

CONFERENCE
PROCEEDINGS

**5th INTERNATIONAL
ACADEMIC CONFERENCE ON
PLACES AND TECHNOLOGIES**

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PLACES AND TECHNOLOGIES 2018

THE 5TH INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

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TABLE OF CONTENTS

IMAGE, IDENTITY AND QUALITY OF PLACE: URBAN ASPECTS

| | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| THE EFFECT OF BEHAVIOURAL SETTINGS ON THE REGENERATION OF URBAN DYNAMIC ARTS, CASE STUDY: TEHRAN AZADI SQUARE Yasaman NEKOU Ali Entezarinajafabadi | 3 |
| DEVELOPMENT SCENARIOS OF THE ZAGREB'S SATELLITE TOWN DUGOSELO - "THE CITY OF THE FUTURE" Lea Petrović Krajnik Damir Krajnik Ivan Mlinar | 11 |
| SUSTAINABILITY OF MODERN-DAY UTOPIAS AS SEEN IN MASS MEDIA Aleksandra Til | 18 |
| URBAN DENSIFICATION OF THE POST-SOCIALIST CITY AND ITS IMPLICATIONS UPON URBAN STRUCTURE: A STUDY OF NIS, SERBIA Milena Dinić Branković Ivana Bogdanović Protić Mihailo Mitković Jelena Đekić | 25 |
| MUSEUM QUARTERS VS CREATIVE CLUSTERS: FORMATION OF THE IDENTITY AND QUALITY OF THE URBAN ENVIRONMENT Ekaterina Kochergina | 35 |
| URBAN NON-MECHANICAL CODE AND PUBLIC SPACE Aleksandra Đukić Valentina Milovanović Dubravko Aleksić | 43 |
| ADDRESSING THE SOCIO-SANITARY EMERGENCY IN AFRICA: THEORIES AND TECHNIQUES FOR DESIGNING A COMMUNITY HEALTH CENTRE IN MALI Adolfo F. L. Baratta Laura Calcagnini Fabrizio Finucci Cecilia M. L. Luschi Antonio Magarò Massimo Mariani Alessandra Venturoli Alessandra Vezzi | 50 |
| THE NETWORK OF LOCAL CENTERS AS A TOOL FOR STRENGTHENING THE SUPER-BLOCK COMMUNITIES: BELGRADE VS. ROME Predrag Jovanović Aleksandra Stupar | 58 |
| TRANSFORMATION OF IDENTITY OF SAVAMALA DISTRICT IN BELGRADE Aleksandra Đukić Jelena Marić Tamara Radić | 66 |
| THE CULTURE OF MEMORY AND OPEN PUBLIC SPACE - BANJA LUKA Jelena Stankovic Milenko Stankovic | 73 |

IMAGE, IDENTITY AND QUALITY OF PLACE: ARCHITECTURAL ASPECTS

| | |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| IMPROVEMENT OF SOCIAL HOUSING THROUGH THE MIXING CONCEPT IMPLEMENTATION Nataša Petković Grozdanović Branislava Stoilković Vladana Petrović Aleksandar Keković Goran Jovanović | 83 |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|

IMPROVING THE IDENTITY OF NON – SURROUNDED COMMUNAL SPACES WITH USING ARCHITECTURAL PROGRAMING. CASE STUDY: NAJAF ABAD (ESFAHAN), IMAM KHOMEINI SQUARE 91
Ali Entezarinajafabadi YasamanNekoui

A CONTRIBUTION TO THE STUDY OF THE ARCHITECTURAL OPUS OF NATIONAL STYLE WITH MODELS IN FOLK ARCHITECTURE AND NEW INTERPOLATIONS 100
Katarina Stojanović

SHOPPING CENTRE AS A LEISURE SPACE: CASE STUDY OF BELGRADE 108
Marija Cvetković Jelena Živković Ksenija Lalović

ARCHITECTURAL CREATION AND ITS INFLUENCE ON HUMANS 119
Nikola Z. Furundžić Dijana P. Furundžić Aleksandra Krstić-Furundžić

INNOVATIVE METHODS AND TECHNOLOGIES FOR SMART(ER) CITIES

POTENTIAL OF ADAPTING SMART CULTURAL MODEL: THE CASE OF JEDDAH OPEN- SCULPTURE MUSEUM 131
Sema Refae Aida Nayer

AN INNOVATIVE PROTOCOL TO ASSESS AND PROMOTE SUSTAINABILITY IN RESPONSIBLE COMMUNITIES 140
Lucia Martincigh Marina Di Guida Giovanni Perrucci

GEOHERMAL DISTRICT HEATING SYSTEMS DESIGN: CASE STUDY OF ARMUTLU DISTRICT 148
Ayşe Fidan ALTUN Muhsin KILIC

DATA COLLECTION METHODS FOR ASSESSMENT OF PUBLIC BUILDING STOCK REFURBISHMENT POTENTIAL 157
Ljiljana Đukanović Nataša Čuković Ignjatović Milica Jovanović Popović

SMART HOSPITALS IN SMART CITIES 165
Maria Grazia Giardinelli Luca Marzi Arch. PhD Valentina Santi

INNOVATIVE METHODS AND TOOLS

PRIMARY AND SECONDARY USES IN CITIES – PRINCIPLES, PATTERNS AND INTERDEPENDENCE 175
Marina Čarević Tomić Milica Kostreš Darko Reba

MODELLING AND ANALYSING LAND USE CHANGES WITH DATA-DRIVEN MODELS: A REVIEW OF APPLICATION ON THE BELGRADE STUDY AREA 183
Mileva Samardžic-Petrović Branislav Bajat Miloš Kovačević Suzana Dragičević

INNOVATIVE DECISION SUPPORT SYSTEM 190
Mariella Annese Silvana Milella Nicola La Macchia Letizia Chiapperino

| | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| URBAN FACILITY MANAGEMENT ROLE | 196 |
| Alenka Temeljotov Salaj Svein Bjørberg Carmel Margaret Lindkvist Jardar Lohne | |
| ANALYSES OF PUBLIC SPACES IN BELGRADE USING GEO-REFERENCED TWITTER DATA | 205 |
| Nikola Džaković Nikola Dinkić Jugoslav Joković Leonid Stoimenov Aleksandra Djukić | |
| SENTIMENT ANALYSIS OF TWITTER DATA FOR EXPLORATION OF PUBLIC SPACE SENTIMENTS | 212 |
| Miroslava Raspopovic Milic Milena Vukmirovic | |
| CITIES AND SCREENS: ARCHITECTURE AND INFORMATION IN THE AGE OF TRANSDUCTIVE REPRODUCTION | 217 |
| Catarina Patricio | |
| CITIZEN EMPOWERMENT, PUBLIC PARTICIPATION AND DEMOCRATIC CITIES | |
| CITIES AS PLATFORMS FOR SOCIAL INNOVATION: AN INVESTIGATION INTO HOW DIGITAL PLATFORMS AND TOOLS ARE USED TO SUPPORT ENTREPRENEURSHIP IN URBAN ENVIRONMENTS | 227 |
| Margarita Angelidou | |
| PROBLEM ISSUES OF PUBLIC PARTICIPATION IN HERITAGE CONSERVATION: GEO-MINING PARKIN SARDINIA | 235 |
| Nađa Beretić Arnaldo Cecchini Zoran Đukanović | |
| A METHODOLOGY FOR STAKEHOLDER EMPOWERMENT AND BENEFIT ASSESSMENT OF MUNICIPAL LONG-TERM DEEP RENOVATION STRATEGIES: A SURVEY WITHIN SOUTH-EASTERN EUROPEAN MUNICIPALITIES | 242 |
| Sebastian Botzler | |
| THE OPPORTUNITIES OF MEDIATED PUBLIC SPACES: CO-CREATION PROCESS FOR MORE INCLUSIVE URBAN PUBLIC SPACES | 249 |
| Inês Almeida Joana Solipa Batista Carlos Smaniotta Costa Marluci Menezes | |
| ARCHITECTURE AS SOCIAL INNOVATION: EDUCATION FOR NEW FORMS OF PROFESSIONAL PRACTICE | 255 |
| Danijela Milovanović Rodić, Božena Stojčić Aleksandra Milovanović | |
| CITY AS A PRODUCT, PLANNING AS A SERVICE | 262 |
| Viktorija Prilenska Katrin Paadam Roode Liias | |
| RAJKA: CHANGING SOCIAL, ETHNIC AND ARCHITECTURAL CHARACTER OF THE "HUNGARIAN SUBURB" OF BRATISLAVA | 269 |
| Dániel Balizs Péter Bajmócy | |
| POSSIBLE IMPACT OF MIGRANT CRISIS ON THE CONCEPT OF URBAN PLANNING | 279 |
| Nataša Danilović Hristić Žaklina Gligorijević Nebojša Stefanović | |

TOWARDS DIMINUISHING DISADVANTAGES IN MIGRATION ISSUES IN SERBIA
(FROM 2015) THROUGH PROPOSAL OF SOME MODELS 287

Eva Vaništa Lazarević Jelena Marić Dragan Komatina

ARCHITECTURAL DESIGN AND ENERGY PERFORMANCE OF BUILDINGS

APPLICATION OF ENERGY SIMULATION OF AN ARCHITECTURAL HERITAGE
BUILDING 303

Norbert Harmathy Zoltán Magyar

APPLICATION OF TRADITIONAL MATERIALS IN DESIGN OF ENERGY EFFI-
CIENT INTERIORS 311

Vladana Petrović Nataša Petković Grozdanović Branislava Stoiljković Aleksandar Keković
Goran Jovanović

DETERMINATION OF THE LIMIT VALUE OF PERMITTED ENERGY CLASS FOR
THE KINDERGARTENS IN THE NORTH REGION OF BOSNIA AND HERZEGOVI-
NA 318

Darija Gajić Biljana Antunović Aleksandar Janković

ARCHITECTURAL ASPECTS OF ENERGY AND ECOLOGICALLY RESPONSIBLE
DESIGN OF STUDENT HOUSE BUILDINGS 326

Malina Čvoro Saša B. Čvoro Aleksandar Janković

ENERGY EFFICIENCY ANALYSES OF RESIDENTIAL BUILDINGS THROUGH
TRANSIENT SIMULATION 332

Ayşe Fidan ALTUN Muhsin KILIC

INNOVATIVE TECHNOLOGIES FOR PLANNING AND DESIGN OF “ZERO-ENER-
GY BUILDINGS” 340

Kosa Golić Vesna Kosorić Suzana Koprivica

ENERGY REFURBISHMENT OF A PUBLIC BUILDING IN BELGRADE 348

Mirjana Miletić Aleksandra Krstić-Furundžić

TYOLOGY OF SCHOOL BUILDINGS IN SERBIA: A TOOL FOR SUSTAINABLE
ENERGY REFURBISHMENT 357

Nataša Čuković Ignjatović Dušan Ignjatović Ljiljana Đukanović

ARCHITECTURAL DESIGN AND NEW TECHNOLOGIES

EVALUATION OF ADVANCED NATURAL VENTILATION POTENTIAL IN THE
MEDITERRANEAN COASTAL REGION OF CATALONIA 367

Nikola Pestic Jaime Roset Calzada Adrian MurosAlcojor

TRENDS IN INTEGRATION OF PHOTOVOLTAIC FACILITIES INTO THE BUILT
ENVIRONMENT 375

Aleksandra Krstić-Furundžić Alessandra Scognamiglio, Mirjana Devetaković, Francesco
Frontini, Budimir Sudimac

| | |
|------------------------------------------------------------------------------------------------------|-----|
| INTEGRATION OF NEW TECHNOLOGIES INTO BUILDINGS MADE FROM CLT | 389 |
| Milica Petrović Isidora Ilić | |
| INTEGRATION OF SOLAR WATER HEATING SYSTEMS INTO GREEN BUILDINGS BY APPLYING GIS AND BIM TECHNOLOGIES | 394 |
| Kosa Golić Vesna Kosorić Dragana Mecanov | |
| IMPLEMENTING ADAPTIVE FAÇADES CONCEPT IN BUILDINGS DESIGN: A CASE STUDY OF A SPORTS HALL | 402 |
| Aleksandar Petrovski Lepa Petrovska-Hristovska | |
| SIMULATION AIDED ENERGY PERFORMANCE ASSESSMENT OF A COMPLEX OFFICE BUILDING PROJECT | 409 |
| Norbert Harmathy László Szerdahelyi | |

ARCHITECTURAL DESIGN AND PROCESS

| | |
|-----------------------------------------------------------------------------------------------------------------|-----|
| THE HABITABLE BRIDGE: EXPLORING AN ARCHITECTURAL PARADIGM THAT COMBINES CONNECTIVITY WITH HABITATION | 421 |
| Ioanna Symeonidou | |
| REFURBISHMENT OF POST-WAR PREFABRICATED MULTIFAMILY BUILDINGS | 428 |
| Aleksandra Krstić-Furundžić, Tatjana Kosić, PhD | |
| THE FUTURE (OF) BUILDING | 438 |
| Morana Pap, Roberto Vdović, Bojan Baletić | |
| COMPARISON OF ARCHITECTS' AND USERS' ATTITUDES TOWARD SPATIAL CHARACTERISTICS OF APARTMENTS | 445 |
| Ivana Brkanić | |
| DIGITAL VS. TRADITIONAL DESIGN PROCESS | 453 |
| Igor Svetel Tatjana Kosić Milica Pejanović | |
| CREATING THE EASTERN CAMPUS CONCEPT AT THE UNIVERSITY OF PÉCS - CONNECTED THE FACULTY OF BUSINESS AND ECONOMICS | 461 |
| Péter Paári Gabriella Medvegy Bálint Bachmann | |

BUILDING STRUCTURES AND MATERIALS

| | |
|---------------------------------------------------------------------------------------------|-----|
| SUSTAINABILITY BENEFITS OF FERROCEMENT APPLICATION IN COMPOSITE BUILDING STRUCTURES | 471 |
| Aleksandra Nenadović Žikica Tekić | |
| POSSIBILITIES OF ENERGY EFFICIENT REFURBISHMENT OF A FAMILY VILLA IN BELGRADE: A CASE STUDY | 479 |
| Nenad Šekularac Jasna Čikić Tovarović Jelena Ivanović-Šekularac | |

| | |
|-----------------------------------------------------------------------------------------------------------------|-----|
| ENHANCING THE BUILDING ENVELOPE PERFORMANCE OF EXISTING BUILDINGS USING HYBRID VENTILATED FAÇADE SYSTEMS | 485 |
| Katerina Tsikaloudaki Theodore Theodosiou Stella Tsoka Dimitrios Bikas | |
| STRUCTURAL ASPECTS OF ADAPTIVE FACADES | 493 |
| Marcin Kozłowski Chiara Bedon Klára Machalická Thomas Wüest Dániel Honfi | |
| STRATEGIZING FOR INFORMAL SETTLEMENTS: THE CASE OF BEIRUT | 500 |
| Hassan Zaiter Francesca Giofrè | |
| THE IMPACT OF USERS' BEHAVIOUR ON SOLAR GAINS IN RESIDENTIAL BUILDINGS | 509 |
| Rajčić Aleksandar Radivojević Ana Đukanović Ljiljana | |
| PRESERVATION OF ORIGINAL APPEARANCE OF EXPOSED CONCRETE FACADES, CASE STUDY: RESIDENTIAL BLOCK 23, NEW BELGRADE | 517 |
| Nikola Macut Ana Radivojević | |

ADAPTIVE REUSE

| | |
|------------------------------------------------------------------------------------------|-----|
| CONVERSION AS MODEL OF SUSTAINABLE SOLUTION FOR DEVASTATED INDUSTRIAL COMPLEXES | 529 |
| Branko AJ Turnšek Aleksandra Kostić Milun Rancić | |
| SILO CONVERSION - POTENTIALS, FLEXIBILITY AND CONSTRAINTS | 537 |
| Branko AJ Turnšek Ljiljana Jevremović Ana Stanojević | |
| ARCHITECTURE OF MULTIPLE BEGINNINGS AS A TOOL OF SUSTAINABLE URBAN DEVELOPMENT | 545 |
| Milan Brzaković Petar Mitković Aleksandar Milojković Marko Nikolić | |
| INHABITING THE TOWER. THE PARADIGM OF THE FORTIFIED TOWERS OF MANI AND THE REUSE PROJECT | 556 |
| Rachele Lomurno | |
| ADAPTIVE REUSE THROUGH CREATIVE INDUSTRY TOOLS: CASE OF URAL-MASH, YEKATERINBURG, RUSSIA | 564 |
| Eva Vaništa Lazarević Timur Abdullaev, Larisa Bannikova | |

URBAN MOBILITY, TRANSPORT AND TRAFFIC SOLUTIONS

| | |
|--------------------------------------------------------------------------------------------------------------|-----|
| POLICY FOR REDUCING EMISSIONS IN AIRCRAFT OPERATIONS IN URBAN AEREAS BASED ON REGULATORY AND FISCAL MEASURES | 579 |
| Marija Glogovac Olja Čokorilo | |
| SIMULATING PEDESTRIAN BEHAVIOUR IN SCHOOL ZONES – POSSIBILITIES AND CHALLENGES | 586 |
| Ljupko Šimunović Mario Ćosić Dino Šojat Božo Radulović Domagoj Dijanić | |

MODEL OF SMART PEDESTRIAN NETWORK DEVELOPMENT USING AN EDGE-NODE SPACE SYNTAX ABSTRACTION FOR URBAN CENTRES 593

Bálint Kádár

THE ROLE OF SMART PASSENGER INTERCHANGES IN THE URBAN TRANSPORT NETWORK 604

Bia Mandžuka, Marinko Jurčević, Davor Brčić

CLIMATE CHANGE, RESILIENCE OF PLACES AND HAZARD RISK MANAGEMENT

THE IMPACT OF CLIMATE CHANGES ON THE DESIGN ELEMENTS OF CONTEMPORARY WINERIES - CASE STUDIES 617

Branko AJ Turnšek Ana Stanojević LjiljanaJevremović

DETERMINATION OF COMMUNITY DEVELOPMENT POLICIES USING URBAN RESILIENCE AND SYSTEM DYNAMICS SIMULATION APPROACH 626

Zoran Keković Ozren Džigurski Vladimir Ninković

QUALITIES OF RESILIENT CITY IN SYSTEMS OF PLANNING SUSTAINABLE URBAN DEVELOPMENT. AN INTRODUCTORY REVIEW. 634

Brankica Milojević Isidora Karan

PLACE-BASED URBAN DESIGN EDUCATION FOR ADAPTING CITIES TO CLIMATE CHANGE 641

Jelena Živković Ksenija Lalović

IMPROVING URBAN RESILIENCE, INCREASING ENVIRONMENTAL AWARENESS: NEW CHALLENGE OF ARCHITECTURAL AND PLANNING EDUCATION 652

Aleksandra Stupar Vladimir Mihajlov Ivan Simic

URBAN RESILIENCE AND INDUSTRIAL DESIGN: TECHNOLOGIES, MATERIALS AND FORMS OF THE NEW PUBLIC SPACE 659

Vincenzo Paolo Bagnato

THERMAL COMFORT OF NIŠFORTRESS PARK IN THE SUMMER PERIOD 666

Ivana Bogdanović Protić Milena Dinić Branković Petar Mitković Milica Ljubenović

LANDSCAPE ARCHITECTURE AND NATURAL BASED SOLUTIONS

SMALL ISLANDS IN THE FRAMEWORK OF THE U.E. MARINE STRATEGY – CHERADI'S ARCHIPELAGO IN TARANTO 679

Giuseppe d'Agostino Federica Montalto

LANDSCAPE AWARENESS AND RENEWABLE ENERGY PRODUCTION IN BOSNIA AND HERZEGOVINA 686

Isidora Karan Igor Kuvac Radovan Vukomanovic

SAVAPARK – A RESILIENT AND SUSTAINABLE NEW DEVELOPMENT FOR ŠABAC 692

Milena Zindović Ksenija Lukić Marović

ADRIATIC LIGHTHOUSES. STRATEGIC VISIONS AND DESIGN FEATURES 702

Michele Montemurro

LANDSCAPE ARCHITECTURE AND INFRASTRUCTURES: TYPOLOGICAL INVENTORY OF GREEK WATER RESERVOIRS' LANDSCAPE 710

Marianna Nana Maria Ananiadou-Tzimopoulou

THE BASIN OF THE MAR PICCOLO OF TARANTO AS URBAN AND LANDSCAPE "THEATRE" 717

Francesco Paolo Protomastro

INTERWEAVING AND COMPLEXITIES OF THE MAN-MADE ENVIRONMENT AND NATURE 725

Dženana Bijedić Senaida Halilović Rada Čahtarević

BUILT HERITAGE, NEW TECHNOLOGIES AND DANUBE CORRIDOR

DIGITAL TOOLS IN RESEARCHING HISTORICAL DEVELOPMENT OF CITIES 737

Milena Vukmirović Nikola Samardžić

APPLICATION OF BIM TECHNOLOGY IN THE PROCESSES OF DOCUMENTING HERITAGE BUILDINGS 751

Mirjana Devetaković Milan Radojević

GIS-BASED MAPPING OF DEVELOPMENT POTENTIALS OF UNDERVALUED REGIONS – A CASE STUDY OF BAČKA PALANKA MUNICIPALITY IN SERBIA 758

Ranka Medenica Milica Kostreš Darko Reba Marina Carević Tomić

MAPPING THE ATTRACTIVITY OF TOURIST SITES ALL ALONG THE DANUBE USING GEOTAGGED IMAGES FROM FLICKR.COM 766

Bálint Kádár Mátyás Gede

INVENTARISATION AND SYSTEMATIZATION OF INDUSTRIAL HERITAGE DOCUMENTATION: A CROATIAN MATCH FACTORY CASE STUDY 777

Lucija Lončar Zlatko Karač

CULTURAL LANDSCAPE OF ANCIENT VIMINACIUM AND MODERN KOSTOLAC – CREATION OF A NEW APPROACH TO THE PRESERVATION AND PRESENTATION OF ITS ARCHAEOLOGICAL AND INDUSTRIAL HERITAGE 785

Emilija Nikolić Mirjana Roter-Blagojević

ALTERNATIVE TERRITORIAL CHANGES OF HOUSING ESTATES TOWARDS A SUSTAINABLE CONCEPTION 793

Regina Balla

HERITAGE, TOURISM AND DANUBE CORRIDOR

- CULTURAL TOURISM IN THE BALKANS: TRENDS AND PERSPECTIVES. 807
Kleoniki Gkioufi
- CULTURAL TOURISM AS A NEW DRIVING FORCE FOR A SETTLEMENT REVIT-
ALISATION: THE CASE OF GOLUBAC MUNICIPALITY IN IRON GATES REGION,
SERBIA 814
Branislav Antonić Aleksandra Djukić
- CULTURAL AND HISTORICAL IDENTITY OF TWIN CITIES KOMÁR-
NO-KOMÁROM 823
Kristína Kalašová
- PLACE NETWORKS. EXPERIENCE THE CITY ON FOOT 830
Milena Vukmirovic Aleksandra Djukić Branislav Antonić
- STORIES WITH SOUP - CULTURAL HERITAGE MOMENTS ALONG THE DAN-
UBE RIVER 837
Heidi Dumreicher Bettina Kolb Michael Anranter
- ETHNIC AND TOPONYMIC BACKGROUND OF THE SERBIAN CULTURAL HERI-
TAGE ALONG THE DANUBE 844
Dániel Balizs Béla Zsolt Gergely

SPATIAL AND RURAL DEVELOPMENT

- BEAUTIFUL VILLAGE PROJECT: AN ARCHITECTURAL AND LANDSCAPE DESIGN
STRATEGY FOR NON-HERITAGE VILLAGES IN HEBEI PROVINCE 859
Dapeng Zhao Bálint Bachmann Tie Wang
- CHANGES IN DEVELOPMENT OF NORTHERN CROATIA CITIES AND MUNICI-
PALITIES FROM 1991 TO 2011: MULTIVARIABLE ANALYTICAL APPROACH 869
Valentina Valjak
- SPECIFICS OF DYNAMICS OF SHRINKING SMALL TOWNS IN SERBIA 879
Milica Ljubenović Milica Igić Jelena Đekić Ivana Bogdanović-Protić Ana Momčilović-Petroni-
jević
- BALANCED REGIONAL DEVELOPMENT OF RURAL AREAS IN THE LIGHT OF
CLIMATE CHANGE IN SERBIA– OPPORTUNITIES AND CHALLENGES 888
Milicalgić MilicaLjubenović Jelena Đekić Mihailo Mitković
- COLLABORATIVE RESEARCH FOR SUSTAINABLE REGIONALDEVELOPMENT:
EXPERIENCES FROM “LEARNING ECONOMIES” ITALY-SERBIA BILATERAL
PROJECT 899
Jelena Živković Ksenija Lalović Elena Battaglini Zoran Đukanović Vladan Đokić

ASSESSMENT OF VALUE OF BIOMASS ENERGY POTENTIAL FROM AGRICULTURAL WASTE IN LESKOVAC FIELD AND ITS IMPORTANCE IN THE SETTLEMENT DEVELOPMENT PLANNING 908

Mihailo Mitković Dragoljub Živković Petar Mitković Milena Dinić Branković Milica Igić

MULTIFUNCTIONAL FACILITIES – FROM PRIMARY FUNCTIONS TO SPATIAL LANDMARKS (STUDY OF TWO CASES IN SERBIA AND BOSNIA AND HERZEGOVINA) 918

Aleksandar Videnovic Milos Arandjelovic

ENERGY REFURBISHMENT OF A PUBLIC BUILDING IN BELGRADE

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ABSTRACT

Statistics show that about 8% of overall EU building sector belongs to Sports and Recreation Building Stock, that represents about one and a half million of these kinds of buildings. It's been estimated that out of whole building sector these public buildings are accounting up to 10% of total annual energy consumption. Considering that in 2008 overall energy use was about 1,768 [Mtoe], there is the potential to reduce energy consumption of about 21 [Mtoe] on a yearly base in the EU Sport Facility Building Stock which is far away of insignificant (SportE², 2018).

Most of the buildings of this kind were built from 1960 to 1980. At the time of construction, energy efficiency was not taken into consideration, and even if it was taken into account, the equipment and fabrics installed at that time are not efficient now as at the time of installation. Energy sources are mostly traditional, fossil fuel based. Since regulations on energy efficiency are more stringent, these facilities must be renovated and then well maintained in terms of energy consumption. Sport buildings are mostly very well postured to adopt RES technologies, as active features, having in mind large open spaces and large outdoor surfaces. However, this paper investigates use of Passive House technologies in these manmade structures that may be productive in energy saving. The case study includes sport centre built in 1974 in Belgrade, Serbia. Different Passive House measures applied on the building structure and benefits in the sense of reducing total annual energy consumption for space heating, as well as conditions related to the comfort of the indoor environment were simulated in software package Integrated Environmental Solutions Virtual Environment, IES VE 2016, that is approved by USGBC, ASHRAE, CIBSE and U.S. Department of Energy.

Keywords: Public buildings, Sport facilities, Belgrade, Energy refurbishment, Passive House technologies

Introduction

Number of sports facilities has grown in all European countries in the last years of twentieth century. In some countries there was a strong policy „sport for all“ that resulted to the increase of sports buildings. The situation was the same in Serbia. Most of the sports centres were built in that period, from 1960 to 1980. Sports centres in Belgrade are located in city area and their overall characteristics are mostly similar. Within the building there is a main sport hall area and a number of other additional facilities. Main sport hall is universal, designed for several sports, including basketball, volleyball, handball and other indoor team games. Generally, sports centres consist of few groups of spaces: group intended to public, group intended to players, management and technical equipment and group for TV and press (Ilić, 1998).

Energy consumption in these types of buildings significantly differs based on location, area and applied structural materials. It includes thermal energy used for space and water heating

and electrical energy for the operation of equipment, air conditioning, ventilation and lightning. Energy consumption notably depends of climate conditions. The average total energy consumption for large scale sports buildings in the Mediterranean type of climate for effective area amounts to 260 kWh/m² and 490 kWh/m² for continental type of climate (IECCU, 1994).

Energy consumption is mostly effected by the required comfort that need to be suitable for different groups of users, the public and players, as well as the services and all other activities offered within the centre. Conditions concerning indoor environment for sports facilities are very complex. Existing sports buildings are not fulfilling standards regulated in accordance with today's environmental requirements. Comfort within sports buildings has to be considered in two ways, from the perspective of spectators and players. There is a need to achieve level of comfort for both groups. In this article the subject of the consideration is the improvement of the energy performance of the envelope of the sports centre Šumice, in Belgrade. Given the difference in the comfort conditions, the main sports hall is considered as a separate thermal zone, while the rest of the building as other zone.

Research methodology

The sports centre Šumice in Belgrade was selected for in-depth analysis of different interventions for improvement of indoor comfort and decrease of energy consumption. After analysing existing building concerning location, structural elements and thermal envelope performances, two scenarios of building improvement were created. Scenario 1 refers to the application of different refurbishment measures on the thermal envelope of the building without the main hall, while in the Scenario 2 the application of measures is only to the main sports hall.

Methodological approach includes following steps:

- Assessment of the existing building model.
- Identification of elements of a thermal envelope requiring refurbishment - priorities are determined based on the highest value of transmission losses (based on the height of the transmission losses).
- Defining measures for energy improvement of selected elements of thermal envelope - architectural refurbishment actions that fulfil conditions regulated by EnerPHit/EnerPHit⁺1 (Passive House Certificate for retrofits) - Creation of Scenario 1 and Scenario 2.
- Analysis of effects of the applied measures; Parameters according to which the suitability of the applied measures is estimated are final energy $Q_{h,nd}$ [kWh/m²a] and obtained comfort conditions. The improvement effects were considered for each measure individually and then cumulatively.
- A comparative analysis of Scenario 1 and Scenario 2, as well as Scenario 1+2.

Case study – Energy refurbishment of Sport Centre Šumice in Belgrade, Serbia

The sports centre Šumice is located in the peripheral zone of the central area of Belgrade, in the southeast direction, at a distance of about 4 km from the downtown. The position of the building is at the edge of the forest area. Building layout and the appearance/design of the exterior and interior parts are shown in the Figure 1.

1 EnerPHit Certification for retrofits is applied for retrofits of the existing buildings where there is no possibility to satisfy passive house requirements. EnerPHit⁺ is applied for buildings where more than 25% of existing non transparent area of the building is covered with internal insulation.

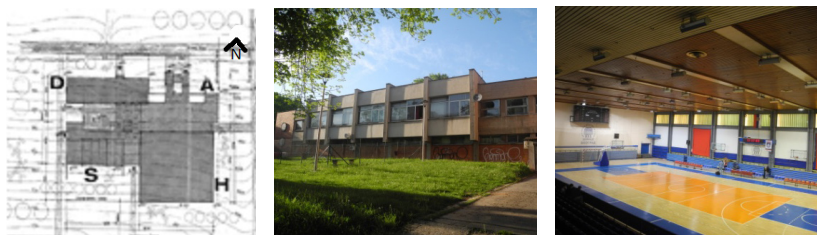


Figure1: Building layout (left - A+D+S-the building without main hall, H-main hall), south façade of the Sport Centre Šumice (middle) and interior of the main sports hall (right). Source: Original project documentation, 1974. Archive of Vozdovac Municipality. Photos taken by Authors.

Some structural and architectural characteristics of the building that are important for further analysis are that the building has three stories, including basement, 1,250 seats in the main sport hall and that the area of the facade is 4,164.2 m² – out of which 25.7% is glazed. The structural system is reinforced concrete skeleton for the building without the main sport hall and for the main sports hall concrete frame, with brick walls as infill. Other important characteristics concerning working hours and HVAC system that exist in the building are shown in Table 1.

Table 1: Operating profile and HVAC characteristics of the Sport Centre Šumice, Belgrade, Serbia (Source: Authors)

| Basic characteristics | Building without main sports hall | Main sports hall |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Operating profile | Administration: from 8am till 16pm, except weekends and holidays. Two administrative workers in the office. | From 8am to 23pm, every day except 1 st of January. Official games during the weekends have 500 spectators. |
| HVAC | Central space heating system for the whole building. Boiler room is located in the basement of the building. There are radiators in each room Termik 808-IV, 480-IV of different size based on situation. Boiler for hot water is 2000 l. Sport hall is not naturally ventilated. | |
| Lighting | Lighting of the foyer by fluorescent lamps 60 W each. Offices have incandescent lamps of 100 W. | Main sports hall has 30+ halide lamps of 1000 W. |

Thermal envelope of the Sport Centre Šumice in Belgrade

Structural elements of thermal envelope of the Sport Centre are shown in Table 2.

Table 2: Thermal envelope of the Sport Centre, existing condition (Source: Authors)

| Thermal envelope, selected positions | Existing building before implementation of proposed energy efficiency measures | | | | | |
|------------------------------------------|------------------------------------------------------------------------------------------------|--------------------------------------------|--------------------------|----------------|----------------------------------------------|-------|
| | Layers - from outside to inside | Thermal transmittance U W/m ² K | Area A (m ²) | F _x | U _x A _x F _x | % |
| Building without main sports hall | | | | | | |
| External wall of the building | Ceramic tiles 8mm Concrete 120mm Expanded polystyrene 75mm Gypsum plasterboard 12.5mm | 0.368 | 1,789.56 | 1.0 | 658.56 | 19.82 |

| | | | | | | |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|----------|-----|----------|-------|
| External wall, basement of the building | Gravel 150mm Half brick as protection Bitumen layer 5mm Cast concrete 250mm Gypsum plastering 12.5mm | 1.159 | 933.26 | 0.6 | 648.99 | 19.53 |
| Glazed surfaces of the building facade | Clear float 6mm Cavity 12mm Clear float 6mm | Uf with frame = 3.201 Ug glass only = 3.201 g EN 410= 0,707 | 947.74 | 0.7 | 663.42 | 19.91 |
| | Aluminium doors with clear float glass 6mm | Uf with frame= 3,201 Ug glass only= 3.201 g EN 410= 0.707 | | 0.7 | | |
| Flat roof | Stone chippings Waterproof roof covering Polyurethan insulation 40mm Vapour control layer Screed 40mm Reinforced concrete 150mm Dense plaster 12,5mm | 0.467 | 2,631.29 | 1.0 | 1,228.81 | 36.99 |
| Ground floor | Gravel 150mm Reinforced Concrete 150mm Bitumen layer Cast concrete 60mm Screed 30mm Clay tile 22mm | 1.291 | 2,631.29 | 0.5 | 1,698.49 | 51.12 |
| Main sports hall | | | | | | |
| External wall, Sport Hall | Face brick 380 Plaster (lightweight) 12.5mm | 1.858 | 1,051.52 | 1.0 | 1,953.72 | 58.81 |
| Glazed surfaces of the main sport hall facade | Pilkington 6mm Cavity 12mm Pilkington 6mm | Uf with frame = 2.857 Ug glass only = 2.856 g EN 410= 0.608 | 121.88 | 0.7 | 243.79 | 7.33 |
| | Wooden door | 2.194 | 45.0 | 1.0 | 98.73 | |
| Pitched roof | Felt bitumen layers with vulkapren in Al colour 15mm Polyurethan board 40mm Roofing felt 0.5mm Syporex 150mm Cavity average height 22000mm Oak 20mm | 0.302 | 1,784.69 | 1.0 | 538.98 | 15.15 |
| Ground floor | Gravel 150mm Reinforced Concrete 150mm Bitumen layer Cast concrete 60mm Elastic layer Timber on 100mm joist Oak 22mm | 0.509 | 1,784.69 | 0.5 | 454.20 | 13.67 |

Fx- correction factor, UxAxFx- transmission losses, %- percentage of transmission losses

Simulated conditions

Energy performances of existing building and models – Scenario 1, 2 and 1+2 after applying various energy efficiency measures, are simulated in software package Integrated Environmental Solutions Virtual Environment 2017, IES VE. Model of the case study is created in

SketchUp 2016 and transferred in IES VE 2017., as shown in Figure 2. Total floor area of the heated space of sport centre is 6,790.5 m². Total heated volume of the building is 30,995.51 m³.

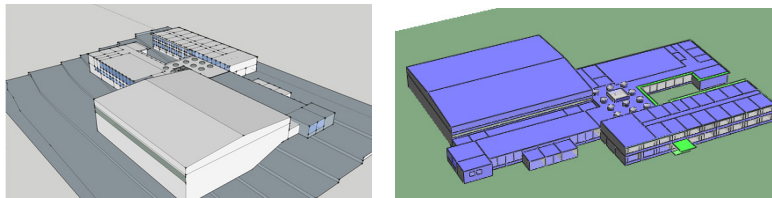


Figure 2: Model of Sport Centre Šumice, existing situation, model in SketchUp 2016 (left), module ModelIT, IES VE 2017 (right).

Operating hours summarized in Table 1 are different for main sport hall and other part of the building. These two parts are treated as two thermal zones based on different thermal requirements. For the simulation of the existing situation infiltration rate was taken as 0.2 ACH. Regarding air exchange there is no natural ventilation in main sport hall but it exists in other parts of the building.

Simulated indoor air temperature during the heating period (from mid-October to mid-March) is taken as 16°C for main sports hall (it goes from 12°C to 18°C for the sports activities) and 20°C for the rest of the building (range for achieved thermal comfort is 24°C for the locker rooms and 26°C for administration) (CIBSE Guide A, 2006). During the period from mid-May to mid-October the simulated indoor air temperature is set at 20°C for the main sports hall and 26°C for all other spaces according to the Rule book on the Energy Efficiency of Buildings (Official Gazette of RS, No. 61/2011). However, regarding European standards, thermal comfort during summer should not be more than 10 % of the occupancy hours over 25 °C in the given year (Passive House Requirements, 2017).

Concerning internal thermal gains in the main sport hall the following sources are present: sports arena lights, sports arena occupancy, sports arena equipment, computers in the administration area, lights and people.

Measures for improvement of elements of thermal envelope - passive measures

Strategy of initial improvement implies upgrading of thermal insulation in terms of material type and thickness. Improving or applying thermal insulation is one of the most effective individual energy efficiency improvement measures. It can be applied as internal or external. In this case study increase in thickness of thermal insulation (applying rock wool or XPS of 15cm on the inner side of the thermal envelope) and improvement of the glazed area (Low-E Triple Glazing SC=0.2) are defined based on the requirements set by EnerPHit/EnerPHit+certification (Passive House Institute, 2017) that shows maximum values of thermal transmittance of different parts of thermal envelope. U values are presented in the Table 3.

Analys of effects of the proposed refurbishment measures

Results of simulation of energy performances before and after refurbishment are presented for Scenario 1 - Sports Centre-building without main sport hall in Table 3 and for Scenario 2 – Main sport hall in Table 4. For each proposed intervention heating energy $Q_{h,nd}$ [kWh/m²a] is calculated.

Table 3: Refurbishment interventions and estimated annual energy consumption for Scenario 1

| Sports Centre- building without main sport hall (Scenario 1) | | | | | |
|---------------------------------------------------------------|------------------------------------------------------------------------|--------------------|-------------------------------------------------------|----------|--------------------------------------------------|
| Positions of thermal envelope | Existing situation before implementation of energy efficiency measures | | | | After applying proposed measures |
| | U | U _{max} | A | Hts | A1 |
| | W/m ² K | W/m ² K | m ² | W/K | Rock wool (15cm) U W/m ² K |
| External wall, first story, office | 0.37 | 0.15 | 1,789.56 | 658.56 | 0.14 |
| Fulfilled condition of thermal comfort , office | | | 13.4% when occupied comfort index is 6-8 ² | | 13.4% when occupied comfort index is 6-8 |
| Q _{h,nd} kWh/m ² | | | 1,037.5 | | 1,010.2 |
| Energy grade Q _{h,nd,rel} | | | Q _{h,nd,rel} = 172.3% E ³ | | Q _{h,nd,rel} = 167.7% E |
| Energy saving | | | | | 2.6% |
| External wall, basement, office -1 | 1.19 | 0.35 | 933.26 | 648.99 | Rock wool (15cm) U W/m ² K 0.2 |
| Fulfilled condition of thermal comfort in the office | | | 18% when occupied comfort index is 6-8 | | 18% when occupied comfort index is 6-8 |
| Q _{h,nd} kWh/m ² | | | 1,037.5 | | 1,014.7 |
| Energy grade Q _{h,nd,rel} | | | Q _{h,nd,rel} = 172.3% E | | Q _{h,nd,rel} = 168.6% E |
| Energy saving [%] | | | | | 2.2% |
| Floor | 1.32 | 0.15 | 2,631.29 | 1,698.49 | XPS (15cm) U W/m ² K 0.15 |
| Achieved thermal comfort in the building | | | 13.4% when occupied comfort index is 6-8 | | 13.6% when occupied comfort index is 6-8 |
| Q _{h,nd} kWh/m ² | | | 1,037.5 | | 771.1 |
| Energy grade Q _{h,nd,rel} | | | Q _{h,nd,rel} = 172.3% E | | Q _{h,nd,rel} = 128.1% D |
| Energy saving [%] | | | | | 25.7% |
| Flat roof, stone chippings | 0.47 | 0.15 | 2,631.29 | 1,228.81 | XPS (15 cm) U W/m ² K 0.15 |
| Achieved thermal comfort in the building, office | | | 13.4% when occupied comfort index is 6-8 | | 14% when occupied comfort index is 6-8 |
| Q _{h,nd} kWh/m ² | | | 1,037.5 | | 957.5 |
| Energy grade Q _{h,nd,rel} | | | Q _{h,nd,rel} = 172.3% E | | Q _{h,nd,rel} = 159% E |
| Energy saving [%] | | | | | 7.7% |
| Glazed area | 3.210 | 0.85 | 1,069.6 | 663.42 | A1 U W/m ² K 1.3 glass only 0.8 |
| Achieved thermal comfort in the building [°C] | | | 13.4% when occupied comfort index is 6-8 | | 14.3% when occupied comfort index is 6-8 |
| Q _{h,nd} kWh/m ² | | | 1,037.5 | | 998.4 |
| Energy grade Q _{h,nd,rel} | | | Q _{h,nd,rel} = 172.3% E | | Q _{h,nd,rel} = 165.8% E |
| Energy saving [%] | | | | | 3.8% |
| Scenario 1, cumulative measures | | | | | |
| Achieved thermal comfort in the building [°C], existing 13.4% | | | | | 15.8% when occupied comfort index is 6-8 |
| Q _{h,nd} existing 1037,5 kWh/m ² | | | | | 541.5 |
| Energy grade Q _{h,nd,rel} =172.3% E | | | | | Q _{h,nd,rel} = 89.8% C |
| Energy saving [%] | | | | | 47.8% |

AL- glazed area- Triplex thermo insulation glass, Low-E Triple Glazing SC=0.2

²Comfort index values are taken from IES VE, Integrated Environmental Solutions Virtual Environment.

³Q_{h, nd} [kWh/m²a] for the existing building, without any intervention is as follows:

Q_{h,nd} = 1,037.54 MWh total heating energy q_{h,nd} = Q_{h,nd}/Af = 1,037.54/6,790.5 MWh/m²a = 155.1 kWh/m²a

Q_{h, nd, rel} = (155.1/90)x100= 172.3%

Q_{h, nd, rel} ≤ 180 for existing sports buildings and presents E energy level

For Sport Centre Šumice - building without main sport hall, energy saving of almost 50% is achieved by implementation of refurbishment measures proposed in Scenario 1. With the same Scenario percentage of comfort index from 6-8 (comfortable) is increased from 13.4% to 15.8% when the analysed space is occupied. After applying measures proposed in Scenario 1 building is upgraded from E to C energy level.

Table 4: Refurbishment interventions and estimated annual energy consumption for Scenario 2

| Main sports hall (Scenario 2) | | | | | |
|-----------------------------------------------------------|------------------------------------------------------------------------|--------------------|------------------------------------------|---------|---------------------------------------------------------------|
| Positions of thermal envelope | Existing situation before implementation of energy efficiency measures | | | | After applying proposed measures |
| | U | U _{max} | A | Hts | A1 |
| | W/m ² K | W/m ² K | m ² | W/K | Rock wool (15cm) U W/m ² K |
| External wall, in the contact with external air | 1.9 | 0.15 | 1,051.5 | 1,953.7 | 0.2 |
| Fulfilled condition of thermal comfort , main sports hall | | | 23.8% when occupied comfort index is 6-8 | | 22.6% when occupied comfort index is 6-8 |
| Q _{ext} kWh/m ² | | | 1,037.5 | | 939.3 |
| Energy grade Q _{ext,ref} | | | Q _{ext,ref} = 172.3% E | | Q _{ext,ref} = 156% E |
| Energy saving | | | | | 9.5% |
| External wall (towards heated part of the building) | 1.8 | 0.35 | 303.98 | 428.9 | Rock wool (15cm) U W/m ² K 0.2 |
| Fulfilled condition of thermal comfort in the office | | | 23.8% when occupied comfort index is 6-8 | | 24% when occupied comfort index is 6-8 |
| Q _{ext} kWh/m ² | | | 1,037.5 | | 1,036.8 |
| Energy grade Q _{ext,ref} | | | Q _{ext,ref} = 172.3% E | | Q _{ext,ref} = 172.1% E |
| Energy saving [%] | | | | | 0.07% |
| Floor of the playground area | 0.51 | 0.15 | 1,784.7 | 454.2 | XPS (15cm) U W/m ² K 0.15 |
| Achieved thermal comfort in the building [°C] | | | 23.8% when occupied comfort index is 6-8 | | 23% when occupied comfort index is 6-8 |
| Q _{ext} kWh/m ² | | | 1,037.5 | | 1,018.3 |
| Energy grade Q _{ext,ref} | | | Q _{ext,ref} = 172.3% E | | Q _{ext,ref} = 169.4% E |
| Energy saving [%] | | | | | 25.7% |
| Roof of the main sport hall | 0.3 | 0.15 | 1,784.7 | 538.9 | XPS (15 cm) U W/m ² K 0.13 |
| Achieved thermal comfort in the building, office | | | 23.8% when occupied comfort index is 6-8 | | 24.1% when occupied comfort index is 6-8 |
| Q _{ext} kWh/m ² | | | 1,037.5 | | 1,028.6 |
| Energy grade Q _{ext,ref} | | | Q _{ext,ref} = 172.3% E | | Q _{ext,ref} = 170.7% E |
| Energy saving [%] | | | | | 0.9% |
| Glazed area | 2.9 | 0.85 | 121.9 | 243.8 | Al ¹ U W/m ² K 1.3 glass only 0.8 |
| Achieved thermal comfort in the building [°C] | | | 23.8% when occupied comfort index is 6-8 | | 23.8% when occupied comfort index is 6-8 |
| Q _{ext} kWh/m ² | | | 1,037.5 | | 1,034.9 |
| Energy grade Q _{ext,ref} | | | Q _{ext,ref} = 172.3% E | | Q _{ext,ref} = 171.9% E |
| Energy saving [%] | | | | | 0.3% |
| Scenario 2, cumulative measures | | | | | |
| Achieved thermal comfort in the building , existing 23.8% | | | | | 21.6% when occupied comfort index is 6-8 |
| Q _{ext} existing 1,037.5 kWh/m ² | | | | | 899.4 |
| Energy grade Q _{ext,ref} =172.3% E | | | | | Q _{ext,ref} = 148.7% E |
| Energy saving [%] | | | | | 13.6% |

For main sports hall, energy saving of 13.6% is achieved by implementation of refurbishment measures proposed in Scenario 2. With the same Scenario percentage of comfort index from 6-8 (comfortable) is decreased from 23.8% to 21.6% when the main sports hall is occupied. After applying measures proposed in Scenario 2 building cannot be upgraded from E energy level. Decreasing of percentage of level of comfort shows that in the space of main sport hall installed HVAC system and its operational level are essential for achieving desired comfort.

Comparative analysis of Scenario 1, Scenario 2 and Scenario 1+2

Comparative analysis of Scenario 1, 2 and consolidated Scenario 1+2 is given in the Table 5 and Figure 3. If Scenario 1 is united with Scenario 2, when the whole building is refurbished, 62.2% of energy saving is achieved. Building is upgraded from E to C energy level (same as with Scenario 1).

Table 5: Comparison of results of energy simulations for Scenario 1, Scenario 2 and Scenario 1+2

| Results of the simulations | Existing | Scenario1 | Scenario 2 | Scenario 1+2 |
|---------------------------------------------|----------|-----------|------------|--------------|
| Q_{ind} [MWh] | 1,037.5 | 541.5 | 899.4 | 392.27 |
| Energy level $Q_{in,nd,rel}$ | E | C | E | C |
| Energy saving after package of measures [%] | | 47.8% | 13.6% | 62.2% |
| Office- Comfort index, when occupied 6-8 | 13.4% | 15.8% | - | 14.6% |
| Main sport hall- Comfort index, 6-8 | 23.8% | - | 21.6% | 22.1% |

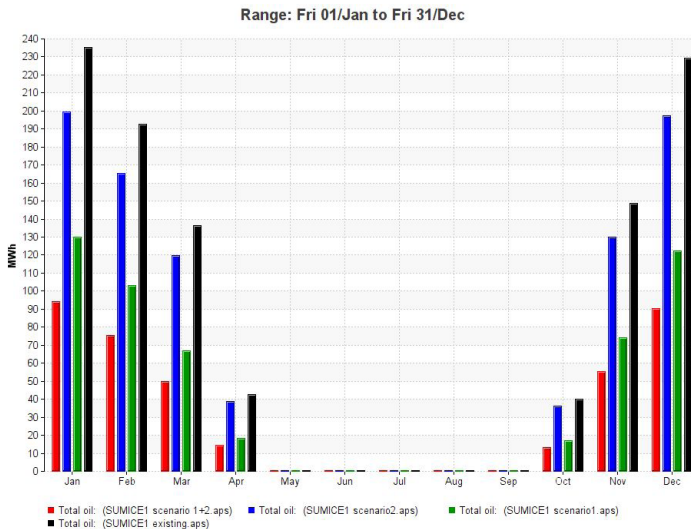


Figure3: Comparison of total oil consumption (heating energy) for Scenarios 1, 2 and 1+2, Apache Module, Vista Pro, IES VE 2017.

Conclusions

Energy consumption for space heating is significantly reduced by implementation of defined

refurbishment measures, which includes improvement of thermal performance of the transparent and non-transparent parts of the thermal envelope proposed in the different scenarios. By applying of Scenario 1, improvement of building without taking into account the main sport hall, comfort is improved by 15% for the overall occupation of the office space. Estimated energy savings for space heating is 47.8%. In Scenario 2, by improving the thermal envelope of the main sport hall, 13.6% energy savings for heating were achieved. In terms of amount of energy for space heating, 138,1 MWh is saved, which is considered to be remarkable savings. But, concerning comfort in the main sport hall percentage of comfortable hours during the occupancy period is reduced. That can be explained by existing of two groups of occupants in the same space with different comfort requirements - spectators and players, sedentary and hard work (sports activities are considered as hard work). In order to solve the situation for both groups of users, it is necessary to install and improve the HVAC system within the building, especially for the main sports hall. By consolidating both scenarios, a savings of 62.2% of the energy for space heating is estimated. The conclusion of this research approach is that if the aim is to improve the energy class, it is only necessary to apply scenario 1 - the effect is the same as the implementation of the 1+2 scenario.

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