IMPROVING ENERGY EFFICIENCY OF KINDERGARTENS IN SERBIA: Challenges and Potentials

by

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Kindergartens are probably the very first public buildings we actively use in our lives. Therefore, they can be considered as the physical structures that are providing for the very important educational and social function. Additionally, they can also be considered as the specific learning tool for future generations where they can encounter the ideas of green and energy-efficient buildings. One of the results of the research project "Energy efficiency in public buildings" has been formulated through the development of Serbian National Typology of Kindergartens which was conceived as a specific tool that can be used for improving this portion of building stock. The paper presents the methodology for identification of typical kindergarten buildings, covering various construction periods, building sizes and illustrates the type of analysis performed for model representatives. The potential for energy upgrades covering physical structure, installed technological systems, as well as expected impact on energy performance, has been estimated. The study presents results based on the analysis of the data derived from the National Typology, stressing out that energy retrofits of large and medium-sized kindergartens built during the 1970s and 1980s should be the primary focus of refurbishment activities. Accounting for almost 60% of total buildings and 69.59% of heated area, they are responsible for 75.97% of energy demands. Estimated energy savings of more than 60% indicate the effectiveness of their retrofit. The paper also presents the potential uses of National Typology as a retrofit tool on various scales, from single-building considerations to a strategic approach at the national level.

Keywords: *kindergartens, building typology, energy efficiency, refurbishment, improvement measures*

Introduction

The existing building stock constitutes, in its most prominent parts, a significant component of our heritage and architects constantly work on maintaining it, improving it and adapting it to ever-changing conditions, often prolonging its lifespan way beyond the initial expectations. Even those buildings that are not recognized for their cultural, architectural or historical value, are, *de facto*, a significant man-made resource [1], having in mind variety of 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 is, therefore, one of the

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premises of sustainable development. In that context, building refurbishment can be considered as the main operational tool for achieving strategic goals in this field. The ecological impact of building stock is reflected mainly through the energy used in buildings and the corresponding CO_2 emissions.

The issue of energy efficiency of public buildings and the importance of their retrofit has been placed in the spotlight once their potential for the promotion of best practice solutions and education of wider public has been realized. Energy Efficiency Directive [2] is particularly focusing on the energy upgrades of these buildings, where in addition to the compulsory development of the public buildings database, a mandatory long-term strategy for their rehabilitation was introduced. Also, a significant share of these buildings' energy consumption – about 25% in the overall building sector [3], has focused recent research into the investigation of their energy performance characteristics and improvement scenarios development [4-6].

Educational buildings are among the most prominent public buildings as can be found in the review of recent research studies. Not only that their energy performance characteristics are examined and new models for energy performance tracking and assessment are proposed [7, 8], but also various comfort issues are studied in detail [9, 10]. Also, many researchers are stressing the wider influence of refurbishment of educational buildings. The "school as a teaching tool" is a concept that engages building users with environmental issues, offering, through informal education, a chance for students to embody principles of sustainable living in their daily activities at school, adopting them as a base standard for their future adult behaviour [11]. Results of recent research [12] indicate that sustainable design in schools improves the environmental attitudes of children towards perceptibly green building features which are later incorporated into their decision making and lifestyle routines. This emphasises the importance of best practice design in new construction of educational buildings as well as in the refurbishment of the existing ones. Some results of conducted projects of the refurbishment of educational buildings in Serbia are also available [13] but these studies are lacking a clear methodological explanation regarding the selection of buildings that were retrofitted, therefore these projects can only be seen as illustrational.

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, strived to set the ground for improving the energy efficiency in Serbia's public buildings, focusing, at this stage, mainly to the sector of schools and kindergartens. Within the project, National Typology of Kindergartens was conceived as a tool for improving this portion of building stock. It has been developed based on the data collected through the nationwide survey, which included approximately 3990 public buildings, using a purposely developed questionnaire. Special attention has been given to schools and kindergartens, the thorough introduction of additional questionnaires which has resulted in the formulation of a unique database of these buildings (563 kindergartens).

Typology based assessment of building stock energy performance has proved to be a valuable tool for supporting decision-making process in building refurbishment both on large scale building stock levels (national, regional) [14-16], as well as for the preliminary assessment of a particular building. The single building application is enabled through typology by using reference (or representative) buildings, which stand for the characteristic building type and serve as the model for in-depth analysis. This methodology has been used in Serbia for the first time for the sector of residential buildings [16], while the most recent research was focused on public educational buildings [17], namely school [18, 19], and kindergarten buildings [20]. This portion of building fund has not been largely investigated, and research focused on kindergarten buildings is rather scarce in the literature review. Several building types, including infant schools, which correspond to the typology of kindergartens in Serbia, have been studied within the investigation of an energy assessment method for school buildings, based on real building performance [7]. However, different occupancy regimes and building characteristics, as well as the significant share of kindergarten buildings in the educational building stock, require a structured and more focused analysis of this building typology, which was developed throughout the study.

The paper addresses a novel typological approach for improving energy efficiency of kindergartens in Serbia. It presents the methodology developed and applied in the process of the typology formulation as well as the core results of the study. Furthermore, it provides new levels of analysis and interpretations of the research data, pointing out the classes and building types which are expected to show the most effective results in the refurbishment process. Paper addresses the direct (at the model building level) and wider (at national level) impact serving as the decision-making tool and also giving directions for further research in the field.

Methods

Previous researches regarding improving the energy efficiency of Serbia's building stock were focused primarily on the housing sector, and the typological approach was identified as one of the crucial tools for addressing this topic on several levels. It provided:
- Clear understanding of structure and energy performance of building stock.
- Strategic assessments on a national level regarding current energy needs, possible savings with different improvement scenarios tailored for particular building types.
- Identification of building types most suitable for energy retrofit and assessing the impact of these retrofits on a 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.

Since the results of the typological approach have already been validated and consistent with similar efforts in other European countries, the same principles were used as a starting point for the development of a national typology of kindergartens. The research involved multidisciplinary team (architects, mechanical engineers, electrical engineers and external consultants for statistical data) and it was conducted through several major steps:
- Drafting the typology matrix.
- Defining the questioners.
- Data collection.
- Creation of valid database.
- Cluster analysis.
- Defining the final typology matrix.
- Detail analysis and calculations for each building type, with three improvement options.

Typology matrix determinants

Typology matrix for kindergarten buildings was drafted following the procedure derived from previous researches, mainly TABULA project [14] and National Typology of

Residential Buildings [16] where construction period and building type were used as initial determinates for types formulation. The construction periods were preliminary drafted before data collection and final classes were shaped after completing the survey as following: prior to 1945 (A), 1946-1970 (B), 1971-1990 (C), and after 1990 (D). The initial draft of eight classes (analogue to the residential typology) was cut down to final four classes by merging classes with low occurrences (prior to 1919, after 2012) and classes with similar building characteristics (1946-1960 and 1960-1970, as well as 1971-1980 and 1981-1990).

As for the building type, majority of these buildings are freestanding structures and the total floor area of a kindergarten building was used as a major defining parameter, formulating three dominant classes: up to 500 m^2 (1), 500-2000 m^2 (2), and more than 2000 m^2 (3). While in typology of residential buildings the building classes were not explicitly related to buildings' floor area, the analysis of various architectural and technical features of Serbian kindergartens showed that the majority of common features within certain construction year class relate to building's size (floor area). Most of the buildings, 42%, are mid-sized (500-2000 m^2), while large number of kindergarten buildings (33%) can be labelled as small and only 10% are large kindergarten buildings, with gross area larger than 2000 m^2.

Data collection and processing

Data collection was organized by GIZ in a manner that was intended to encourage engagement of local municipalities and their experts. Unlike the previous researches, where the professional agency was commissioned to execute the survey, the questionnaires for a national typology of kindergartens were developed having in mind the expected oscillations in motivation and educational level of individuals completing the forms. The survey intended to cover as many as possible buildings nationwide, where local municipalities were asked to provide relevant data by filing the three-step questionnaires, depending on the building type. First level questionnaire, targeting collection of basic data, was designed to cover all public buildings, while the most comprehensive third level was designed specifically for schools and kindergartens. It comprised a detailed set of questions regarding:

– Building characteristics: geometry (size, number of floors, shape, height, roof type, *etc*.), a materialization of building components (wall structure, roof structure, window type, *etc*.), applied retrofit solutions (added insulation, window replacement, adding of volumes, attic retrofits, *etc*.).
– Occupancy regimes.
– Building installations (HVAC systems, hot water preparation, fuel type used).
– Electrical systems (lighting systems characteristics, PV systems).

The data was collected during October-December 2016, and the initial database was formed. After data validation, 563 questionnaires referring to kindergartens remained, and the data were pondered in regard with 2591 kindergarten building officially registered by The Statistical Office of the Republic of Serbia and local municipalities in 2016.

Cluster analysis was applied on pondered database in order to facilitate the formation of typology, enabling selection of reference buildings (types) with the introduction of sub-types, where necessary. The cluster analysis has provided generic descriptions of typical buildings and for each building type the real representatives, with characteristics closest to the derived data, were selected from the final database.

The cluster analysis included architectural features crucial for energy performance and potential improvements:

– Gross floor area, 3 classes, as per preliminary typology.
– Compactness of the floor plan, 3 classes (compact, partially complex, complex).
– Number of floors, 4 classes relative to aboveground and 3 classes relative to underground levels.
– Roof type, 3 classes (flat, pitched, combined).
– Key thermal envelope components materials (facade wall, windows, doors, floors, roofs…).

National typology of kindergarten (pre-school) buildings in Serbia

The typology of kindergarten buildings in Serbia was defined after the previously described steps, containing 9 basic types with two sub-types in B2 due to similar occurrences of buildings with a rather different size (720 m^2 and 1450 m^2 of gross floor area, one and two levels above ground, tab. 1).

For each type a relevant representative was examined in detail, using the available technical documentation, *in-situ* observations and interviews with the facility's staff and management. The energy performance calculations for an existing condition, as well as for three improvement levels, were done according to current Serbian regulations for Energy Performance Certificate (EPC) calculation methodology, using the software package *Knauf Term Pro*. The calculations included thermal envelope, HVAC, DHW systems and electrical power and energy systems. The improvement levels were defined through three energy retrofit scenarios:

– **Improvement 1** proposes the bettering of thermal envelope only, while the existing heating system and the energy source remain the same.
– **Improvement 2** was defined to encompass a comprehensive thermal envelope refurbishment, but it also includes the improvement of the heating system mainly through changing the fuel source to more ecological one (mainly biomass) where appropriate. Basic change of light sources has been included as well.
– **Improvement 3** is the most comprehensive and most complex level. In all HVAC systems, the existing energy source is replaced with an air-to-water heat pump. Domestic hot water is primarily prepared by using solar panels or a heat pump whenever the solar energy is insufficient. All lighting installations have been improved and automatic control system installed.

Results and discussion

Until the late 1960's, the kindergartens were built using traditional building techniques, with massive masonry bearing walls, pitched roof and simple wooden windows. The design was focused on meeting the basic functional, hygienic and medical requirements and the facilities were dedicated mainly to single age group (nursery, kindergarten or pre-school) or a combination of two compatible age groups. Energy retrofit of these buildings can often be done using simple measures while resulting in significant reductions of energy demands – by 42.93-46.10% for all buildings except type B2a for *Improvement 1* and up to more than 70% for building types after *Improvement 3*, fig. 1.

However, these buildings are often in need of more complex architectural intervention that would expand their capacities and/or improve physical and didactical conditions of a given facility. Furthermore, small kindergartens were often built in smaller settlements and due to the depopulation, some of these might face repurposing.

Table 1. National typology of kindergarten buildings in Serbia

Period	1 – SMALL < 500 m^2	2 – MEDIUM 500-2000 m^2	3 – LARGE > 2000 m^2
A before 1945	 GFA – 235 m^2 NoF – GF Cmp – compact RT – pitched roof FC – brick	 GFA – 725 m^2 NoF – GF/GF + 1 Cmp – compact RT – pitched roof FC – brick	
B 1946-1970	 GFA – 460 m^2 NoF – GF Cmp – partially complex RT – pitched roof FC – brick	 GFA – 720 m^2 NoF – GF Cmp – compact RT – pitched roof FC – brick  GFA – 1450 m^2 NoF – GF + 1 Cmp – partially complex RT – partially flat FC – brick/clay block	
C 1971-1990	 GFA – 285 m^2 NoF – GF Cmp – compact/partiall complex RT – pitched roof FC – brick	 GFA – 1450 m^2 NoF – GF + 1 Cmp – compact/complex RT – pitched roof FC – brick/clay block	 GFA – 2700 m^2 NoF – GF + 1 Cmp – compact/ partially complex RT – pitched roof FC – brick/cocrete
D after 1991		 GFA – 1500 m^2 NoF – GF + 1 Cmp – compact/ partially complex RT – pitched roof FC – brick/clay block	 GFA – 2450 m^2 NoF – GF + 2 Cmp – complex RT – combined FC – clay block/concrete

Note: Parameters for cluster analysis: GFA – gross floor area, NoF – number of floors, Cmp – compactness, RT – roof type, FC – façade; GF – ground flor

During the 1960's, the buildings accommodating several age groups and offering some variety of auxiliary spaces (type representative B2b) start to emerge throughout the country, often within the new developments of housing blocks. This trend continued in the following decade, and it was dominant during the 1970's. While small kindergarten buildings retain most characteristics of other, older buildings, larger facilities were designed according to more contemporary principles. Materials and technical systems are also somewhat advanced compared to previous building types and their initial energy demands are lower than for the previous building types. Still, their thermal performance is rather poor, and their current energy performance classes are very low, ranging from E to G. The basic retrofits, *Improvement 1*, can reduce their energy demands by 30-35%, while deep renovation, *Improvement 3*, cuts their energy demands by 75-80%, fig. 1. Having in mind that this portion of kindergarten buildings (Class C + Type B2b) account for 63.2% of total buildings, 75% by area and 82.3% of total energy demands, it is obvious that these facilities are the most suitable for energy retrofits.

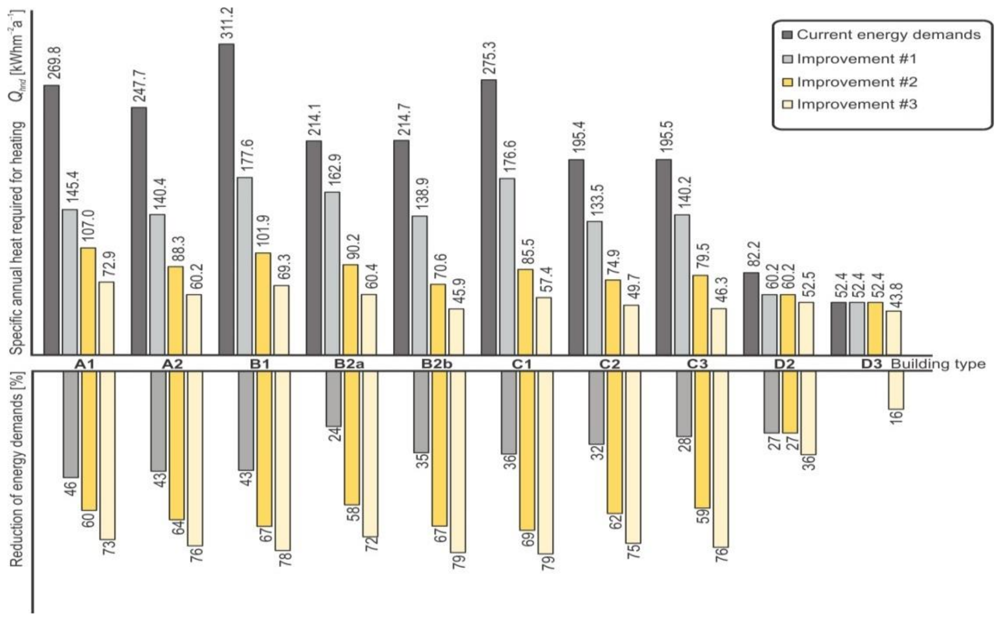

Figure 1 Overview of energy demands and potential savings for kindergarten building types

Class D buildings were constructed either in accordance with national (JUS, later SRPS) standards which were aligned with the German (DIN) standards of the time or in accordance with current national standards aligned with EN ISO 13790 (since 2012). The result is rather good energy performance of these buildings (EPC rating between C and D), so even those that do not meet current design regulations can be significantly improved only by implementation of extensive sets of measures. Figure 1 shows the calculated savings for Class D buildings: in case of sample building D3, only measures listed as *Improvement 3* can be applied while for buildings like D2 there is no significant difference between *Improvement 1* and *Improvement 2* measures. Therefore, their energy retrofits at the moment should be considered only related to particular cases where there is some other external incentive for interventions (damaged elements of the building or the equipment, need for expansions, *etc*.).

National typology as an energy retrofit tool

The data collected for each building type, together with the results of analysis and calculations related to the initial condition and the three proposed improvement levels were presented in a way that could serve as a simple retrofit assessment tool for the kindergarten management and/or relevant local stakeholders (mainly local authorities in charge of operation and maintenance of the institutions) that enables them to have some reference regarding the expected energy savings and reduction in CO_2 emissions prior to engaging into specific works, fig. 2.

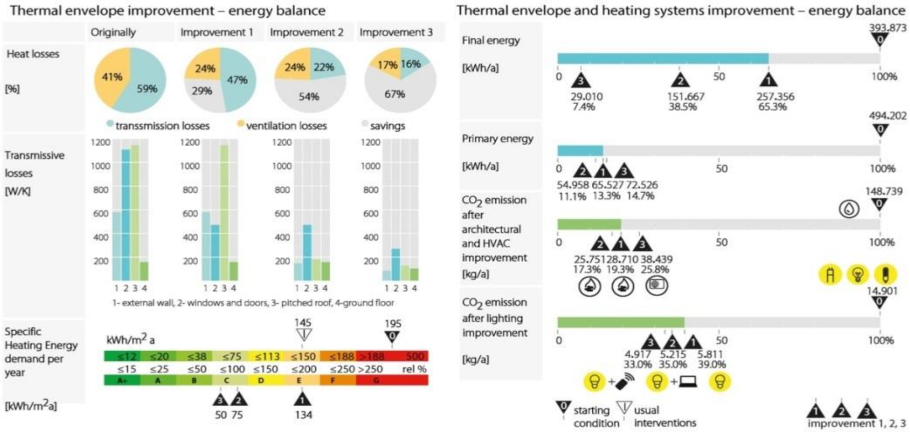

Figure 2. Sample of summary pages for a building type from National Typology of Kindergarten Buildings in Serbia [19] presenting the type C2 – page 11/12 (left) and 12/12 (right)

The complete set of information per building is very elaborative (twelve pages per type), starting with the description of basic data, in order to facilitate recognition of similar buildings: massing, fenestration, heated floors and volumes, gross and net heated area, typical floor plan, pictures of the representative building, and current energy performance class. Further, constitutive elements of the thermal envelope (description, sketches and U-values), HVAC and lighting systems are also depicted. Since most of the buildings have undergone some modifications through the years, all common interventions both on the thermal envelope as well as on building services and equipment have been identified and explained. Improvements are defined as three energy retrofit scenarios which were elaborated and briefly explained, with their impact fully calculated. Results of all interventions have been presented graphically, side by side, so that prospective user can easily compare the outcomes, fig 2. The data presentation and graphics were designed in a way that the impacts of partial improvements can be assessed as well, allowing for taking into consideration various combinations of proposed measures across the three improvement scenarios. In this way, the generic type can be used as a starting point for considering retrofit scenarios more sensitive for each particular case.

Energy retrofit impact on a national level and guidelines for future research

The share of kindergarten buildings in the overall energy demands of the existing building stock is rather small: taking into account that public buildings consume some 25% (compared to 75% for residential), and that all educational buildings account for 17% of public buildings [3, 17], that is 4.25% of total energy demands in the building sector, it is clear that targeting this portion of building stock alone would not have a significant impact on energy demands on a national level. However, this type of buildings should provide adequate comfort for the very sensitive population while mainly financed by local municipalities. Energy retrofit of kindergarten buildings, therefore, should be analysed in a somewhat wider context [11, 12, 21].

Table 2 shows the cumulative national-level data for identified building types. It is notable that the type C2 (mid-size, 1971-1990) accounts for 34.62% of the total number of buildings and 41.39% of the total heated area while consuming 44.6% of total current energy demands. The current energy demands of this building type alone surpass the estimated total energy demands of all kindergartens after *Improvement 2*. On the other hand, type D3 (large, built after 1990) that accounts for 9.61% of heated area consumes only 2.78% of energy.

These data should facilitate decision-making processes and help shaping of adequate energy efficiency policies on national and on the local level. General data analysis, such as the one presented in tab. 2, helps identify the most convenient target groups in regard to general and specific goals. The typology contains series of datasets that can be used for defining the priorities, incentives and making various projections for future development.

If analysed per building size classes, it is notable that mid-size kindergarten buildings are the most dominant group, accounting for 55.15% of all buildings, 58.83% of the overall net area and 60.43% of total energy demands, tab. 3. It is also noticeable that the mid-size kindergartens contribute the most – in current consumption as well as in estimated energy demands after the proposed improvements. The best overall energy performance is noted within the cluster of large kindergarten buildings (Class 3, larger than 2000 m^2). Although the Class1 kindergartens have the most compact volumes and rather modest window-to wall ratio compared to the others, apparently the larger structures seem to have better energy performance. Even taking into account the *Improvement 3* scenario, Class 1 remains the worst-performing class.

If analysed per construction year classes, it is notable that Class C (1971-1990) buildings account for the most – by the number of buildings (59.01%), by heated area (69.59%) and by current energy demands (75.97%, tab. 4). The *Improvement 1* brings this class close to EPC rating D, While *Improvement 2* puts them safely within the values for EPC rating C (calculated according to current Serbian legislation). The 1970's and 1980's were the decades of intense construction and development, and some of the kindergarten building designed in that period carry specific and distinctive architectural qualities. Having in mind the volume of buildings of this period and their architectural values, they require special treatment and focus of future research should be placed on them. Being 40-50 years old, C class buildings are also often in a condition that requires some major works and the energy retrofit process can be efficiently coupled with other maintenance and improvement works. Adjustments of the capacities, modernisation and additional facilities can also be included into consideration. Communicating the concepts of energy efficiency to the youngest population and general public would be the most effective through this building class.

The database produced during the study can also serve as a valuable source for future research. The questionnaire was designed having in mind, from the very start, the energy optimisation of kindergarten buildings and extensive data collected on these buildings' properties, materials, equipment and operation can be used for exploring and defining future activities. Such activities may range from the development of new design guidelines (enabling the verification of the theoretical estimations by comparing them with the actual buildings) through the process of monitoring and comparisons between performance of retrofitted and not retrofitted buildings of the same type or class, selection of pilot/flagship projects, *etc*.

Table 2. Overview of the volume of kindergarten building types (by number and by heated area) with energy demands estimations

Building type	Number of kindergartens		Heated area			Current energy demands			Improvement 1		Improvement 2		Improvement 3	
			Typical	Total		Typical Q_{hnd}	Total		Typical Q_{hnd}	Total	Typical Q_{hnd}	Total	Typical Q_{hnd}	Total
	Pcs	%	[m²]	[m²]	%	[kWh/m²a]	[MWh/a]	%	[kWh/m²a]	[MWh/a]	[kWh/m²a]	[MWh/a]	[kWh/m²a]	[MWh/a]
A1	236	9.11	164	38,704	1.47	269.76	10,440.79	2.19	145.39	5,627.17	107.01	4,141.72	72.87	2,820.36
A2	100	3.86	550	55,000	2.09	247.73	13,625.15	2.85	140.44	7,724.20	88.27	4,854.85	60.23	3,312.65
B1	184	7.10	270	49,680	1.89	311.16	15,458.43	3.24	177.57	8,821.68	101.93	5,063.88	69.30	3,442.82
B2a	128	4.94	600	76,800	2.92	214.10	16,442.88	3.44	162.89	12,509.95	90.18	6,925.82	60.41	4,639.49
B2b	117	4.52	1,200	140,400	5.33	214.69	30,142.48	6.31	138.92	19,504.37	70.58	9,909.43	45.93	6,448.57
C1	323	12.47	180	58,140	2.21	275.32	16,007.10	3.35	176.59	10,266.94	85.46	4,968.64	57.36	3,334.91
C2	897	34.62	1,215	1,089,855	41.39	195.40	212,957.67	44.60	133.54	145,539.24	74.93	81,662.84	49.69	54,154.89
C3	309	11.93	2,215	684,435	25.99	195.48	133,793.35	28.02	140.15	95,923.57	79.47	54,392.05	46.26	31,661.96
D2	187	7.22	1,000	187,000	7.10	82.18	15,367.66	3.22	60.22	11,261.14	60.22	11,261.14	52.48	9,813.76
D3	110	4.25	2,300	253,000	9.61	52.44	13,267.32	2.78	52.44	13,267.32	52.44	13,267.32	43.83	11,088.99
TOTAL	2,591	100.00		2,633,014	100.00		477,502.83	100.00		330,445.58		196,447.69		130,718.41

Table 3. Overview of the building size classes (Class 1-3) with energy demands estimations

Class: Building size	Number of kindergartens		Heated area			Current energy demands			Improvement 1		Improvement 2		Improvement 3	
			Typical	Total		Typical Q_{hnd}	Total		Typical Q_{hnd}	Total	Typical Q_{hnd}	Total	Typical Q_{hnd}	Total
	Pcs	%	[m²]	[m²]	%	[kWh/m²a]	[MWh/a]	%	[kWh/m²a]	[MWh/a]	[kWh/m²a]	[MWh/a]	[kWh/m²a]	[MWh/a]
1 (<500 m²)	743	28.68	204.67	146,524	5.56	285.41	41,906.32	8.78	166.52	24,715.79	98.13	14,174.24	66.51	9,598.09
2 (500-2000m²)	1,429	55.15	913	1,549,055	58.83	190.82	288,535.83	60.43	127.20	196,538.90	76.84	114,614.08	53.75	78,369.36
3 (>2000m²)	419	16.17	2,257.5	937,435	35.60	123.96	147,060.67	30.80	96.30	109,190.89	65.96	67,659.37	45.05	42,750.95
TOTAL	2,591	100.00		2,633,014	100.00		477,502.83	100.00		330,445.58		196,447.69		130,718.41

Table 4. Overview of the construction year classes with energy demands estimations

Class: Construction year	Number of kindergartens		Heated area			Current energy demands			Improvement 1		Improvement 2		Improvement 3	
			Typical	Total		Typical Q_{hnd}	Total		Typical Q_{hnd}	Total	Typical Q_{hnd}	Total	Typical Q_{hnd}	Total
	Pcs	%	[m²]	[m²]	%	[kWh/m²a]	[MWh/a]	%	[kWh/m²a]	[MWh/a]	[kWh/m²a]	[MWh/a]	[kWh/m²a]	[MWh/a]
A (< 1945)	336	12.97	357	93,704	3.56	258.75	24,065.94	5.04	142.92	13,351.37	97.64	8,996.57	66.55	6,133.01
B (1946-1970)	429	16.56	690	266,880	10.14	246.65	62,043.78	12.99	159.79	40,836.00	87.56	21,899.14	58.55	14,530.88
C (1971-1990)	1,529	59.01	1,203.33	1,832,430	69.59	222.07	362,758.13	75.97	150.09	251,729.74	79.95	141,023.53	51.10	89,151.77
D (> 1991)	297	11.46	1,650.00	440,000	16.71	67.31	28,634.98	6.00	56.33	24,528.46	56.33	24,528.46	48.16	20,902.75
TOTAL	2,591	100.00		2,633,014	100.00		477,502.83	100.00		330,445.58		196,447.69		130,718.41

Conclusions

The National typology of kindergarten buildings in Serbia has identified ten building types and respective reference buildings – real example buildings – that were used to assess the potential energy savings. Based on the elaborate methodology and extensive survey in the process of data collection, reference buildings were identified, enabling projection of refurbishment potential on the whole kindergarten buildings stock, or to specific subsets of the stock, covering national or regional/municipal level. This makes building typology a useful tool for strategic decisions and policymaking, while the data collected and processed during this research present a generous base for further studies and retrofit assessments of this portion of building stock. The data collection, in this research, initially relied on the collaboration with the local authorities nationwide but applied approach could not provide even distribution of collected data, since some municipalities were very responsive, some did not respond at all, and some provided incomplete or invalid data.

The typology can be used for prioritizing on various levels, defining incentives, evaluating subsidies proposals, *etc*. Analyses that was presented in the paper, cross-referencing overview of cumulative nation-level data per building size class and per construction year class, has shown the greatest refurbishment potential in mid-size kindergarten buildings from the 1970's (type C2). Although, as per individual type, A1 has shown the greatest reductions after basic improvement scenario (46.10% for *Improvement 1*) and C1 for *Improvements 2* and *3* (68.96% and 79.17%, respectively), the distribution of identified building types is such that the overall impact of type C2 is more relevant since this type alone accounts for 34.62% of buildings, 41.39% of heated area and 44.6% of estimated current energy demands. Type C1, for example, accounts for 12.47% of buildings, 2.21% of heated area, and 3.35% of current energy demands while for the type A1 the respective shares are 9.11%, 1.47%, and 2.19%.The typology can also be directly used as a refurbishment tool for local authorities for a quick overview of the 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 during certain periods kindergarten buildings were often designed and constructed following similar models, even almost repeated ones with minor adaptations to local conditions, it would be possible to even find the reference building almost identical to the one that is to be refurbished. Typology has addressed the fact that some kindergartens have already undertaken certain measures (usual interventions, such as window replacement, roof insulation, *etc*.) so the comparisons show both as designed and real existing condition (fig. 2 – conditions 0 and I, respectively). The results indicate that in many cases *Improvement 2* scenario might be the most beneficial. It covers some measures that are maybe already applied in a specific case and provides a combination of architectural and technical improvements that result in significant reductions in heating energy demands with optimal reductions of primary energy needs, CO_2 emissions, *etc*. In case of type C2, for example, energy performance after *Improvement 1* is only slightly better than the one after the usual interventions already executed on a number of buildings, while *Improvements 2* and *3* result in the same EPC rating, fig. 2.

The typology, however, does not address the specific architectural qualities that can be found among kindergarten buildings. Architectural features of Class C (1971-1990) buildings should also be investigated more thoroughly in order to find the proper design strategies. The impact of the "school as a teaching tool" concept should be further explored and substantially connected to the retrofit strategies for kindergarten buildings. The similarity of small (Class 1) kindergartens to housing regarding building technologies and main energy refurbishment issues could be used to communicate the concept more vividly to the general public.

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