5th INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

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PLACES AND TECHNOLOGIES 2018

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

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ABSTRACT

Sustainability and resilience of public buildings nowadays represent key features that transcend the functional and institutional role of their physical structures. In contemporary societies, public buildings are often envisioned as model buildings as well, serving as good practice examples, demonstrating the immediate and long-term benefits of green building principles. School buildings play a very important role in this communication, and in developed countries they themselves serve as a learning tool. Being educated in a green and energy efficient building, students adopt building's design and operation features as everyday standard, transferring the same design and operational modelsas well as comfort levels (expectations) to their future working and living spaces.The wider effect on the local community is similar. The average lifespan of school buildings implies the necessity to pay special attention to refurbishment of these structures enabling prolonged and contemporary use.Within a project "Energy efficiency in public buildings", a collaboration between GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), University of Belgrade – Faculty of Architecture and Ministry of Mining and Energy of the Republic of Serbia, special attention was paid to the school buildings. *National Typology of School Buildings* was conceived as a tool for improving this portion of building stock. A nationwide survey was conducted, covering 3990 public buildings with apurposely developed questionnaire for schools and kindergartens, resulting in formulation of unique database of these buildings (1857 schools). The paper presents methodology for identification of typical school buildings, covering various construction periods and building sizes. The paper further illustrates the type of analysis performed for type representatives, estimated potential for energy upgrades and expected impact on energy performance. The expected impact on local and national level is also being assessed.

Keywords: schools, public buildings, building typology, energy efficiency, improvement measures

Introduction

Existing building stock can be considered a precious man-made resource (Rovers, 2004), having in mind the resources that are embedded in any built structure – the land, the infrastructure, materials, work and energy used. The sustainable use of existing building stock, therefore, is one of the premises of sustainable development and building refurbishment is the main operational tool for achieving strategic goals in this area. The ecological impact of building stock is reflected mainly through the energy used in buildings – it is estimated that buildings consume

more energy than transport, industry and agriculture combined. In contemporary societies, public buildings are often envisioned as model buildings as well: they serve as good practice examples and demonstrate the immediate and long-term benefits of green buildingprinciples. This results in wider impact, that by far transcendsthe particular reductions in energy consumption and CO_2 emissions related to an individual public building. School buildings play very important role in this process, since they address the youngest population during the years of their formation. "School as a teaching tool" is a concept that engages building users with environmental issues in buildings, offering informal education, a chance for students to embody sustainable living in their daily lives at school and adopt it as a base standard for their future adult behaviour (Cole, 2014).

The project "Energy efficiency in public buildings", a collaboration between GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), University of Belgrade – Faculty of Architecture and Ministry of Mining and Energy of the Republic of Serbia, strives to set the ground for improving the energy efficiency in Serbia's public buildings, and the special attention was paid to schools and kindergartens. Within this project, National Typology of School Buildingswas conceived as a tool for improving this portion of building stock. A nationwide survey was conducted, covering 3990 public buildings with apurposely developed questionnaire for schools and kindergartens, resulting in formulation of unique database of these buildings (1857 schools). The paper presents methodology for identification of typical school buildings, covering various construction periods and building sizes. The paper further illustrates the type of analysis performed for type representatives, estimated potential for energy upgrades and expected impact on energy performance. The expected impact on local and national level is also being assessed.

Methodology

Previous researches regarding improving energy efficiency of Serbia's building stock were focused primarily on housing sector, and typological approach was identified as one of the crucial tools for addressing this topic on several levels:

- Clear understating of structure and energy performance of building stock;
- Strategic assessments on national level regarding current energy needs, possible savings with different improvement scenarios and within particular building types;
- Identification of building types most suitable for energy retrofit and assessing the impact of these retrofits on national level;
- Identification of the key improvement measures for each building type and assessment of resulting reductions in energy use, primary energy and CO_2 emissions;
- Guidelines and technical measures for energy improvements (three scenarios) for each building type were developed in a way that can be applied at similar buildings offering owners and users valuable information.

In order to provide adequate applicability of school buildings typology on such wide scope of assessments and stakeholders, reference buildings were identified after through analyses and their characteristics were used for in-depth analyses of each particular building type. The reference buildings were identified using the experience from previous researches andmethodology developed for *TABULA* project (Ballarini et al, 2014) and *National Typology of Residential Buildings in Serbia* (Jovanovic Popovic et al. 2013).

Typology matrix determinants

The methodology developed for*National typology of residential buildings in Serbia* was based on *TABULA*project methodology, with construction period as one of key determi-

nants in typology matrix while the second determinant was defined through four basic building types (single family house, terraced house, multi-family house and apartment blocks). Typology of school buildings was drafted following the similar procedure: construction period and building type as determinates for basic types. The construction periods were drafted prior to data collection and finally four classes were shaped after completing the survey as following: prior to 1945 (A), 1946-1970(B), 1971-1990(C), after 1990(D). As for the building type, the total area of a school building was used to define three classes: up to 500m^2(1), 500-2000m^2(2) and more than 2000m^2(3).

Data collection and processing

Typology was developed using data obtained through the surveyintended to cover allpublic buildings nationwide, where local municipalities were asked to provide relevant data by filing the three-steps questionnaires, depending on the building type. First level questionnaire, requiring the basic data covered all public buildings, while the third level was designed specifically for schools and kindergartens. The elaborate questionnaire (Figure 1) was designed by multidisciplinary team (architects, mechanical engineers and electrical engineers) and the additional explanations were provided in order to facilitate the proper responses.

The data for 1857 schools was collected during October-December 2016and the initial database was formed. These data were pondered in regard with 3890 schools officially registered by The Statistical Office of the Republic of Serbia in 2016. Cluster analyses was applied on pondered base in order to facilitate formation of typology, selection of reference school buildings and formation of sub-types where necessary.

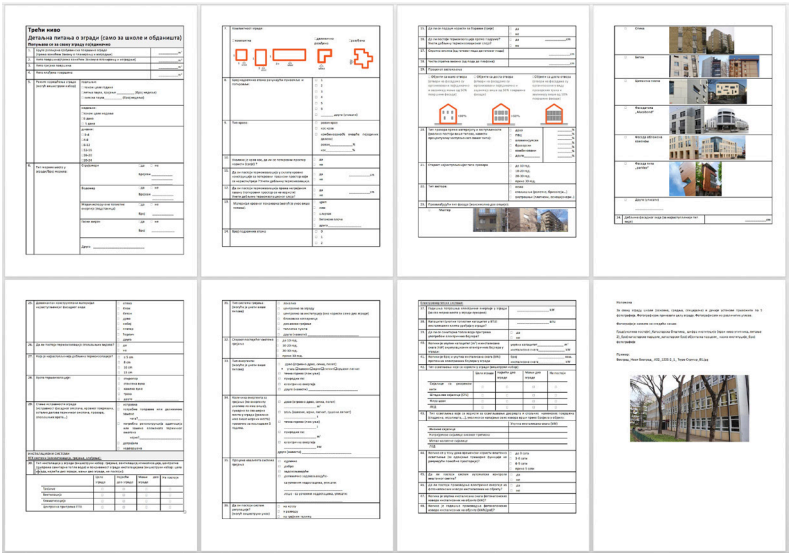

Figure 1: Questionnaire (3rd level, schools and kindergartens only)

Typology of school buildings in Serbia

The typology of school buildings in Serbia (Table 1), was defined as the result of the extensive research using methodology described in the previous chapters. It contains 10 basic types (in regard with construction year and total area) out of which 3 types occur in variations regarding the number of floors. Due to the similar occurrences in cluster analysis, types A2, A3 and C3 have two sub-types, making total of 13 typical school buildings presented.

The smallest schools (Class 1) usually are the remote units of elementary schools, with just a few classrooms to accommodate first four years of compulsory education. The oldest ones were built in architecture and building technology resembling the houses of the time, while soon the model designs were developed that were repeatedly used throughout the country, with adjustments to local needs and conditions.They were so frequent that today 41.05% of school buildings belong to this type. However, their share in total school buildings' area is only 4.87%, and they consume only 3.42% of current energy used in school buildings. The retrofitting these buildings therefore is much more relevant in terms of education and communicating the benefits of energy efficiency to the students and to the general population than in terms of overall savings on national or regional level.

The mid-sized schools (Class 2) were usually built for elementary schools orsmaller gymnasiums and high schools. Before the World War Two, some of these buildings were built as representative buildings and today they are listed for their historical, architectural and cultural values. In the post-war period, the accent was on functionality and meeting the needs of the new society. Today, mid-sized schools account for 26.3% of school buildings with share of 20.29% in total area and consume 22.47% of energy used in school buildings.

The largest school buildings (Class 3) were built for elementary schools and gymnasiums in urban areas. Pre-war buildings of this class were very representative, demonstrating the strong symbolic values attributed to the education and cultural prosperity and today most of these structures are listed and protected. Great architectural diversity can be noticed in the post-war period, from purely functional structures, to elaborate designs of modern and post-modern as well as contemporary architecture, introducing not only the new aesthetics but also reflecting the tendencies in school design theoretical doctrine. Although 1270 Class 3 school buildings present 32.65% of total number of buildings, their built area is 74.84% and they consume 74.10% of energy used in school buildings which illustrates the potential impact of their energy refurbishment.

Typology as a refurbishment tool

Typology of school buildings can be used as a refurbishment tool on several different levels – from national level for strategic decisions and policy making down to preliminary considerations of refurbishment options for any particular school building.

Strategic decisions and policy making

Typology of school buildings in Serbia was conceived primarily as a refurbishment tool that should facilitate decision-making processes and shaping of adequate energy efficiency policies on national and on local level. General data analysis, such is the one presented in Table 2, helps identify the most convenient target groups in regard with general and specific goals. The typology contains series of datasets that can be used for defining the priorities, incentives and make various projections for future development.

Table 3: Basic data regarding school buildings in Serbia and calculated energy needed for heating

Building type	Number of schools		Area			Current energy demands			Improvement #1		Improvement #2		Improvement #3	
			Typical school	Total		Typical school Q_{hnd}	Total		Typical school Q_{hnd}	Total	Typical school Q_{hnd}	Total	Typical school Q_{hnd}	Total
	Pcs	%	[m^2]	[m^2]	%	[kWh/m^{2}a]	[MWh/a]	%	[kWh/m^{2}a]	[MWh/a]	[kWh/m^{2}a]	[MWh/a]	[kWh/m^{2}a]	[MWh/a]
A1	**596**	**15.32**	165	**98340**	**2.08**	313.20	**51.68**	**1.24**	171.60	**28.31**	121.88	**20.11**	80.02	**13.20**
A2	**165**	**4.24**	567	**93555**	**1.98**	249.71	**141.59**	**3.41**	155.44	**88.13**	99.08	**56.18**	68.89	**39.06**
A2pt	**135**	**3.47**	917	**123795**	**2.61**	251.43	**230.56**	**5.55**	184.69	**169.36**	100.13	**91.82**	66.58	**61.05**
A3	**104**	**2.67**	2168	**225472**	**4.76**	197.69	**428.59**	**10.31**	132.60	**287.48**	85.93	**186.30**	56.59	**122.69**
A3pt	**138**	**3.55**	2389	**329682**	**6.96**	237.08	**566.38**	**13.63**	175.38	**418.98**	96.40	**230.30**	69.82	**166.80**
B1	**664**	**17.07**	102	**67728**	**1.43**	292.29	**29.81**	**0.72**	180.13	**18.37**	103.90	**10.60**	64.92	**6.62**
B2	**449**	**11.54**	870	**390630**	**8.25**	191.73	**166.81**	**4.01**	124.03	**107.91**	70.51	**61.34**	45.07	**39.21**
B3	**538**	**13.83**	2408	**1295504**	**27.36**	197.36	**475.24**	**11.44**	136.40	**328.45**	66.34	**159.75**	43.49	**104.72**
C1	**337**	**8.66**	191	**64367**	**1.36**	318.06	**60.75**	**1.46**	184.25	**35.19**	120.74	**23.06**	80.30	**15.34**
C2	**274**	**7.04**	1288	**352912**	**7.45**	306.65	**394.97**	**9.50**	184.48	**237.61**	91.90	**118.37**	60.97	**78.53**
C3	**219**	**5.63**	2080	**455520**	**9.62**	191.91	**399.17**	**9.61**	129.57	**269.51**	77.13	**160.43**	50.45	**104.94**
C3pt	**194**	**4.99**	4288	**831872**	**17.57**	231.13	**991.09**	**23.85**	130.79	**560.83**	65.40	**280.44**	40.35	**173.02**
D3	**77**	**1.98**	5270	**405790**	**8.57**	41.53	**218.86**	**5.27**	37.04	**195.20**				
TOTAL	**3890**	**100.00**		**4735167**	**100.00**		**4155.50**	**100.00**		**2745.34**		**1593.89**		**1120.39**

School building refurbishment

For each building type a set of detailed information is provided, using a reference building (real case study) to demonstrate the key architectural and technical features, current energy rating, proposed upgrades and respective energy savings through three refurbishment scenarios.

The graphics, general numeric data and short description should enable easy identification of proper building type (Figure 2a). This is accompanied with the description of material and structural properties, school building's current energy passport class - EPC (Figure 2b), drawings, descriptions and energy-related data of thermal envelope's key components, heating and hot water systems and lighting systems and fixtures – for as designed/existing condition (Figure 2c) and for 3 refurbishment scenarios (Figure 2e, 2f, 2g). Examples of other buildings belonging to the same type are given as well (photos and brief description, (Figure2d). The energy balance with EPC ratings for three proposed refurbishment scenarios and respective changes in final energy, primary energy and CO_2 emissions are presented in graphics in order to clearly communicate the benefits of energy retrofit to both to the experts and to wider audience.

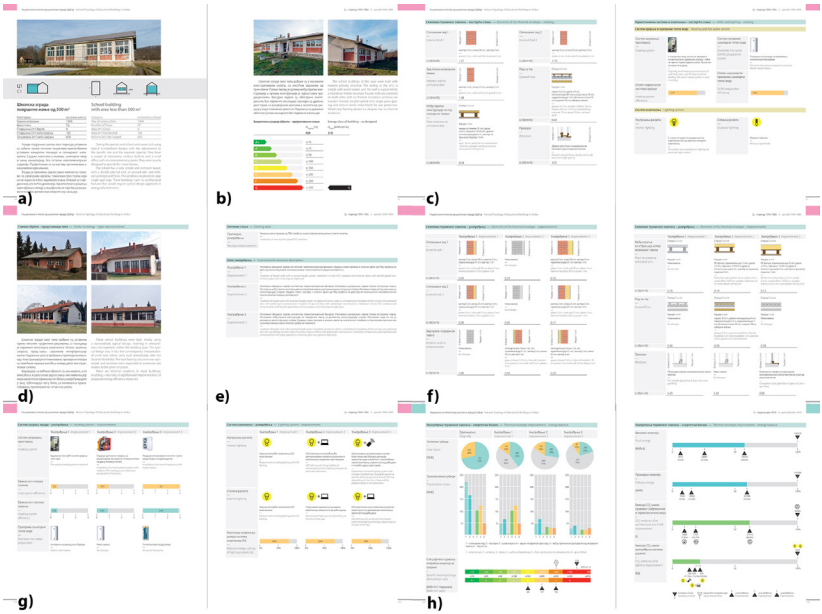

Figure 2: Example of school building type representation in National typology of school buildings in Serbia

Conclusions

National typology of school buildings in Serbia has identified 13 building types and respective reference buildings – real example buildings – that were used to assess the potential energy savings. Due to the elaborate methodology and extensive survey for data collection, the valid reference buildings could be identified, so that the refurbishment potential could be projected to the whole school buildings stock, or to subsets of the stock, covering national or regional level. This makes a building typology a tool for strategic decisions and policy making, while the data collected and processed during this research can be used for further studies and retrofit assessments of this portion of building stock.

The quality of input data is crucial for validity of such projections and for identification of representative reference buildings. The data collection in this research initially relied on the collaboration with the local authorities, but this approach could not provide even distribution since some municipalities were very responsive, some did not respond at all and some provided incomplete or invalid data. The need for additional data collection and validation caused delays in research and has proven the necessity of professional survey in order to obtain quality data.

The typology can also be used for prioritizing on various levels, defining incentives, evaluating subsidies proposals etc. Finally, the typology, presented in this form, can be directly used as a refurbishment tool for local authorities for quick overview of energy performance of a school building(s) similar to the one(s) in their district, to plan retrofitting and to be able to make rough estimations on potential savings. Having in mind that school buildings were often designed and constructed following certain models, even repeated ones with minor adaptations to local conditions, it would be possible o even find the reference building almost identical to the one that is to be refurbished. Typology has even addressed the fact that some schools have already un-

dertaken certain measures (i.e. window replacement, roof insulation etc.) so the comparisons show both "as designed" and real existing condition, covering all school buildings belonging to the same type, regardless of their current condition.

The typology, however, does not address the specific architectural qualities that can be found among school buildings. The retrofit options for listed pre-war buildings need to be developed, and architectural features of the buildings constructed 1971-1990 (Class C) should also be investigated more thoroughly in order to find the proper design strategies. The impact of the "school as a learning tool" concept should be further explored and substantially connected to the retrofit strategies for school buildings.

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