this share exceeded 35% of the total net built area at the time when the apartments were sold at as much as 4,000 €/m^2. More remote locations were characterized by less amount of constructed space allocated to the owners, down to 25% (20%), with the apartment prices ranging from 1,600 to

2,000 €/m^2. It should be pointed out that these principles were formed in the period of 2006-2008, which was characterized by the highest real estate prices [8].

On the other hand, new regulations on energy efficiency in buildings [9] have set new requirements regarding the performance of the buildings significantly decreasing the respected indicators: the allowed U value for walls was reduced from 0.9 W/m^2K to 0.3 W/m^2K and for windows from 2.7 W/m^2K to 1.5 W/m^2K. More stringent requirements are also set for all other elements of the thermal envelope. The regulations require, for the first time on our market, certification of buildings, stipulating that all new buildings and major refurbishments fulfil at least C rating [10]. This is confirmed by provision of detail study of buildings energy efficiency as part of technical documentation for obtaining a building permit, and verified by issuance of Energy performance certificate (EPC) in the process of technical approval for obtaining the usage permit. C category is defined as the relative ratio of calculated annual energy consumption for heating comparing to the prescribed amount for the certain type of building. For buildings of multifamily housing it means annual consumption of energy for heating of less than 65 kWh/m^2. There are plans for further tightening of the regulations and for inclusion of the actual liner losses (thermal bridges) into calculations, which will further affect thickening of the thermal envelope, thus reducing the net usable floor area of the building. Moreover, further harmonization of current legislation with the Directive on the energy performance of buildings (EPBD) [11] and EPBD recast [12] is planned, including adjustment of calculation methodology and limitations of the total energy consumption in the building.

Having in mind new conditions, it is clear that previous market rules are no longer economically viable. Besides, the demand for housing has fallen due to the economic crisis causing a drop in property prices, with the direct consequence in reducing the percentage of the lot owners' participation in the division of the built floor area of the building and, subsequently, in fewer construction projects.

In such market circumstances with lower apartment prices and new regulations which reduced the net sales area of the building, it is necessary to find economic incentives for investors and land owners so as to encourage further housing construction process. Investors are the drivers of the market, and therefore their perception, action and rationale is extremely important [13]. Most of the market barriers for development of more sustainable buildings also lie in little motivation of investors towards green building practices, among which those that demonstrate performance over the short-term, are most interesting for them. End consumers, especially in the residential sector, typically place higher value on amenities such as finishes over less visible like energy efficiency [14]. Since it didn't create a marketable value that would generate profit, there is a shortage of incentives for investors to address issues of energy efficiency. In this way, the circle of disinterest between consumers, investors and architects for issues of energy efficiency has led to a total indifference regarding this subject. So far, the market has not fully recognized the actual parameters of energy efficiency and there has been no emphasis on the overall energy performance of buildings in the sales process so that it has not affected the pricing in the desired way. General shortage of available flats on market and newly imposed credit lines from commercial banks lead towards the great boom of reel estate business, until the beginning of the economic crisis, and one can say that it was possible to sell any apartment in the market regardless of the quality of construction. The quality of executed works in construction process, apart from technical approval commonly were done without detailed technical inspection, and had not been verified in any other way.

Currently Belgrade real estate market has been very slow, mainly because of continuous economic crisis, and partly due to the larger scale developments by the state (Building Directorate of Serbia) through the construction of two new settlements: Stepa Stepanovic and Dr Ivana Ribara with more than 5300 flats at the relatively modest prices of up to 1250 €/ m^2 that had drawn the potential buyers [15]. Since construction industry employs a great number of people across various industries, and its economic recovery is extremely important in times of economic crisis and high unemployment, we can speculate that the shift towards a market that recognizes the value of building energy performance can lead to a significant adjustment of the construction industry, in the way of building refurbishment and energy efficient rehabilitation?

4 IMPLEMENTATION OF SUNSPACES – OPPORTUNITIES

Sunspaces have been in use as a passive design element since the very beginning of raising issues of buildings' sustainability. Solar architecture movement used sunspace elaborately as a design element for harvesting solar energy, together with other elements which provide adequate thermal comfort and energy efficiency (zoning plan, thermal walls, night ventilation, etc.). Recent research [16] places it among one of a dozen prevailing strategies for accomplishing superior energy performance of buildings, based on the analysis of contemporary low energy building designs. Others pledge for the greater attention towards passive solar energy efficient design since they can provide an important, easily feasible and thus low cost step towards reducing environmental impacts [17]. In studies which have investigated the influence of sunspace on thermal comfort during winter and summer conditions for different locations in Europe [18], conclusions are driven regarding the ratio between their effectiveness in winter and summer months, and recommendations for improvement of summer thermal performance using passive techniques is given for locations where overheating problems were greatest. Recommended passive techniques include buried pipes, night ventilation and shading elements, of which night ventilation provided best results, but combinations of techniques is strongly recommended. Numerous research focus on evaluation of sunspace performance through various calculation models and their comparison [19, 20], resulting in more accurate and reliable data obtained through thermal simulation modelling (Energy Plus, TRNSYS) and improvement of relevant standards. Calculation procedure for sunspaces defined by Serbian regulations [9] is based on simplified method as defined in ISO 13790, for which is proved to be slightly imprecise in mid season and cold months [19].

However, sunspaces, as parts of the energy system, have not been used in multi-family housing in Belgrade so far. The first encouraging signs of the use of alternative energy sources as part of systemic measures to improve energy efficiency in buildings were noticed in Belgrade Master Plan adopted in 2003 [21]. This plan provides for more compact construction in the zones outside the city center, the opportunity to install 6cm thermal insulation exceeding the construction line, and installation of active and passive solar energy receptors as permanent elements of the building. The application of the sunspace is defined by only one article: “If the effectiveness of the sunspace in energy savings for heating of the building is documented in the project, the area of the sunspace which equals the area of the glass on the sunspace shall not enter the calculations for the construction index or the occupancy index” [21].

Based upon this recommendation the authors of the regulations on energy efficiency in buildings [9, 10] took over this principle so that the opportunity to use sunspaces extended from Belgrade to the whole of Serbia. Being aware of all economic impact that energy efficient especially solar systems will have on construction costs, authors of the sub-law regulations opted for a series of measures and explications which will foster their application. Final version of the regulations, however do not state in detail the solar measures i.e. many were actually dropt out, but some stimulating factors are still remaining. When defining the most common terms used in regulations [9, Article 2] section 32 and 33 are stating that: “surfaces occupied by sunspaces, double facades and layers of insulation thicker than 5cm are not counting in occupancy index and construction index proven that they improve the energy efficiency of the building”. In this way a use of such systems is enabled without minimizing the net area, and thus possible profit. Adding a solar system like sunspace is allowed also for the existing buildings even over the regulation line to a max of 1.2 m under certain, prescribed conditions [9, Annex 4]. Significance of such definitions and their impact on total construction cost can be better understood if we knew that in city of Belgrade investor is obliged to pay tax per m^2 of constructed area, and that amount of this tax ranges from 100 to 360 €/m^2 in the central regions, almost approaching the net cost of the constructions themselves [22].

Understanding the principles of market mechanisms we can say that It is exactly such an application as of sunspaces that allows for the opportunity to use their construction not only as a measure to improve energy efficiency of buildings but also as a way to increase economic viability of housing construction in Belgrade. This is also an important incentive to development of interest for sustainable building practice through its value on the market.

5 CASE STUDY / A RESIDENTIAL BUILDING IN DOWNTOWN BELGRADE

As an illustration of the procedure a residential building designed in the center of Belgrade in 2010, has been analyzed. It represents typical construction enterprise with the following urban planning parameters: the occupancy index of 60%; the construction index of 3.5; the number of floors: garages, the ground floor, 4 floors, and the retracted floor; abutted on both sides with the matching construction and regulation lines (**Figure 1**).

Figure 1. Ground floor and typical floor of the case-study building

From the aspect of urban disposition this kind of development impose a whole range of restrictions deriving from the scale of the project, planning parameters and urban matrix. First of all, the size of the building lot, which represents the typical Belgrade residential lot developed for the single family housing, but later adopted for multifamily housing without fully appreciating the changes in the space usage it requires. Provision of parking requests, for example, have grown from only two parking spaces to almost 25, reflecting on the design in construction of two story underground garage with car elevator system, determining the layout of ground floor and increasing the total cost, since there is no collective parking garage for the whole block. Also, the depth of the building lot and prescribed urban planning parameters, did not allow a compact building design which would at the same time satisfy the investor’s demands in terms of net constructed area. If we were to reach near the maximum allowed net constructed area first problem was the provision of daylight as the depth of the building exceeded 22m. The adopted solution was to divide the building into two wings connected via a stairway zone. In this way, the separation of the wings by 7.2m, which corresponds to the minimum width of the street, secured the use of natural light, natural ventilation, and two-sided orientation of all units. Influence of such concept on energy performance is illustrated through the surface to volume factor (A/V_e) which exceeds 1.2, while with compact solutions is less than 0.8 for the same heated surface. With respect to the anticipated adoption of new regulations in thermal protection of buildings and considering the standard of the design of the building, a sandwich type façade wall with three main layers was designed: 19cm hollow clay block, 12 cm thermal insulation, 12 cm brick, and 3 cm mortar/artificial stone, amounting to the total thickness of 46 cm. In comparison to standard practice, in which the usual wall thickness was approximately 25 cm (19cm clay block and 5+1 cm contact façade), the designed façade was 21 cm thicker. Although design and construction has been executed before the introduction of new regulations majority of thermal envelope elements are fully compliable. The calculation of the obtained net useful area yielded that the total "loss" due to a higher design quality of the façade was approximately 55 m^2, which, at the property price for the location of 2,500 €/m^2, amounted to the loss for the investor of about 137,500 €. In order to provide an acceptable and profitable design solution with appropriate environmental characteristics, an innovative approach for Belgrade real estate development conditions at given moment was proposed, utilizing the recommendations set by Master plan and professional experience of the design team, "covering" a high portion of the south facing rear, courtyard façade with a sunspace. By implementing such design solution the following parameters were achieved:

- Total useful area available to the tenants provided by the sunspace and, at the same time, not being calculated as the built area was 112 m^2;

- Due to the increase in the floor area of the apartments, the market price was increased for approx 280,000 €;
- Including the tax for urban construction land due to the increase in useful floor area, the construction of the sunspace had a cost of 33,600 €.

Considering all the financial aspects, the gain harvested for the investor by the sunspace construction strategy is about 100,000 €.

6 ENERGY MODELLING

According to the above mentioned legislation, the verification of the energy efficiency is required in order to obtain a building license for the design of a building with a sunspace, the area of which is not calculated into the occupancy index or the construction index.

The sunspace was designed as the addition to the original courtyard façade with south orientation, having a wider volume in the ground floor and a more narrow "body" on upper levels maximizing the potential of the insolation (**Figure 2**). First analysis investigated the trajectories of the sun`s movement and influences of surroundings structures proving that the planned sunspace is not going to be overshadowed and that potential for solar gains exists. The whole structure was designed as aluminum framework with thermal break (no cold bridges in the structure) glazed with double pane insulating glazing. In order to prevent summer overheating design has incorporated operable window sections enabling natural flow of air and ventilation as well as screening by the means of internal blinds or curtains. The connection between the sunspace and the adjoining rooms is achieved through the existing openings meaning that no additional mechanical installations were provided. Use of only natural air circulation mechanisms means that impact of applied sunspace is restricted to a certain zone of the building thus resulting in lower level of potential benefits.

Figure 2. Façade of the building with the sunspace and respected energy model

Further research in sunspace application would include elaboration of additional mechanical installations for extracting the hot air and using it either in a direct way, via ventilation systems or indirectly as a source for activation the thermal mass of the building. This type of application would probably result in much better performance characteristics but it requires sunspace of much more complex structure as well as sophisticated controlling devices and other technology which requires adequate definition of property facility management and maintenance programs, which is very difficult to apply for typical scale of developments in current market conditions in Serbia.

Also, It is interested to note that Serbian regulations on energy efficiency still only include certification of buildings based on energy need for heating while other consumptions of energy (cooling, electricity, preparation of domestic hot water) are mentioned but calculation will include them upon the definition of national energy efficiency calculation software. Introduction of cooling loads calculation will significantly affect future applications of sunspaces as passive design elements in Serbia. This research aims to investigate their loss-to-gain ratio and applicability in moderate climate conditions in Serbia.

Performance of the planned sunspace has been tested through the computer modeling software. For this purpose IES Virtual Environment software package for modeling and dynamic simulation of thermal properties of buildings has been used. The choice of the software package was conditioned by the complexity of the dynamic analysis of the sunspace, in which it was necessary to analyze the coupled effects of the classical thermal calculation, natural ventilation, and insolation. In order to gain relevant performance data full year building simulations were executed based on typical weather conditions for Belgrade (ASHRAE IWEC2 weather data). Beside the standard modeling procedures, analysis included detailed solar shading and natural ventilation (multi zonal air flow) modeling.. Having in mind that the number of rooms per floor was 30, decision was made to model each room as a separate zone, additionally sunspace was modeled as one separate zone per floor – 7 in total. Temperature gradient was not modeled since the sunspace has also possibility to be used as a terrace where each floor level of the sunspace is modeled with solid floor and ceiling. This approach enabled analysis of other zones and generally improves the simulation precision by avoiding any approximations related to zoning. Once the simulation is executed we had results for the whole building and also for each zone including sunspace and the adjacent rooms. The results for the whole building were of interest to the municipalities because they proved the validity of application of the designed system as energy efficiency improvement measure. Analyzing the simulations results only for the adjacent rooms to the sunspace the energy saving effect was more intense since the direct influence of the sunspace on these rooms. Analyzing the installed mechanical systems in residential sector and influence of sunspace on their design it has to be noted that in Serbia it is not common practice to have both heating and cooling systems. Heating systems are necessary since the design temperatures for Belgrade is -12.1^{0}C. Heat source is either district heating system or boiler (gas, heating oil, biomass …) and heat is distributed to rooms by radiators. Cooling system is usually not designed nor installed during the construction process. Nevertheless practice shows that almost each apartment has at least one split system cooling device (direct expansion system with one outdoor and one indoor unit), and this type of cooling system has been modeled in the simulation. Mechanical ventilation has not been included in simulation because this type of system has not been designed..

Modeling was also used as the design guidance tool for architects and various proposed solutions were tested in order to achieve optimal results. Main characteristics which were tested by different modeling scenarios are:

- ventilation control (closed and sealed structure in winter and operable ventilated in summer - opening control was done by scheduling) differentiated by percentage of openings on sunspace, and
- shading coefficient of glazing (SC).

The basic model of the building without the sunspace was used in defining the overall consumption as the starting point (base case - **BC**), while the **S0** represents the model of the building with the designed sunspace characteristics as they have been proposed by the original architectural design documentation (**S0** – original case). Both internal and external shading are part of the design. Simulations were performed for six different scenarios, based on variations of original design. Main characteristics which were tested by different modeling scenarios are:

- **S0-S3**: ventilation control (closed and sealed structure in winter and operable ventilated in summer) differentiated by percentage of openings on sunspace, and
- **S4-S6**: shading coefficient of glazing (SC).

Characteristics of analyzed models are given in **Table 1**.

Table 1. Variants of the model and characteristics

7 RESULTS AND DISCUSSION

Presented results are for the zones in direct contact with sunspace. Annual heating and cooling requirements (loads) have been extracted from the whole building simulations. A comparison of the basic model (the building without the sunspace) and the model with the sunspace as defined in the architectural design (S0) revealed that the heating and cooling energy savings for the whole building were 2% and 3%, respectively, which has been anticipated having in mind the type, position and lack of mechanical installations in the sunspace. However, the analysis of the impact of the sunspace on the energy savings for heating and cooling of the units directly adjacent to the sunspace showed much better results. Energy consumption for heating and cooling was reduced by 11% and 8%, respectively (**Table 2.** and **Table 3**). In scenarios with the improved sunspace characteristics (S1-S6), the testing was done only of the effects of the sunspace on the units directly adjacent to it. It was noted that it was possible to reduce energy consumption for heating and cooling by 11% and about 25%, respectively.

Analyzing the influence of glazing solar coefficient (**Table 2.**) it can be concluded that greatest total savings are related to significant reduction in cooling loads in scenarios with low glazing SC (S4 and S5, 25% and 20% reduction, respectively), while heating load reduction is minimal, even negative (S4, -2%). More optimal ratio between winter heating loads and summer cooling loads reduction is achieved in scenarios with higher glazing SC (S6 and S0), resulting in significant overall consumption reduction (1.9 and 1.4 MWh, respectively).

Table 2. Annual heating and cooling loads and percentage of savings for zones in contact with Sunspace – comparison of glazing solar coefficient influence

Table 3. Annual heating and cooling loads and percentage of savings for zones in contact with Sunspace – comparison of ventilation influence

Analyzing the influence of sunspace ventilation on summer cooling load reduction (**Table 3.**) it can be seen that it influences the cooling load by reducing it between 4% and 9%. Significant increase in percentage of sunspace ventilation openings (above 50%) does not have further influence on cooling load reduction (S3 compared to S2 scenario).

Best overall impact having in mind influence on both seasonal regimes, heating and cooling is achieved with moderate quality glazing (SC 0.5) and 30% of sunspace ventilation openings (S6 scenario, savings of 1.9 MWh annually). Therefore, based on the analysis of various scenarios and technical solutions, it can be concluded that for the climate characteristics of Belgrade, the greatest impact on energy consumption reduction is achieved by application of sunspace with average glazing solar coefficient and at least 30% of sunspace envelope opening for ventilation. Additional verification of impact of planned interventions on energy efficiency performance could be done by measurements, but it has to be said that this kind of measurements are very hard to execute and can result in non- reliable results, due to the occupancy behavior and lacking of legal regulations for implementing of procedures.

8 CONCLUSION

The analyzed case presents the most common building type being constructed in downtown area of Belgrade recently. Its urban layout and related building regulations impose a large number of restrictions in its design, which nave negative impact on the overall energy performance.

At the same time the existing legislation enables the construction of sunspace which would not be listed in the total floor area, therefore excluded from taxation, provided that it contributes to reduction of the overall energy consumption. In this way such intervention provides a good financial incentive for investors and, at the same time, calls for further development of methodology for sunspace application.

Application of sunspace has been analyzed as a method to improve living conditions as well as energy performance having in mind various design options and technical characteristics. Simulations were performed for six different scenarios, varying the shading coefficient of glazing (SC) and percentage of ventilation openings on sunspace. All scenarios had internal and external shading as part of the design.

For the entire building, the energy reductions for heating and cooling were only 2% and 3%, respectively, but for the part of the building adjacent to the sunspace, they were significantly higher, 11% and 8%, which can be explained by the lack of appropriate mechanical installations.

Best results in minimizing energy consumption in both seasonal regimes were achieved by implementation of sunspace with moderate quality glazing (SC 0.5) and 30% of ventilation openings (savings of 1.9 MWh annually). Therefore, based on the analysis of various scenarios and technical solutions, it can be concluded that for the climate characteristics of Belgrade, the greatest impact on energy consumption reduction is achieved by application of sunspace with average glazing solar coefficient and at least 30% of sunspace envelope opening for ventilation.

At the same time, the construction of the sunspace generates financial gains that allow for its economic viability. For the building in the case study, financial gains were approximately 100,000 €, without calculation of influence of sunspace on future energy performance costs reduction.

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Table 1. Variants of the model and characteristics

Model	Sunspace	Percentage of openings on sunspace	Glazing SC
BC – base case	**N**	-	-
S0 – original design	**Y**	30%	0.85
S1	**Y**	10%	0.85
S2	**Y**	50%	0.85
S3	**Y**	100%	0.85
S4	**Y**	30%	0.20
S5	**Y**	30%	0.35
S6	**Y**	30%	0.50

Table 2. Annual heating and cooling loads and percentage of savings for zones in contact with Sunspace – comparison of glazing solar coefficient influence

Analyzed model	Glazing SC	Heating load (MWh)	Cooling load (MWh)	Heating load reduction (%)	Cooling load reduction (%)	Total reduction (MWh)
BC	-	**6.9**	**9.5**	-	-	-
S0	0.85	6.2	8.8	11%	8%	1.4
S4	0.20	7.1	7.2	-2%	25%	2.1
S5	0.35	6.8	7.6	2%	20%	2
S6	0.50	6.5	8.0	7%	16%	1.9

Table 3. Annual heating and cooling loads and percentage of savings for zones in contact with Sunspace – comparison of ventilation influence

Analyzed model	Percentage of sunspace openings	Heating load (MWh)	Cooling load (MWh)	Heating load reduction (%)	Cooling load reduction (%)	Total reduction (MWh)

BC	-	**6.9**	**9.5**			-
S0	30%	6.2	8.8	11%	8%	1.4
S1	10%	6.2	9.1	11%	4%	1.1
S2	50%	6.2	8.7	11%	9%	1.5
S3	100%	6.2	8.6	10%	9%	1.6

- We examine recent changes in building sector in Serbia
- We identify and discuss conflict of new energy efficiency regulations and market
- Application of sunspaces can increase market value and energy efficiency
- Modeling the various solutions proves the potential of sunspace application
- Application of sunspaces is feasible in current practice and urban conditions

Figure(s)

Figure(s)