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CITIES ADAPTATION TO THE CLIMATE CHANGE BY USING GREEN BUILDING PRINCIPLES

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ABSTRACT

The paper will analyse some of the concepts and principles of green building in the context of cities adaptation to climate change, which could be applied more in Serbia in the future. Having in mind the problem and their impact on the adaptation, mitigation and resilience of cities to the new changes two different approaches have being considered.

The first approach considers the city area as an environment defined through plans on a different level that integrates defining rules and tools for adapting to climate change. The second direction is focused on the impact of independent projects, which can be the initiators of adaptation to climate change on a wider scale.

The paper will present two case studies from Belgrade, Serbia. The first one is the "Study of the possibility of installing solar photovoltaic panels on a flat roof of the market in Blok 44 in New Belgrade", whose investor is "JKP Gradske pijace" (PE City markets), The second study analyses the competition entry for the former Beobanka building in Zeleni venac, Belgrade. The project's aim was to determine the possible ways of integrating the principles of green building in the processes of adaptation of existing buildings to new uses.

Keywords: urban planning; climate change; green building, individual building practices, Belgrade, Serbia

1. INTRODUCTION

When it comes to adapting cities to climate change, the principles of green building have become one of the most important premises in both urban planning and building design. Different methodologies, set by cities or states, which are primarily focused on the reduction of carbon dioxide consumption, considering its impact

on climate change, have achieved ambitious goals in the contemporary practice¹. Such goals are stimulated by significant financial resources, which help encourage the "green programmes".

Green Cities Programme Methodology, based on the work of OECD and ICLEI, offers the following definition of a Green City: "Green City is a city which shows high environmental performance relative to established benchmarks in terms of i) quality of environmental assets (air, water, land/soil and biodiversity), ii) efficient use of resources (water, energy, land and materials) and iii) mitigating and adapting to risks deriving from climate change, while maximizing the economic and social co-benefits and considering its context (population size, socio-economic structure and geographical and climate characteristics)" [2].

All these issues are particularly relevant to Serbia, considering that the energy efficiency of buildings in the public and private sector in urban areas is poor. Serbian cities produce communal solid waste that, without treatment, ends on non-sanitary landfills, waste recycling in urban areas is negligible (up to 5%) in comparison with the EU's today's average of 39% and the EU's goal of recycling 50% of municipal waste from total generated waste by 2020 [3].

For the sustainable development of green cities, it is critical to recognize the relationship between environmental aspects and economic and social issues. This thinking is also very much in line with the UN's 2030 Agenda for Sustainable Development and the Sustainable Development Goals (UN 2015) and particularly the Goal 11, calling for governments to make cities and human settlements inclusive, safe, resilient and sustainable.

The City of Belgrade is one of the cities that has expressed a desire to take a systematic approach to addressing urban environmental challenges. It is about to sign the Covenant of Mayors (CoM) for Climate and Energy and thereby commits to reduce its CO₂ emissions (and possibly other greenhouse gases) by at least 40%, increase its resilience to the impacts of climate change and provide secured access to sustainable and affordable energy by 2030. In order to achieve this, it is necessary to adopt, at the national level, the Law on Climate Change and the Carbon Dioxide Emission Reduction Strategy, which have a key impact on the development of policy and practice in this field.

2. GREEN BUILDING PRINCIPLES - STATUS AND PERSPECTIVES IN SERBIA

A building's environmental performance can be improved through the following strategies:

- through the application of adequate expert solutions in the urban planning process;
- by maximizing the positive characteristics of the building's location, and minimizing the negative ones (egg: proper orientation of the building in relation to the dominant winds, sunshine, appropriate building massing, glazing ratio, applications of green roofs and walls, etc.)
- through the application of technical and technological solutions and materials that reduce the energy needs of a building;
- through the use of materials and equipment with recycled content, which can be reused or recycled at the end of the building's lifecycle;
- by generating renewable energy, and offsetting a percentage of a building's energy demand;
- by applying sustainable water strategies, including the collection and reuse of rainwater, treatment and reuse of grey water and black water;
- by properly managing waste during construction and throughout the use of the building;
- by applying measures to ensure adequate thermal, visual and acoustic comfort of building occupants;
- by encouraging occupants to, when necessary adapt their behaviour and use a building in the most energy efficient way.

The Serbian Green Building Council (a member of the World Green Building Council) is a local body which promotes the benefits of green design and construction, and their contribution to the mitigation of climate change effects [4]. It highlights the areas where reducing carbon dioxide emission reductions can be achieved,

¹ Intergovernmental Panel on Climate Change's (IPCC) report indicated that cities consume somewhere to 70% of total global energy and generate 80% percent of global carbon emissions [1]

and where the investments should be focused. These include: energy (electricity and heating), construction, industry, traffic (road traffic, railway, air traffic), municipal waste management, land and forest use, agriculture, etc. When it comes to cities, the building sector is of primary importance. The planning addresses the reconstruction of existing and the construction of new settlements and individual buildings, by relating these to carbon dioxide emissions. The emissions can be reduced through the design, construction, use and maintenance of buildings.

2.1. Situation in Serbia: science and practice

A significant number of scientists and researchers in Serbia is working in the fields directly or indirectly related to climate change, through projects of the Ministry of Education, Science and Technological Development of the Republic of Serbia and through international scientific projects. A large body of research has been published in international and domestic journals and monographs, and presented at conferences dedicated to this topic. It would be highly beneficial if the aforementioned Ministry, together with the Serbian Chamber of Commerce, addresses the practical application of the theoretical and experimental research, available knowledge and experience.

Regarding the issues of climate change in the field of urban planning and design, it seems that, in Serbia, the biggest progress could be achieved through legislative mechanisms. However, the effects of the actual implementation of these mechanisms in practice (the real contribution to mitigating the climate change effects) is difficult to estimate.

Energy efficiency and the application of renewable energy sources are the main priorities for reducing carbon dioxide emissions and mitigating the effects of climate change. The significance of energy efficiency is still not sufficiently recognized in Serbia, by the state, local self-governments, investors, citizens, or the media, which should play a very important role in this matter. The energy consumption in Serbia is twice as high as the average consumption in the 35 OECD countries. Since the buildings consume 60% of the final delivered energy, energy efficiency measures can have the greatest effect on reducing the country's emissions. Despite of this, the residential owners consider energy efficiency measures solely as an additional expenditure, and only 10% of domestic investors recognize them as a comparative advantage over the competition. On the other hand, so far 1766 engineers in Serbia, from various professions within the Serbian Chamber of Engineers, have been trained and licensed by responsible engineers for the energy efficiency licence [5].

Regarding the application of renewable energy sources in cities, the biggest progress has been made in the domain of solar photovoltaic systems.

More frequent extreme events such as floods, droughts, strong winds and very cold periods with increased snowfall require an examination of the vulnerability of settlements and the existing building stock in Serbia. Additionally, new adaptation models should be proposed for existing and newly constructed buildings, in order to withstand such challenges. A multidisciplinary approach is necessary for such proposals. Planners and architects are expected to expand their knowledge of the topic, as well as collaborate closer at the local and regional level.

The responsibility of the profession is to actively participate in the identification and forecasting of possible consequences of climate change and to propose effective and economical adaptation measures.

3. TWO EXAMPLES OF USING GREEN BUILDING PRINCIPLES

The research paper presents two examples of using the green building principles in Belgrade, Serbia. The first case study shows for possibilities of using photovoltaic panels and solar thermal collectors on a roof of a building of a local market in Belgrade, and the second case study presents a competition entry for the adaptation of the former Beobanka headquarters in central Belgrade. Both examples show the application of green building strategies in the city of Belgrade.

3.1. Study of the possibility of installing solar photovoltaic panels on a flat roof of the market in Blok 44 in New Belgrade

This research study has been carried out in the Institute of Architecture and Spatial & Urban Planning of Serbia and it was focused on the possibilities of installing photovoltaic panels and solar thermal collectors on roofs and facades of public buildings [6]. The main objective of this study was the use of solar energy for the substitution of electricity consumption in urban environments. The market building in Block 44 in New Belgrade

was conceived as a pilot project within which the methodology would be established, as well as the criteria that would indicate all advantages and disadvantages of using the green building principles on an existing building in the city.

The building of the market is situated in the zone of New Belgrade at N 44°48'2" latitude and E 20°22'58" longitude, at the corner of Jurija Gagarina and Nehruova streets. The building is in the urban environment with medium lot coverage. There are no tall buildings in the immediate vicinity which would cast shadows on the roof of the market building (Fig. 1). The territory of New Belgrade belongs to the area rich in solar resources and potential of solar energy is high and suitable for the use of both active and passive solar systems. The annual average daily solar radiation received on a surface ranges between 3.76 and 3.86 kWh/m² [6], [7].

The study shows ways of using existing surface of the building's roof for renewable energy generation. The masonry building shaped like Cyrillic "П" is closing the market on three sides (eastern, southern and western sides) [6]. Its roof structure is stable, and has the following dimensions: 55.72 x 16.49 m, 98.50 x 10.49 m and 47.72 x 16.49 m (Fig.2). The roof planes on which the solar systems are to be installed are at an angle of 17° to the south (Fig.1).

The lowest sun angles on 21st December are considered when positioning the panels. The applicable angles are those from the southeast direction (at 9 am) and southwest direction (at 3 pm), which are at our latitude about 12°, while from the south direction (at noon) about 22°. In the periods before 9 am and after 3 pm the solar energy can be used only to a limited extent. Shadow analysis were used to prove that after the adequate spacing of the panels, only a small number of solar devices are in shadow between 10 am and 2 pm on 21st December, while on 21st March, 21st September and 21st June, the solar devices are not in shade at any point during the day (Fig.3, Fig.4).

After the adequate placement of the panels, the research considered three different design option. The first included only photovoltaic panels, the second and the third were a combination of photovoltaic panels and solar collectors. The initial calculations were conducted using the standard photovoltaic panels of the following dimensions: 148x67 cm, an area of 1 m², and a capacity of 160W [7]. The assumption is that the panels are to be installed at the optimum angle of 35° for the purpose of generating maximum electricity each year².

In the Option 1 (Fig. 3,4), the photovoltaic panels in the eastern and western wing are arranged in rows of 16 panels (dimension of panels: 148x67 cm). The photovoltaic panels in the southern wing are arranged in three rows, where a double row of panels is formed in the last, third row. In the Option 2 solar thermal collectors are to be installed on the eastern and western wings in two rows with 12 panels in each row instead of the 2 last rows of photovoltaic panels. In addition to using the solar energy for generating electricity, this option is heating the water for the needs of the market building and its internal zones, used mainly for the sales of dairy products. The Option 3 has all elements as the Option 2, but it also envisages the installation of additional photovoltaic panels in the central part of the building. The central zone's dimensions are 8 by 24 meters, and photovoltaic panels are positioned in 7 rows with 11 panels in each row. Depending on the selected option, it is proposed to install between 954 and 1031 square meters of solar panels on the roof of the market in the Block 44. The panels could generate 196.6 MWh in the Option 1, 184 MWh in the Option 2, and approximately 200 MWh in the Option 3. The generated energy could offset the energy needs of the market for 3.5 to 4 months a year [7]. The estimated return of investment is between 9.3 and 9.5 years, while the expected lifespan of the system is 25 years [7].



Figure 1: Position of the building in relation to the context



Figure 2: Model of the building with new (central) roof

² When the panels are oriented at an angle of 17° towards the southeast in relation to the strict southern orientation the overall annual electricity consumption should be reduced by 3% relative to the maximum (southern) one

in relation to the south (17 degrees rotated)

source: Google Earth

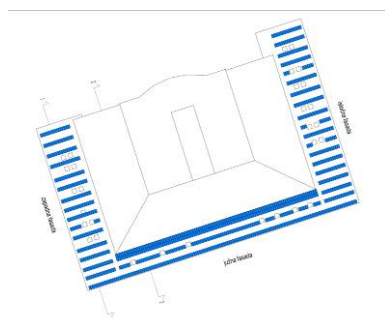


Figure 3: PV panels disposition in Variant 1

source: Study of Possibilities of Installing the Solar Photovoltaic Panels on the Flat Roof of the Market in the Block 44 in New Belgrade

source: www.gradjevinarstvo.rs

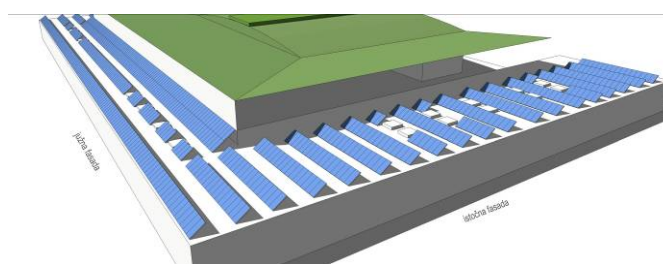


Figure 4: model of PV panels with shadows 21st of March,

source: Study of Possibilities of Installing the Solar Photovoltaic Panels on the Flat Roof of the Market in the Block 44 in New Belgrade

3.2. Competition entry for design of the Balkan eco-center at the Zeleni venac in Belgrade

3.2.1. Competition Requirements

In October 2018 Stattwerk Belgrade conducted an architectural competition for the design of the Balkan eco-centre in the former Beobanka HQ building³ in central Belgrade. The competition was asking for a new approach to green building design in Belgrade. The main emphasis was on the environmentally sustainable adaptation of the existing building. The architectural proposal was supposed to, as far as possible, retain the structural system of the existing building. The breakdown of new functions includes office areas (20 percent of total area), rental apartments (10 percent of total area), educational eco centre (5 percent of total area), a restaurant, a sky garden, a lounge, and a car park (incl. spaces for bicycles and electrical car charging).

The design proposal had to be energy efficient, in order to allow the building to be independent from the conventional infrastructure (electricity grid). Another important aspect of the proposed design was supposed to be the integration of renewable energy technologies, which would ensure the project's energy independence. The competition requirements gave examples of renewable energy technologies including wind turbines, solar panels, kinetic energy generated in floors of common areas with high frequency of visitors or the car park, geothermal energy, etc. The application of new technologies was encouraged, even if these are not available in the Republic of Serbia, as long as the technologies had been tested and are proven to be efficient. The design was supposed to consider vertical gardens and green roofs. The car park should have been designed to promote ecological means of transportation, especially cycling and electrical vehicles [8].

3.2.2. Design Proposal

The presented competition entry (authors: Brankov B. & Stojković M.) is aiming to show the assessment of the competition requirements, exposing whether these could be met through the application of adequate green building principles, while identifying the challenges to achieving the building's energy independence.

The proposed design is offering an adequate visual representation of the existing building's massing and its clear structural solution (Fig. 5). The existing structural grid was used as the starting module for the formation of the new building's functional zones and shading elements [9]. The complex comprises of three buildings: Building A, a 6 storey south facing building on Zeleni Venac Street, Building B - a 14 storey tower, and Building C, a 7 storey building on Carice Milice Street (Fig. 6).

The competition requirement for the provision of 500 parking places was met by providing a new four levels parking structure (one underground and three over ground), inside the building C's courtyard. The car park structure has the appearance of a green hill, and is used as a garden for the office employees which can access it directly from the first floor of the building C.

³ Building was designed by architect Milica Šterić in 1956-60. as the main headquarters of project house "Energoprojekt", but became the HQ of "Beobanka"

Shading Design

The external overhangs on the building A (Fig. 6, Fig. 7), which predominantly houses the eco centre and office areas are designed to the vertical shadow angle of 50 degrees, providing shading during summer and most of midseason, while allowing passive solar heating in winter. In addition to their solar performance, the overhangs are sized and positioned to maximise the views out. The tower (building B) has vertical greenery which is designed following similar principles as the fixed overhangs on the building A. The hanging greenery helps provide shade during summer and midseason, while allowing the low-angle winter sun in the apartments and offices (Fig. 7). The façade of the building C has a saw tooth shape, with west and south facing glazing (Fig. 7). The west facing glazing is overshadowed by the surrounding buildings and receives little radiation, and therefore does not require external shading. The south facing glazing has glass integrated photovoltaic cells, which also provide shading [9].

It is recommended that all spaces have internal blinds for glare protection.

Energy Independence

In order to offer the possibility of becoming an 'off the grid' building as per the competition requirements, the proposal was designed to be powered solely by electricity. A range of strategies has been assessed, with the initial aim of improving the performance over and above the current regulations, and then meeting the resultant, reduced energy demand through renewable energy.

The building model was produced using IES-VE 2017, which is an advanced dynamic thermal simulation software approved by USGBC and many other organisations and an approved software for code-compliance modelling. The building has been modelled with its surroundings, and the simulation used a climate file for Belgrade. The simulations have shown that by relying on the passive design strategies (relaxed temperature set-points, natural ventilation, the envelope performance as per the Passivhaus requirements), the building's energy demand can be reduced by up to 20% over a code-compliant building. Further savings can be achieved through the application of active strategies. A highly efficient lighting design is likely to reduce the total energy demand for another 9%. A combination of improved lighting design, efficient equipment and systems can result in up to 40% of total energy demand reduction. The application of photovoltaic cells on the roofs and the facades can help reduce the total energy demand down to 50% of what a code compliant building would require. The rest of the energy would have to be provided by off-site renewables.

Due to the building's shape – significant height with limited roof area, it is not feasible to achieve energy independence with currently available renewable technologies in an economically sustainable manner. However, due to constant advancements of green technology this might become possible in the future. For now, the key focus should be on the passive strategies and the responsible use of energy in buildings operation [9].

Renewable Energy

The average wind speeds in Belgrade range from 2.7 m/s to 4.0 m/s, which is not sufficient for the application of most small-scale wind turbines. The lowest speed at which a wind turbine is able to generate any power is around 3 or 4 m/s. As a result, any installed turbines would operate for a small percentage of hours and would have a long pay-off period. Additionally, the application of wind turbines in residential or mixed-use towers proved to be challenging due to noise and vibration issues (example: Strata Tower in Elephant and Castle, London). For all these reasons, the study did not consider the integration of wind turbines.

Kinetic energy plates are supposed to harvest energy from cars passing over a compressible ramp which drives a generator. This technology is essentially not harvesting free energy, since the cars need to burn more fuel in order to drive over the ramp.

The energy benefit of the application of similar kinetic energy plates in high frequency areas like corridors is expected to be very low due to the building's function and expected number of visitors. While this technology might be appealing to showcase in the eco-centre, it would not generate a substantial amount of energy to help the building achieve its energy independence goal.

Belgrade has a good potential for solar energy generation. By assessing the radiation levels on the building's façade (Fig. 7), the proposal is offering the best location for the installation of photovoltaic panels. Photovoltaic panels are primarily positioned on the building's roofs, for maximum energy generation. The roof of building B (the tower) is covered with high efficiency monocrystalline photovoltaic panels (PV area: 430 m²,

PV efficiency: 21%). The building A has a roof-top bar covered with a photovoltaic canopy (total canopy area: 674 m², PV area: 472 m², PV efficiency: 12%). Finally, the roof of the building C (office building) is expected to be used only during lunch breaks, and, for this reason, has a photovoltaic floor instead of a canopy, as this technology allows for improved panel efficiency (PV area: 336 m², PV efficiency: 18%). In addition to these areas, there is a potential for glass integrated amorphous silicon cells in south facing glazing of the saw-tooth façade of the building C. This technology is less efficient, but can help provide shading, while generating energy. The total energy generated from the roof areas and south-facing glazing represents around 7% of the code compliant building's total energy demand, and around 16% of the proposed building, with highly efficient envelope and systems.

Sustainability and Wellbeing Benchmarking Systems

In addition to saving energy, the design proposal is addressing the visual, thermal and acoustic comfort of the building occupants. A meaningful integration of public art, food growing facilities, outdoor terraces, canteen, fitness centre and communal areas, all help address occupants' wellbeing. The design has a potential to achieve both WELL Building Standard and LEED BD+C Platinum ratings.

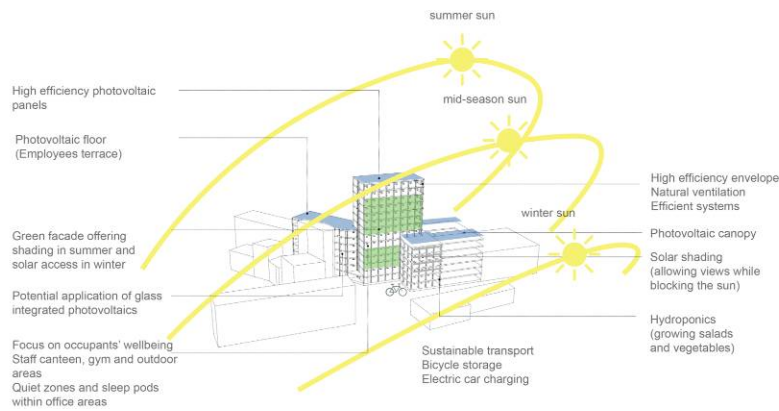


Figure 5: Key environmental design strategies

source: design proposal for Balkan-eco center (Brankov&Stojković)

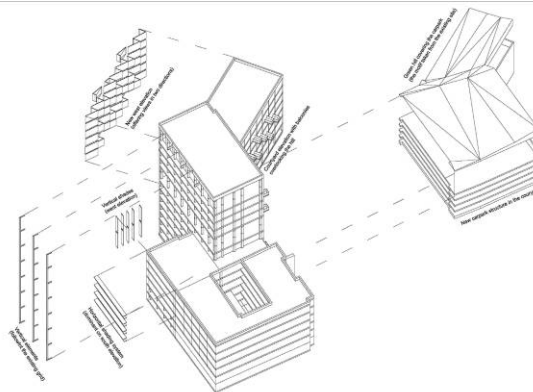


Figure 6: Model of the building with shading elements, vertical vegetation and covered car park

source: design proposal for Balkan-eco center (Brankov&Stojković)

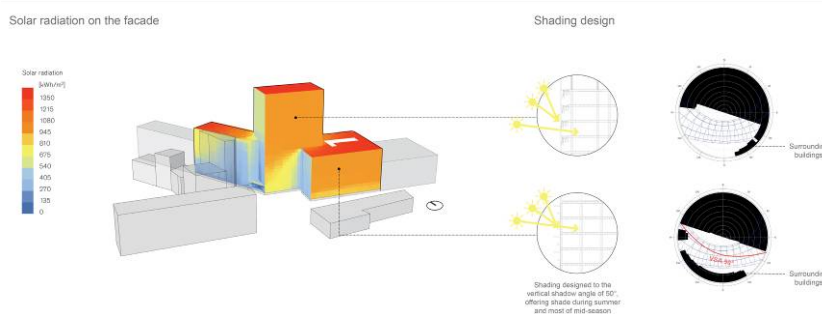
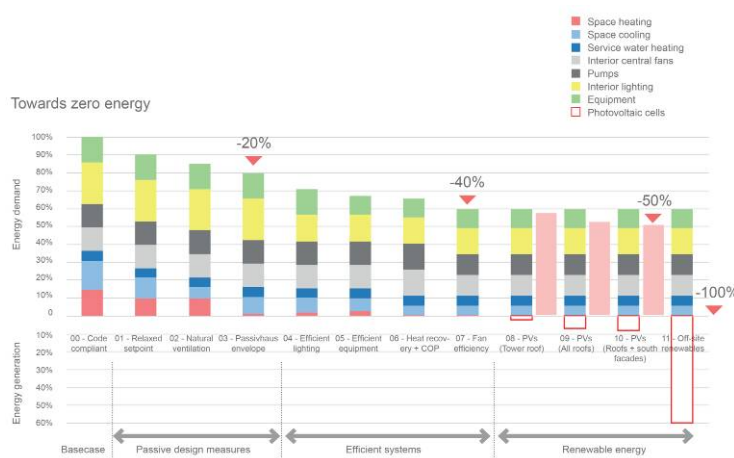


Figure 7: Solar radiation on the facade of the building and shading design

source: design proposal for Balkan-eco center (Brankov&Stojković)

**Figure 8:** Energy reduction strategies

source: design proposal for Balkan-eco center (Brankov&Stojković)

4. DISCUSSION

Both presented case studies show the application of green building principles. The study of the photovoltaic panels and solar thermal collectors on the roof of the Market in the Blok 44 in New Belgrade is focused primarily on the application of renewable energy systems. It offers simple improvement options for an existing building, highlighting the potential benefits of such proposal in the analysed climate. The study's methodology can be easily adjusted to other building types and locations.

The design proposal for Balkan-eco centre is showing a holistic approach to green building. It is aiming to maximise the positive characteristics of the building's location and context, create suitable solutions for the building facades, addresses occupants comfort and wellbeing, and apply advanced technical and technological solutions that help reduce the building's energy demand. It shows how green technologies should be an integral part of any landmark building. At the same time, the simulation results show that, with the currently available technologies, it is still difficult to design a net zero energy mixed use tower. Nevertheless, the project's façade design and the energy performance optimisation methodology, especially its roadmap to a zero energy building, can be applied to other buildings.

Green principles can bring multiple benefits at the building and city level. More studies should showcase green building features in a coherent way, assessing their visual, economic and environmental impact. This would help improve the understanding of available technologies and their potential applications, and help accelerate their integration in Serbia's construction industry.

5. CONCLUSION

Resilience of cities and their adaptation to climate change are based on the basic principles of green building, which include a series of measures and actions that must be continually developed, adapted and applied in different fields. These fields, among others, include legislative, social, economic and technical, and require adequate managing due to numerous overlaps.

As a way of creating the right environment for future green construction in Serbia, it is necessary to pass a law on climate change, a national strategy to reduce emissions of carbon dioxide and other harmful gases into the atmosphere, and to develop a unique methodology for developing action plans for adapting local communities to climate change. All these documents must comply with the highest EU standards. The focus of a city's action plan on climate change must be on informing and educating its citizens, managing energy consumption and sustainable energy production, water resources, transport, sustainable procurement, managing natural resources, natural and cultural heritage, etc. Creating a set of regulations and by-laws will mobilize the right experts, and stimulate the investment in transformation and new technological solutions.

The study for the market in the Block 44 and the design proposal for Balkan-eco centre show two paths of use of green building principles in a contemporary practice. The principles of green building in Serbia are momentarily in their infancy, especially when it comes to built projects. It is, therefore, of utmost importance that the most successful examples of good practice are promoted and rewarded. Initiatives that go towards achieving the principles of green building need to be recognized by local authorities, experts and citizens. The transformation to a greener future is a slow process which requires both major financial investments and time. It is therefore important that at the outset, the cooperation between the public, private and academic sectors is combined with the expertise in the use of state-of-the-art technologies [10]. The formation of pilot projects is of exceptional importance in this field. One of the measures could be the establishment of demonstration zones and pilot projects focused on climate change adaptation and mitigation that help stimulate initiatives in the market, similar to urban and regional development zones established in Western countries.

The green building practices could be further encouraged by an energy price policy, information campaigns, favourable tax structures, tax incentives, donations and government favourable loans, international technical assistance and development programs [11]. The ultimate goal is to get the successful practices, tested in pilot projects, implemented on a national scale.

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