

# **BUILDING PERFORMANCE SIMULATION FOR COST EFFECTIVE SOLAR INTEGRATED REFURBISHMENT OF URBAN RESIDENTIAL BUILDINGS**

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## **1. BUILDINGS VERSUS FOSSIL FUEL DEPLETION AND GLOBAL CLIMATE CHANGE**

The energy and environmental crisis is something we are faced with on a daily basis, while its more severe form will be more evident in the near future, considering the increasing depletion of traditional fossil energy resources and their increasing prices, as well as more and more evident irreversible consequences of the fossil fuel use – pollution and degradation of the key life support systems on the Earth, air, water and soil, and, finally, increasingly evident global climate change. In addition, some "water conflicts" are active or latent for hundreds and thousands of years. Freshwater in the world's lakes and rivers makes up about 1 part in 10,000 of all the water on Earth. A vulnerable global heritage on the Earth in the past, today became under siege and progressive degradation. There are approx. 70 trouble spots in the world linked with water, from the Middle East to the Sahel, from arid zones of Latin America to the Indian sub-continent and serious water shortage is predicted in 10-30 years /1/.

Global climate change, a phenomenon under suspicion only until yesterday, has become a centre of our fear induced attention due to numerous consequences, including human victims, severe weather disasters as well as changes caused by the fall of the plant production system, or specifically, food production in the regions that have been considered the most fertile regions on our planet until recently.

To turn irreversibility to sustainability Energy Efficiency and RES - Renewable Energy Sources technologies are needed /1/. The most important to delay fossil energy resources exhaustion and to reduce pollution controlling climate change are: low-carbon energy technologies combined with improvements in end-use efficiencies/energy efficiency and renewable energy sources (thermal, PV and photo-thermal conversion of solar energy, biofuels and biomass energy, geothermal and wind energy, wave and OTEC energy, as well as fuel cells and hydrogen based on RES utilization /1/.

The path to the end of these irreversible destruction processes emerges in the development and spreading of renewable energy sources. However, their efficient and economical introduction must be preceded by the energy efficiency optimization to the level of minimum energy demands, which are achieved by the aggregate application of all known available measures, knowledge, technologies and energy efficient systems and equipment. The role of new IT knowledge and technologies, particularly in construction sector can be crucial. Using new information technologies gained and exchanged knowledge and experience shall become instrumental to the success of approaching sustainable buildings and sustainability generally (/2/, /3/).

For the effective and reliable approach to the buildings energy efficiency optimization and RES integration very important is to distinguish the difference of the system performance criteria on the:

- 1st Law Energy Efficiency = (“useful” energy outputs)/ (“paid” energy inputs)
- 2nd Law Energy Efficiency – Exergetic Efficiency used when the quality of energy, and not only the quantity of energy is anticipated /8/.

2nd Law efficiency the performance of a system relative to an ideal - reversible one which operates between the same thermodynamic limits. These criteria usually have different values for the same system. In conjunction with them, to be complete relevant analysis is to encompass the embodied energy - the energy embodied in the: production of the plant, materials produced by it, materials and labor needed for its operation, and distribution of its material products to the customer. A more consistent definition would also include the total energy investment, embodied in the fuel, materials and labor needed for the plant operation over its lifetime ( $L$  years), as well as the energy embodied in non-energy  $k$  products of the plant /8/.

Energy consumption in buildings, including residential ones, accounts for the highest percentage of the total energy consumption in many countries. On average, this consumption is between 40 and 60 %, and in Serbia it is approximately 50 %. Therefore, the improvement of energy efficiency in buildings is in strong focus today, and there are programs organized by many countries or groups of countries (EU for example) drawing attention and directing actions for reduction of energy consumption in buildings, focusing demonstration in addition to R&D, market strategies, regulations and financial incentives, various measures, preparation of regulations, standards, etc.

Dissipation i.e. distributional character of solar energy and other renewable energy sources is very similar to scattered buildings in rural, but also in urban environments, with green interspaces. Therefore, the most natural way to increase the use of solar energy is primarily by the buildings passive solar/bioclimate design and then by the implementation/integration of appropriate solar thermal collectors, PV panels and /or PV/Thermal systems in buildings, primarily on building facades and roofs (/4/-/7/).

In addition, according to the need to reduce CO<sub>2</sub> and other GHGs emissions, buildings should be evaluated based on both – the existing and/or projected energy requirements and emission of refrigerants. Buildings heating, ventilating, air-conditioning and refrigerating (HVAC&R) systems contribute to GHGs releases indirectly through their energy-use related effects, and directly through the effect of refrigerant losses (CFC's). Additional considerations in the options in building design and operation are any excessive energy and environmental consequences associated with the production or manufacture of building components. Decision-makers shall consider all environmental impacts prior to taking actions in response to climate change. It would be counterproductive to require that refrigerant substitutes have low global warming potentials which at the same time may result in higher energy requirements or compromised safety.

## **2. BPS FOR ENERGY EFFICIENCY AND SOLAR ENERGY UTILIZATION OPTIMIZATION**

Energy-related impacts of buildings must be considered in their life-cycle environmental analysis. Primary are those factors that affect the energy consumption in the operation of the building and its HVAC and other technical systems in addition to the selection of energy-

efficient equipment. Those are facades concepts and choices in building envelope alternatives, glazing and fenestration, types of building structure thermal mass and insulating materials, lighting and day-lighting control, natural ventilation and energy-recovery opportunities, and HVAC systems regimes and operational modes such as temperature control, air volume control, motors and pump types of control, indoor and outdoor air quality and environmental protection. All of these considerations have an impact on the buildings energy efficiency, HVAC&R requirements and resulting CO<sub>2</sub> emission.

The designers' preoccupation to perform energy efficiency optimization, reducing energy consumption and to achieve better thermal ambience levels has favoured the setting up of numerous building thermal dynamic simulation programs. The progress in the modelling of phenomena and its transfer into the professional field has resulted in various numerical approaches ranging from software's dedicated to architects for design use to tools for laboratory use by the expert thermal researcher. In each of these cases, the objective results, the precision advocated and the time delay of the results are different parameters which call for a multiple-model approach of the building system (/2/,/3/).

Since the initial significant diffusion of simulation and design models, one of the major problems is their appropriateness to a particular user during the design process. For the building designers and operators, from the first stages of conception, different options should be rapidly explored to identify the important parameters. Step by step during the progress, more detailed tools are necessary to perfect the design.

Thermal models are very often obtained by a combination of elementary models, each one describing the thermal behaviour of the elements of the building. Once the elementary models have been chosen, this approach gives a rigid or *monolithic* building model. It replies precisely to the users needs (HVAC designer for example). On the other hand, when justifying the multimodel approach, it must be made evident that the implied models are greatly conditioned by the availability of data concerning the constituents of the building. In the initial stages of a project, these data are very limited (outlines and dimensions). At each stage of the building evolution, these data become more complex (materials, schedules, HVAC systems) and thus enable the use of much more complex models. At the final stage, varied levels of detail can be obtained, or to proceeded to sensitivity analysis.

In BPS aimed to the building's energy efficiency optimization main objectives are on one side - to evaluate relevant building's HVAC, lighting and other building's service systems, as well as energy demands/loads, and the annual energy consumption, and on the other, to study the results (hourly/sub-hourly) of a building component over a given climatic period.

A holistic approach to building design requires a method to estimate the performance that will result from the energy flows and interactions between the different technical domains. However, energy related indicators, such as energy consumption or daylight utilisation, are insufficient for whole building performance characterisation, but the occupant comfort is also an important issue which has to be included. Multiple-domain comfort assessment is required for IEQ (thermal environment, light, air quality and acoustics).

Finally the analysis of the overall performance of a building should also take into account the ecological cost of providing this comfort (/2/, /3/). BPS in design or redesign, reconstruction and refurbishment phase is to encompass following domains: building intrinsic performances (energy consumption, acoustics, etc.); occupant comfort; and life cycle impacts assessment

(LCIA), which characterises the environmental impacts of building energy consumption, the construction materials and processes occurring during the LC (including the construction, use, maintenance and deconstruction phases). Hence, an important issue in the holistic assessment of performance is the construction of the building model. The physical model should hold the information required by each domain to allow a multiple-domain simulation. Sustainable buildings, energy efficiency optimization, RES integration and building performance simulation are areas in which international input and cooperation shall be crucial to accelerate knowledge advance and dissemination, as well as technology development and transfer (2/8/-/11/).

Summarizing given above, can be stated - BPS is a powerful method and technique for predicting building's dynamic behavior (building and all technical systems integrally) and for performing building's energy efficiency and RES integration optimization. BPS enables building's environmental technologies and sustainability harmonization as follows:

- Building Envelope and Structure with Environment and Indoor Environment
- Quality - IEQ
- Building and Service Technical Systems
- Building purpose - users and HVAC and IAQ
- Building Water Supply and Sewage/Waste Systems and Outside Environment
- Building's Energy Supply/Production
- Renewable Energy and Material Sources

### **3. BPS SUCCESSFUL STORIES BASIS FOR THE REFURBISHMENT PROJECTS**

As buildings use approx. 40 - 60 % of national energy in different countries it is crucial to improve/optimize their energy efficiency (particularly of the existing buildings), for all countries economies. Improved energy efficiency by the implementation of relevant passive measures and minimized energy loads and energy demand/use is necessary prerequisite to approach effective Solar and other RES implementation. Energy efficient introduction of RES implementation reduce LCC - life cycle costs, improve comfort and habitability.

In this paper reviewed will be in short, a few case studies on building's energy efficiency and RES integration optimization, performed by the implementation of BPS, results of which have been later confirmed by the constructed buildings/systems operation – for us gained very important satisfactory experience and confidence. Based on those results, currently is prepared project proposal for the New Belgrade Residential Concrete Blocks refurbishment.

**USCE Tower's envelope energy efficiency optimization /1/.** The EC – Euroconstruction's UŠĆE Tower (23.000 square meter office building) is one of a number of new important developments on the entire site in Belgrade (Fig.1.). It has been seriously damaged during bombing in 1999, and has been redesigned. Its envelope/reconstruction - particularly its facades multifunctional optimization, thermal behavior and thermal load control, day-lighting and solar thermal as well as eventually PV electricity production - is of significant importance for the further city energy efficiency improvement.

Implementation of building performance simulation in rational planning, entailing the matching of energy demand and supply in order to assist sustainable energy management development based on energy efficiency and renewable energy technologies implementation, has resulted in recently finished reconstruction of the UŠĆE Tower.



**Fig. 1 General and aerial view of the UŠĆE Tower in Belgrade**

It has been demonstrated that effective demand side integrated resource planning, encompassing integrated energy efficient - sustainable building planning, combining new urban segments, implementing renewable energy/materials sources, creative energy conscious solutions, offer excellent opportunities for demonstration of the principles of sustainable development in the urban areas. Thus, in addition to its very distinct importance for the UŠĆE building and site sustainability development, this project and finished reconstruction have more general impact: promotion of the integrated building engineering approach, efficient energy use and resources conservation, as well as environment protection at the Belgrade City and regional level. Additionally strategic objectives addressed are the reduction of greenhouse gases and pollutant emission, and the security of energy supply.

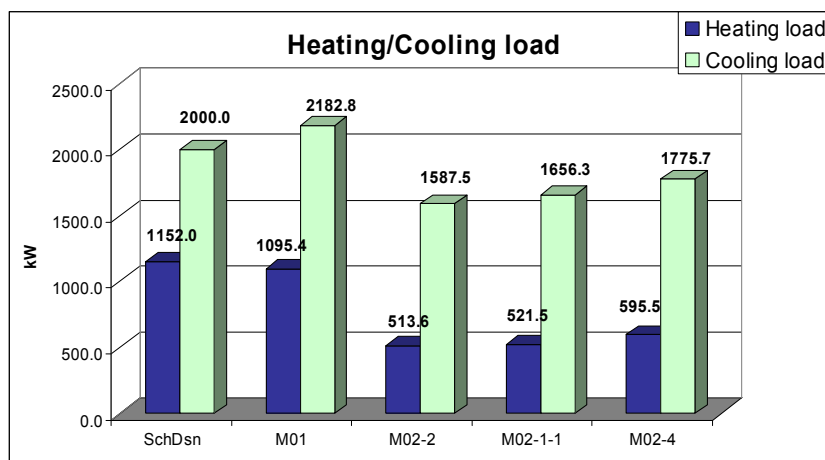
To approach energy optimization of the USCE Tower, different options/models of its envelope and construction have been studied by BPS - Building Performance Simulations. Analyzed are in the hydrometeorological conditions defined for Belgrade TMY – Typical Meteorological Year: its dynamics of thermal behaviour, energy loads, predicted total and specific energy consumption, daylighting and artificial lighting, PCM thermal storage, energy efficiency, and energy related costs. Simulations had been performed using EnergyPlus, TRNSYS, and Adeline.

The results of the UŠĆE Tower - envelope and construction energy optimization study are given here. Three main constructions options have been analyzed: Scenario I: Façade without

parapet, Scenario II: Façade with parapet, and Scenario III: Advanced Construction of the Scenario I with the Façade/HVAC System's Energy Efficiency Improvements Measures.

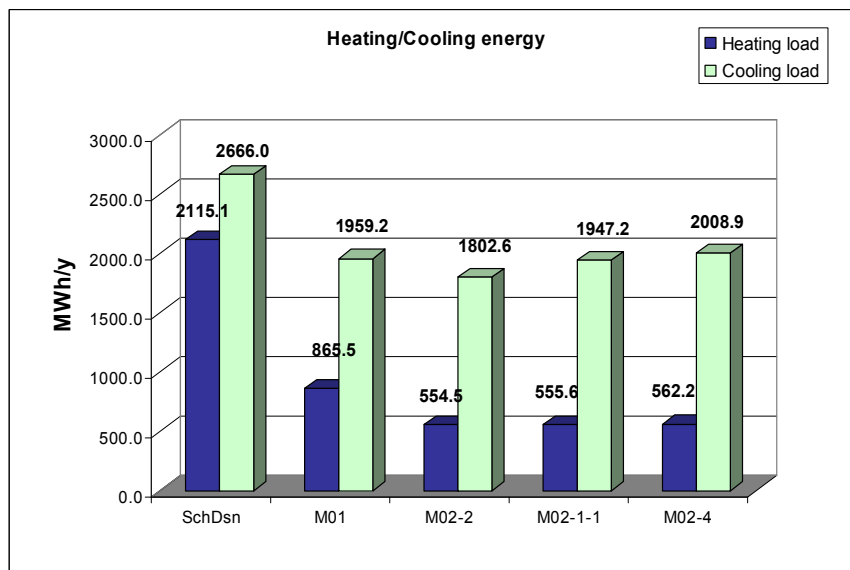
The final level optimization covered 5 different wall structure/façade glazing combinations, which have been selected through preliminary screened 11 models. These glazing types are as follows: MScheme Design; M01 Standard double glazed; M02-1-1 Pilkington 66/33 on one façade and 50/25 on other façade; M02-2 Pilkington 50/25; and M02-4 Glaverbel-Azur Planibel TOP N. After detailed comparison of all results, as the most prospective, with significantly reduced installed capacities, as well as reduced energy consumption for both heating and cooling, are selected models MO2-1-1, MO2-2 and MO2-4.

To elucidate differences and easily focus on optimal solution, there is graphic presentation in a form of diagrams for comparative analysis presented in Fig. 2 and 3.



**Fig. 2 Predicted peak cooling and heating loads**

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**Fig. 3 Predicted annual cooling and heating energy usage**

Percentage reductions in heating loads/heating energy usage from the original Scheme Design are for models MO2-2, MO2-1-1, and MO2-4, which are 55.4/73.8, 54.7/73.7, and 48.3/73.4 respectively. Reductions in cooling loads/cooling energy usage for the same models are respectively 20.6/32.4, 17.2/27.4 and 11.2/24.6 and the total energy savings are also respectively 50.7, 47.65 and 46.22%.

Thus the USCE Tower energy efficiency optimization did confirm that commercial office buildings use the most of energy supply for air-conditioning systems, ventilation and lighting systems. Controlling day-lighting and window's or glazing solar heat gains, enabled creation of extraordinary comfortable and "productive" indoor environment beside important energy savings and improvement of building's energy efficiency. Obtained savings both in loads and annual energy use, encouraged other investors to apply similar BPS approach in their project development.

**Natural and Mixed Ventilation Design via CFD and Architectural Modeling /6/.** Urban design of the University Block 32 in New Belgrade was planned as a structure of seven groups of buildings, car pathways and footpaths inside, as well as an underground garage below the whole building block.



**Fig. 4. View of the Block 32 building structure with atrium.**

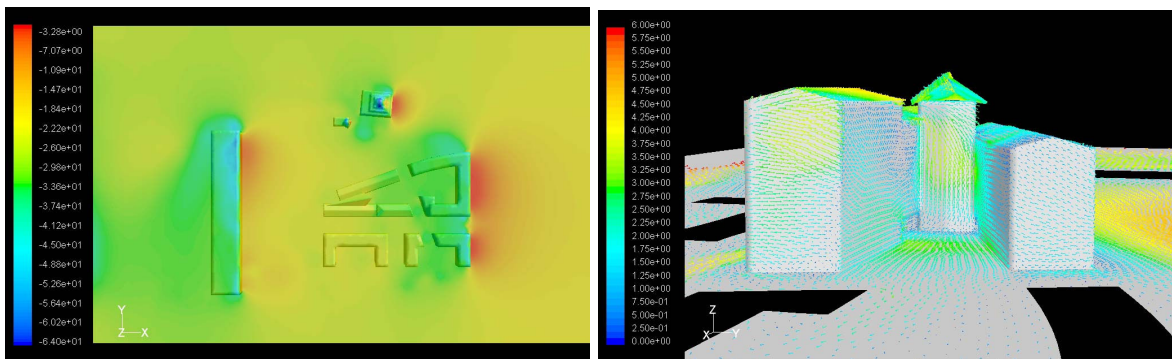
The atrium concept for a part of the building structure was determined by the design conditions and offers a specific technical and technological solution in order to achieve necessary comfort of the interior space. The main problem of the architectural concept was the issue of the indoor air quality, and the architectural modeling - design approach has been searched trying to find the adequate strategy

Performed study, aimed to the buildings complex energy efficiency optimization, demonstrated that numerical simulations and computational fluid dynamics can be usefully integrated with architectural modeling, providing designers with a powerful single CFD based architectural modeling and design framework /6/. The CFD investigation goal was to determine the wind influence and relevant pressure conditions in order to determine natural ventilation effects in the building envelope structure.

Ventilation of residential area of both buildings leaning on the atrium, has been planned to occur by the extraction of the polluted air from apartments into the atrium, and using the mechanism of natural ventilation, by further displacement into the atmosphere.

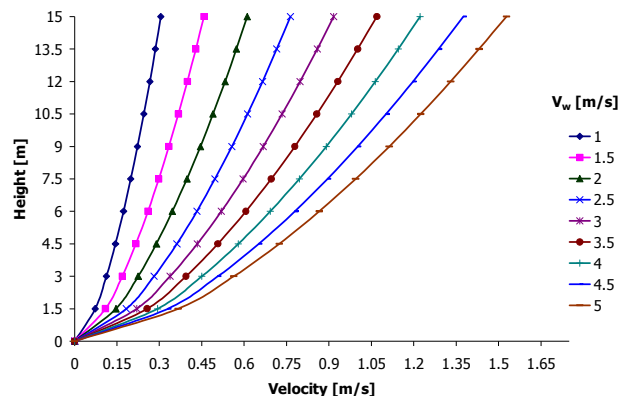
To get insight in the airflow within the whole building block, surrounding structures in the building block were also analyzed, particularly those located on the main wind flow directions as for example the pressure distribution at the whole studied building's block domain, and the surrounding buildings which make obstacles to flow (see for example Fig. 5. left).

The main airflow stream of the northwest orientation goes along the whole surface of the lower building and the air overflows the roof all the way to the yard in front of the atrium. The atrium roof position partly prevents airflow from the back side into the atrium, but “speeding up” flow on the lower side is obvious, allowing for the modification of the referential model by enlarging the atrium lower back opening.

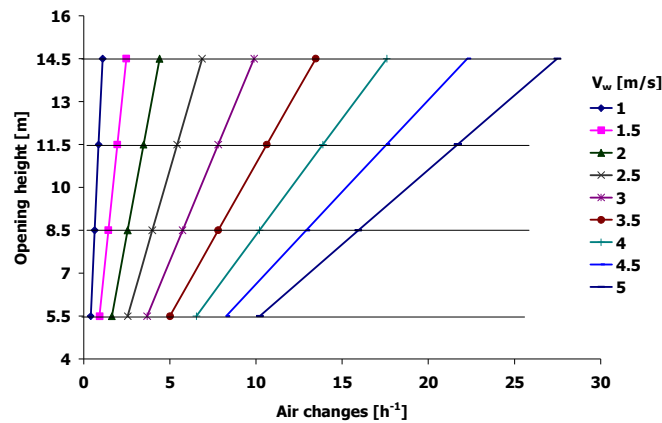


**Fig. 5. Pressure distribution at the building block for the Southeast wind (left) & velocity distribution in atrium backyard and surrounding structures (right)**

Further in the same study using CFD, has been determined, for the building's block as obstacles, relevant dynamics of spatial wind's vectors distribution and related fields of air velocities and static pressures values around the building and at the building's envelope surfaces. On the diagrams in Fig. 6 and 7. are presented dependences of the inlet air velocities (m/s) (Fig. 6), and air changes ( $h^{-1}$ ) (Fig. 7) for the openings at different height (m) on the wind vector normal component intensity  $V_w$  (m/s) /6/.



**Fig. 6. Dependence of the inlet air velocities (m/s) at different height (m) on the wind vector normal component intensity  $V_w$  (m/s).**



**Fig. 7. Dependence of the air changes ( $h^{-1}$ ) at different openings height (m) on the wind vector normal component intensity  $V_w$  (m/s).**

Using these values as input data, simulation study of the apartment indoor air flow and natural ventilation has been further performed and proceeded by the combined ventilation (natural and mechanical) control and energy efficiency optimization.

### **3. ENERGY EFFICIENCY OF NEW BELGRADE'S EXISTING RESIDENTIAL BUILDINGS**

#### **3.1. New Belgrade Residential Buildings - Social Housing Status**

Architectural and energy condition of buildings and poor social and economic status of tenants determine the approach towards improvement. Namely, we go through a period of inconsistent value systems regarding architectural and urban planning practice in Serbia, which leaves certain consequences on the valuable architectural and urban heritage of New Belgrade. The compact, reduced and space-saving building construction, large green surfaces, good ventilation and abundance of sunlight, urban complexes characteristic for the time of their construction, are the qualities that should be recognized and preserved. Unfortunately, the construction wave during the 1990s and 2000s was not always appropriate regarding the specific urban context of New Belgrade.



**Fig. 8. New Belgrade's Residential Buildings Blocks**

In the meantime, numerous residential buildings erected during the period of intensive construction in New Belgrade, from 1950s to 1980s, have become dilapidated and completely untended (Fig. 8).

Many of them have visibly damaged façades, moisture penetration into the walls and lack of indoor comfort, primarily inadequate air temperature with high infiltration of outdoor air, regardless of extremely high energy consumption for heating from the Belgrade district heating system and high consumption of energy for air-conditioning units (Fig. 9.), leading to the alarming increase of peak loads in the electricity network during the summer period.

On the other hand, dilapidation and decrepitude of buildings cause a sense of desertedness and rejection as well as a lack of hope that changes are possible, since there are no adequate institutions that would offer citizens the models for solving their inadequate housing conditions. Therefore, when there are individual initiatives for changes, the most common reactions of tenants are non-involvement in joint activities or skepticism, which eventually results in a severe *status quo* situation.

At the same time, these buildings are the ones that represent the identity of New Belgrade, and it is necessary to find a solution for the future architectural revitalization, not only in order to preserve the buildings, but also to improve standards, harmonization and socialization, especially for young people at the time of dramatic social and economic changes and appearance of new principal social values.

Tenants, especially those who have become the owners of their flats, have considerably changed their attitude towards the space they live in. The owners make the majority of tenants, but the tenants who do not own the flats have not changed their attitude to the property, which is not private or their personal. There is no one who would take proper care of flat maintenance and housing quality improvement.



**Fig. 9. Façades of the building AP 23-35 with visible damage and outdoor elements of air-conditioning units**

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New Belgrade residential buildings area is covering 4.096ha. Within these exclusively high rise residential buildings are approx 90.000 dwellings with total dwellings area of 5.000.000 sq. meters. Average dwellings area is 67 sq. meters. 90 % of dwelling are within Belgrade's District Heating System.

The City Housing Company with 220 employees, whereof approx. 180 those who are employed on a full-time basis, in charge of 13,226 buildings with about 262,045 flats, can hardly meet the basic maintenance demands, and cannot possible make plans for necessary reconstruction and revitalization of buildings and improvements in regard to the current needs for energy efficient heating and increasing cooling demands during the summer.

There are no business organization which, in addition to maintenance and improvement, deal with the planning and construction of such social housing buildings and flats in Belgrade. On the other hand, the tenants, who mainly own their flats, lack experience in independent management, decision-making and problem solving, after the decades of socially-owned property and, consequently, problems in buildings remain unsolved and even more severe.

When identifying the method for the project development, it is necessary to have in mind the financial standing of tenants, which is often very diverse, and, therefore, one cannot expect equal participation of tenants in financing the solutions for their buildings. Left to their own resources, tenants sometimes choose quick, but often inadequate solutions, allowing the private investors to construct a new floor on their building for the compensation in the form of financing the solution of their current problems in the building.

It can be certainly expected that the project of architectural improvement of buildings (improvement of energy efficiency – improvement of indoor environment and comfort, as well as provision of cleaner and healthier outdoor environment), would bring positive social changes and reduce some social problems.

According to the above-mentioned, there is a need to find and provide tenants or the municipality with a possible “good practice” model for solving the above-mentioned problems, by a well-established institutionally organized system, which would provide high-quality maintenance of buildings, but also constant care for necessary improvements regarding the reduced energy consumption, better indoor environment, maintenance of green environment of the existing buildings and plans for construction of new residential buildings of the construction standard level which is financially suitable for the numerous group of young and new inhabitants of Novi Beograd. Additionally, the application of energy efficiency principles to reconstruction (retrofitting) could be a great motivation for tenants and, generally, for inhabitants of Novi Beograd to be personally involved.

### **3.2. Refurbishment Project Proposal Preparation**

The aim of the project is an architectural revitalization (reconstruction, retrofitting) through the application of measures and technologies for improving and optimization of energy efficiency of residential buildings in New Belgrade, for the purpose of providing energy efficiency on the quality level which will ensure cost effective integration of renewable energy sources - RES utilization.

As the project initiative originates from the tenants of a four-floor building with 7 entrances and three substations of the district heating system of “Beogradske elektrane” (Belgrade Power Plants), situated in 23 – 35 Aleksinačkih Rudara Street (hereinafter referred to as AP23-35), this building was chosen as a typical residential building of New Belgrade. This building will be an object of the research of several potentially interesting models for the implementation of the measures intended to improve energy efficiency and identify a possibility to optimize energy efficiency of the existing residential building for the RES integration.

Within the preparation of the project implementation proposal, the following activities were performed:

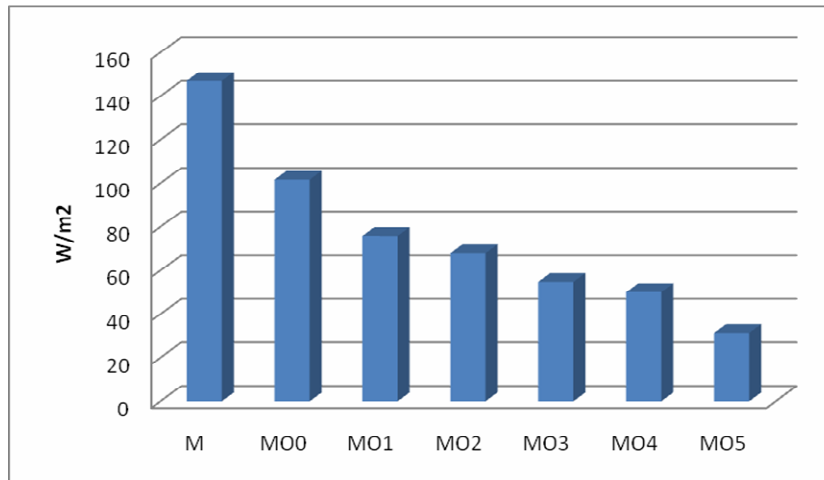
- a. The original architectural and design documentation of the building AP23-35 was collected,
- b. All relevant measures from the architectural drawings were taken and entered in the 3-D computer model of the building.
- c. The construction physics of the building was analyzed according to the design documentation,
- d. Scenarios – models for retrofitting outer walls of buildings and replacement of joinery and glazing were defined,
- e. For a couple of scenarios – models of the retrofitted building, computer models were created and calculations were made, for meteorological data of the typical meteorological year (TMY) of Belgrade, such as:
  - total and specific (per surface unit) heat losses of the building – thermal load of heating and heat gains - thermal load of cooling; total annual energy demand for heating and cooling and appropriate specific value per surface unit.

### **3.3. Project Feasibility - Preliminary Analysis of Possible Effects**

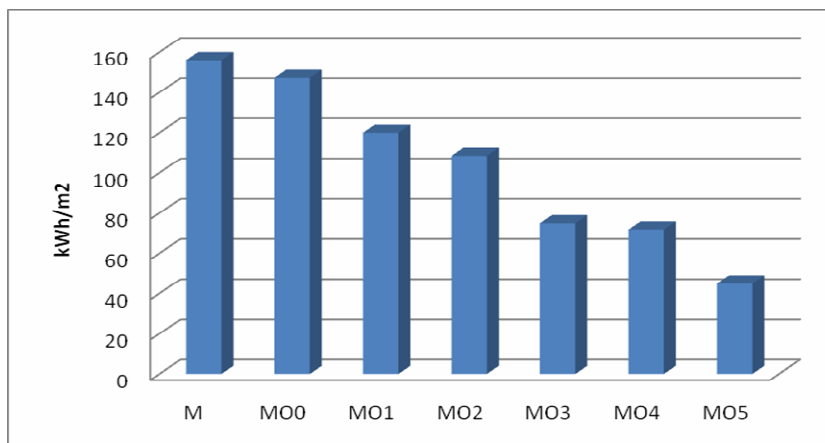
The calculations defined under the time  $e$ . in the previous section 3.2. were made for the meteorological data of the TMY - Typical Meteorological Year of Belgrade, for the following construction models of the building AP 23-35:

- MO1 – model of the building according to the design of 1969;
- MO0 – model of the building approximately as it is today;
- MO1 - MO5 are the models of the building with improved energy efficiency construction;
- M – model in accordance with the data obtained from “Beogradske elektrane” (Belgrade Power Plants) regarding energy consumption of the building concerned.

The results of the performed calculations are presented on Fig. 10 - 12. The diagram on Fig. 12. shows that, in relation to the basic model MO0 in this first rough presentation, it is possible to reduce the specific heating power demand by approx. 4 times, and that the rated power in the substation of the district heating system is approx. 40% higher than required.

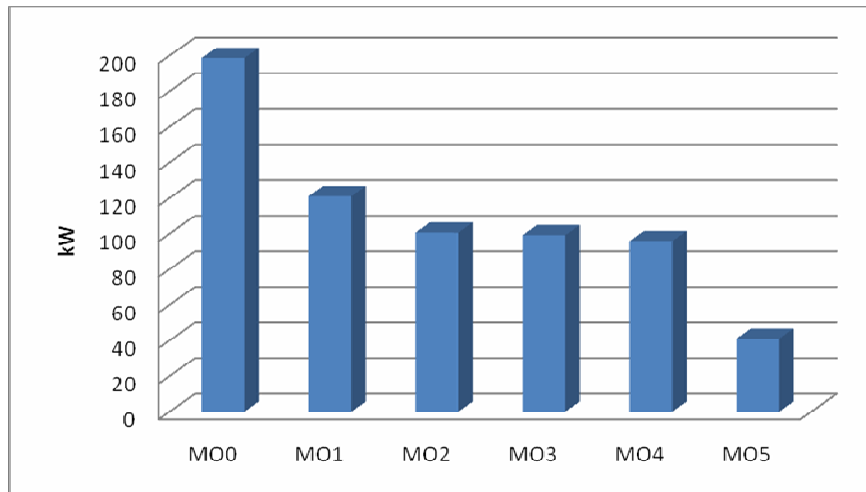


**Fig. 10. Specific heat losses**



**Fig. 11. Specific annual heating power demand**

The diagram on Fig. 11. shows that the annual energy consumption for heating might be reduced by 4 times only by improving the façade envelope. Furthermore, there is a good accordance of the results of energy consumption determined by the dynamic simulations with the consumption measured by “Beogradske elektrane” (Belgrade Power Plants).



**Fig. 12. Cooling power demand**

The diagram on Fig. 12. shows the results of the required cooling or air-conditioning power, indicating to possible decrease of the same by approx. 5 times. It is interesting that the cooling power demand determined by the simulations is very close to the power of installed air-conditioning units.

The presented preliminary results more than convincingly confirm and emphasize the significance and magnitude of possible effects of the project implementation, not only on the energy of residential buildings, but on the entire complex energy consumption in New Belgrade.

In addition these results are excellent approval that approach to refurbishment can successfully lead to the cost-effective integration of solar energy utilization. Namely, not only reduced loads by the refurbished envelope's thermal features, but the fact that building's envelope construction attacked by the moisture penetration needs intervention/reconstruction to the ventilated façade offer challenge to perform "Synergetic refurbishment approach" increasing energy efficiency and integrated solar energy utilization. Concerning the construction works and existing building structure statics, low weight PV cells and PV system's simplicity would make it the most appropriate of the solar technologies candidate to be integrated in renewed façade (/6/-10/).

### **3.4. Tasks and Programme Segments**

The basic tasks that should be performed in order to achieve the aim of the project implementation are as follows:

- a. To investigate and determine the models and energy efficient optimal solutions for improving the envelope and the entire building structure, optimal architectural solutions, and optimal technologies of re-construction works for AP 23-35 in regard to relevant limitations.
- b. To investigate and determine possible and optimal improvements of the technical systems of AP 23-35: lighting and sanitary hot water supply, and of the heating and air-conditioning systems of AP 23-35 in regard to energy efficiency of the thermal and

electrical energy supply and energy supply of the municipality of New Belgrade and the City of Belgrade, as well as in regard to other relevant limitations.

- c. To investigate and determine possible and optimal solutions of integrating solar energy by photovoltaic conversion, and for full coverage of loads by RES to assess energy of underground water and ground – soil as well as wind energy, in regard to relevant limitations in energy supply or operation of the technical systems of AP 23-35.
- d. Relevant limitations of the optimizations specified under the given items *a* to *c*, are the following: reduction of heat losses and heating demands, and heat gains and cooling demand during the summer, or reduction of rated powers, required investments, possible annual energy savings of final and primary energy, i.e. efficient method of reaching high level of energy efficiency of the building according to the requirements of the implementation standards for the EU Directive on Energy Efficiency of Buildings.
- e. Performance of analysis and typisation of all the existing housing blocks in New Belgrade according to architecture, construction type, time and quality, including materials and technical services, according to the standards effective at the time of construction.
- f. Measuring of thermal characteristics of the building structure of given building types, including the building AP 23-35, and by application of the previously verified method within the analysis of the selected building AP 23-35 in the project proposal, analysis and determination of optimal improvements though reduction of energy consumption on the level of other typical buildings in New Belgrade.
- g. Determination of possible reduction of CO<sub>2</sub> emission and emission of other greenhouse gases, which could be achieved by the project implementation, as well as determination of possible overall economic, environmental and social advantages, i.e. total benefits of the approach to the sustainable development of New Belgrade, which can be achieved by the project implementation.
- h. Determination of possible effects of the implementation of the project results on the improvement of energy efficiency of the district heating system of New Belgrade and vice versa, the effects on the improvement of energy efficiency of “Beogradske elektrane” (Belgrade Power Plants) or relevant subsystems and the entire system of the district heating in New Belgrade.
- i. Based on the previous item and all performed analyses and optimizations of the given scenarios of using renewable energy sources on the building level, determination of the approach towards energy efficient and sustainable introduction of the renewables and distributed generation, i.e. cogeneration and trigeneration in the system of the central generation of electric and thermal energy of the urban complex of New Belgrade.

In order to provide numerous necessary data on the building or buildings and the existing management system, and in order to identify all the problems relevant for making conclusions and implementing the study results during the study preparation process, and in order to establish a form of the structure of the new institutional business system (private, public or combined public private partnership) which would be in charge of spreading the implementation of the results and leading the further development of the project on the level of New Belgrade and the entire Belgrade city, a good communication and active participation

of all responsible and potentially interested parties are planned during the preparation of the study.

These participants include: the building tenants; the Municipality, the City; donors who support such type of projects; interested private sector. Study project team should include beside experts in BPS, energy efficiency and RES technologies, person carrying out related and relevant activities within the competent public institutions: The City Housing Company, Belgrade Power Plants, Belgrade Electric Power Distribution Company, Public Utility Company for Greenery, Water Supply and Sewerage Company, Energy Agency and Energy Efficiency Agency.

### **3.5. Architectural and Energy Efficiency Approach Concepts & Additional Benefits**

In addition to the achievement of the project goals and expected effects of the project implementation, which would undoubtedly classify New Belgrade among a prestigious group of towns heading towards the sustainable “Kyoto cities”, the implementation of the preliminary architectural and energy related interventions in the building would have the following additional benefits: increase of the flat (housing space) market value; positive social effects – motivation of tenants to participate in the project and promotion of social environmental awareness and action for the purpose of spreading similar ideas, programmes and projects; activation of common surfaces in the building – for example, the green flat roof and space to be used by all the tenants; urban planning improvement – improved quality of the building and its environment has effect on the quality of wider urban environment.

The application of energy efficient principles in retrofitting the existing buildings may become a brand of New Belgrade, which, being one of the richest municipalities in the country, may become the leader in promoting the sustainable urban development, especially due to its valuable architectural advantages and potentials, such as:

- Flat roofs are potential surface for green roofs and common space for activities of all the tenants or for new energy efficient roof floor suitable for characteristic architecture of New Belgrade or global innovational architectural tendencies;
- Green surfaces should not be considered as unused potential surfaces for construction; they rather represent a true treasure, especially at the time of enormous increase of traffic, creating a more pleasant microclimate and thus contributing to the location quality and price;
- Simplified and sometimes “aloof” façades of the modern architecture as from the 1950s represent a good potential for possible interventions in order to improve energy efficiency and architectural quality of buildings.



**Fig. 13. Green surfaces; green roof and integration of photovoltaic panels**

Among possible interventions for architectural and energy reconstruction of AP 23-35, which would have multifunctional significance in terms of energy, environment and society, the following interventions on a typical flat roof have been considered:

- GREEN ROOF with a green garden to be used by tenants – reconstruction of the existing flat roof into a green roof with a passable terrace and partial covering with pergolas or eaves with integrated photovoltaic cells and fence in the form of a lattice with green trailing plants;
- PARTIAL CONSTRUCTION of spaces for children and older tenants on the existing roof, with greenery segments on the common terrace and complete covering with a flat panel that supports the green roof;
- COMPLETE CONSTRUCTION of a new floor for residential purposes, ending with the green roof or the roof plate that contains photovoltaic panels for electricity generation.



**Fig. 14. Green roof; wind turbines and PV panel integration in the façade**

The 3D presentations of the preliminary created architectural and energy designs are given on Fig. 13. and 14. as illustrations of attractiveness of possible concepts of the future solutions – façade improvement, roofs with greenery, additional space to be used by tenants for socializing, and integration of photovoltaic panels for using solar energy for electricity generation and urban wind turbines – air-conditioning units.

**Rough estimation of potential PV electricity installed power and production.** In the Table 1. are given relevant characteristics of PV panels selected for the AP 23-35 façade integration.

For the Belgrade TMY – Typical Meteorological Year, implementing BPS by dynamic simulations have been determined incident solar global radiation and potentially produced electricity (Table 2.) by the PV panels integrated in the building’s facade (Fig. 14 right).

**Table 1. Characteristics of selected photovoltaic cells**

Module type		BP SX 3195
Maximal power	W	195
Voltage on $P_{max}$	V	24,4
Current at $P_{max}$	A	7,96
Short-circuit current	A	8,6
Open-circuit voltage	V	30,7
Nominal operating cell temperature	°C	47
Number of cells		72
Area	m <sup>2</sup>	1.41

**Table 2. Monthly sums of incident solar global radiation on vertical surface per m2**

Orientation	Incident Solar Radia.		Produced Electricity	
Incident angle	[90°]		[90°]	
Month	kWh/m <sup>2</sup>	kWh	kWh/m <sup>2</sup>	kWh
January	23,1	30316	2,2	2819
February	40,6	53219	3,8	5015
March	61,1	80046	5,8	7640
April	69,9	91566	6,8	8859
May	86,7	113587	8,5	11118
June	96,4	126347	9,5	12436
July	101,2	132587	10,0	13119
August	84,2	110348	8,3	10897
September	66,1	86544	6,5	8476
October	46,3	60708	4,5	5858
November	26,2	34323	2,5	3245
December	18,4	24049	1,7	2240
$\Sigma$	<b>720.3</b>	<b>943646</b>	<b>70.0</b>	<b>91729</b>

**Table 3. Building integrated PV area, installed power and yearly produced electricity**

Orientation	Angle	Surface Area	PV Area	Inst. Power	Produced Energy/year
	Deg.	m <sup>2</sup>	m <sup>2</sup>	kW	kWh
West	90	700	697,9	96,5	49015
West	90	370	366,6	50,7	25908
West	90	240	239,6	33,2	16805

For the total installed area on the west oriented facade of 1310 square meters total installed PV power potential for selected PV cells/panels is 179,7 kW. One third of that power would be enough to power all existing AC split units in the same building. Thus, obtained result is more than significant justification to proceed with development of proposed project on the “Cost Effective Solar Integrated Refurbishment of Urban Residential Buildings in New Belgrade”.

### **3.6. Programme and System Areas of the Project**

Within the project implementation, concurrently with the basic activities defined in the section 3 of the project proposal, other activities would be carried out, those important for the programme interconnection and functioning along with the development and contingent consideration of necessary modifications of the housing system management on the level of the municipality of New Belgrade and the entire city of Belgrade.

Also, a special attention would be paid to the analysis of advantages as well as disadvantages or obstacles to the development of the project implementation and possible applications of the project results. The identification of main barriers would create a basis for the method of their consideration and elimination.

According to the present experience in Serbia, following barriers to the energy efficiency improvement and introduction of solar and other renewable energy sources must be faced: organizational and political barriers, legislation barriers, financial barriers, administrative barriers and still information-related barriers.

As stated earlier in this paper (Section 3.4.), in order to provide the project input data, it is necessary to have a mutual cooperation of all the participants – the project developer, the municipality, the city and other competent public institutions: Public Housing Company, Belgrade Power Plants, Belgrade Electric Power Distribution Company, Public Utility Company for Greenery, Water Supply and Sewerage Company, but other institutions and governmental bodies should also be involved, such as the Ministry and Agency for Energy and the Ministry for Area Planning and Environment Protection and others, when it is necessary to identify the barriers and measures for their elimination.

## **4. CONCLUSIONS**

The aim of performed study was to justify the proposed project on the “Cost Effective Solar Integrated Refurbishment of Urban Residential Buildings in New Belgrade”. Obtained results are reliable justification of the significance of the proposed project and deliverables which could be planned and expected if the it comes to realization.

Project “Cost Effective Solar Integrated Refurbishment of Urban Residential Buildings in New Belgrade” is to be realized and in addition to its direct results, it could provide Belgrade, Serbia and broader region with series of BPS and RES dynamic performance simulations results/parametric data, which could be basis for the preparation of future regulations on energy efficiency of buildings.

Aimed, also to the establishment of a platform for economic, effective and efficient implementation of the EE Directive on Energy Efficiency of Buildings, its implementation

could directly assist in creating a relevant database for required analyses, that could be a basis for the formulation of guidelines, incentives, regulatory issues, and appropriate standards for improving energy efficiency in residential buildings in Serbia.

Finally, it is to be stressed also, that not only for the refurbishment processing, but generally for certain segments of design, construction and utilization of building integrated RES systems, necessary are new, specific codes and standards to be developed, as well as to be addressed special design problems and introduced further creative innovations for precisely defined requirements.

## REFERENCES

1. Todorovic M. S.: *Sustainability Research and Education via Interdisciplinarity and Harmony*, International Conference on Advances in Infrastructure for Electronic Business, Science, and Education on Internet, Proceedings, F 3-6, paper No. 161, pp. 1-10, Scuola Superiore G. Reiss Romoli, L'Aquila, 2000.
2. Todorovic M. S.: *A Global Space for Building Performance Dynamic Simulation Science and Technology - Network of Excellence for Sustainable Building's Integrated Projects*, International Building Performance Simulation Association Conference, Chicago, 2003.
3. Todorovic M. S.: *RES Integrated Building's Performance Simulation and Energy Efficiency Optimization for Sustainable Local and Regional Development*, ASHRAE Technical Committee Seminar - RES Integrated Sustainable Buildings, Kansas City, 2003.
4. Todorovic M. S. and others: *USCE Tower - Building Envelope and Construction Energy Optimization Study*, EnPlus/DERES-LTT, Euro Construction, Belgrade, 2003.
5. Todorovic M. S.: *Feasibility Study with Preliminary Design for Solar Energy Utilization for Heating in Special Hospital of the SPA Rusanda*, SEEA - EAR, Belgrade, 2006.
6. Todorovic M. S.: *Natural and Mixed Ventilation Design via CFD and Architectural Modelling*, International Journal of Ventilation, Vol. 5, Issue 4., pp. 447 – 458, 2007.
7. Todorovic M. S.: *Building Integrated PV Air-conditioning and Water Heating in Special Hospital of the SPA Rusanda*, Passive and Low Energy Cooling Conference, Crete, Greece, 2007.
8. Todorovic M. S.: *Dynamic Exergetic System Performance: Prediction and Validation*, Seminar Advanced Applications for New Heights in Net-Zero-Energy Buildings, ASHRAE Conference, New York, 2008.
9. Todorovic M. S.: *Performance Determination of PV, Thermal and Hybrid PV/Thermal Integrated in Buildings Structures*, Seminar Advanced testing Procedures and Standardization of Solar PV and Thermal Components and their Buildings Integration - International Harmonization of Approaches, ASHRAE Conference, Salt Lake City, 2008.
10. Todorovic M. S.: *Performance Prediction and Validation of Buildings Structures Activation and Multifunctionality*, COBEE – the First World Conference on Building Energy and Environment, Dalian, China 2008.
11. Todorovic M. S.: *RENEX BUILDINGS-Renewable Energies Network of Excellence for Sustainable Buildings Integrated Projects*, EoI, EU-FP6, <http://eoi.cordis.lu/docs/into25800.doc>.

## ABSTRACT

This paper is addressing technical advances in building's refurbishment introducing energy efficiency and RES - renewable energy sources – solar PV and thermal, wind, geothermal, biomass, solid wastes.

It discusses importance of BPS - Building Performance Simulation for wider energy efficiency and RES implementation in urban context, in residential buildings, leading to sustainable buildings and sustainable local and regional development. It considers specifically practical experience in BPS approach to sustainable buildings design and redesign aimed to the buildings refurbishment. Presented are a few case studies in Serbia focusing: optimization of building envelope and structure energy efficiency, natural and mixed ventilation optimal control, as well as simulation of PV integrated building facade in synergy with the facade structure energy efficiency optimization. Further, activities, and whole structure of the project proposal for the “Cost Effective Solar Integrated Refurbishment of Urban Residential Buildings in New Belgrade” have been presented, including some preliminary study results justifying the significance of the proposed project content. As an example of prospective BPS implementation in rational city energy system planning (particularly its District heating/cooling) it could assist in the future city-wide sustainable energy management.

Finally, it has been shown ‘smart-optimization” approach to refurbishment can successfully lead to the cost-effective integration of solar energy utilization. Synergy of needs for façade/envelope’s thermal features improvement, and its moisture removal by air ventilation offers challenge to perform “Synergetic refurbishment approach” increasing energy efficiency and integrated solar energy utilization. Concerning the construction works and existing building structure statics, low weight PV cells and PV system’s simplicity would make it the most appropriate of the solar technologies candidate to be integrated in renewed façade.

**Keywords:** energy efficiency, Building performance simulations, buildings dynamic performance prediction, renewable energy sources, PV solar conversion