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APPLICABILITY OF THE "TYPOLOGY OF RESIDENTIAL BUILDINGS IN BOSNIA AND HERZEGOVINA", AT A MUNICIPALITY OR CITY LEVEL, CASE STUDY - SINGLE-FAMILY HOUSES IN THE CITY DERVENTA

Abstract

In order to make correct estimates of energy consumption for heating, reduction of energy consumption, and CO_2 emissions by applying energy efficiency measures, it is necessary to know the structure and characteristics of the building stock. The Typology of residential buildings in Bosnia and Herzegovina identified the structure and characteristics of residential building stock through different periods at the level of Bosnia and Herzegovina. This paper analyses the differences between national and city or municipal typology. Conducted analysis for the City Derventa, shows that in the case of single-family houses, the application of national instead of local typology can result in certain deviations in the estimation of energy consumption, savings, and CO_2 emissions.

Keywords: single-family houses, typology, energy consumption, energy efficiency

ПРИМЈЕНЉИВОСТ ТИПОЛОГИЈЕ СТАМБЕНИХ ЗГРАДА У БОСНИ И ХЕРЦЕГОВИНИ НА НИОВУ ОПШТИНА ОДНОСНО ГРАДОВА, СТУДИЈА СЛУЧАЈА – СЛОБОДНОСТОЈЕЋЕ КУЋЕ У ГРАДУ ДЕРВЕНТА

Сажетак

Да би се направиле исправне процјене потрошње енергије за гријање стамбеног сектора, смањења потрошње енергије и емисије CO_2 примјеном мјера енергетске ефикасност потребно је сто реалистичније познавати структуру и карактеристике стамбеног фонда. „Типологија стамбених зграда Босне и Херцеговине“ идентификовала је карактеристике стамбених објеката на нивоу државе Босне и Херцеговине по појединим периодима изградње. Овај рад анализира разлике између националне и локалне типологије. Проведена анализа на примјеру града Дервента, показује да у случају слободностојећих кућа, примјена националне умјесто локалне типологија може довести до одређених одступања у процјенама потрошње, уштеде енергије и емисије CO_2.

Кључне ријечи: слободностојеће куће, типологија, потрошња енергије, енергетска ефикасност

1. INTRODUCTION

Buildings are responsible for about a third of global energy consumption and a quarter of CO_2 emissions [1]. In the European Union (EU), buildings are the largest consumers of energy (40% of total final energy consumption in 2012), and are responsible for 36% of the emissions of CO_2. Some research showed that about 58.44% of the total energy in Bosnia and Herzegovina is used in the residential sector [2]. Increasing energy efficiency in the building sector is fundamentally important for decreasing energy consumption, fossil fuels consumption, and greenhouse gas (GHG) emissions, and of course, gives the possibility of using renewable energy sources on a much larger scale. In order to create different scenarios for the reconstruction of the building sector, and planning of the necessary investments, it is very important to have data about the structure and characteristics of residential building stock at the local, regional, entity, and national levels. Local, regional, and national typologies are very valuable tools for those types of analyses.

The Typology of residential buildings in Bosnia and Herzegovina was created as a result of a two-year scientific research project (2014-2016) [3], and presents the classification of existing residential buildings according to the type and period of construction until 2014. It contains a calculation of the energy need for heating buildings, building structures, thermo-technical systems for heating, and domestic hot water systems, as well as a proposal of measures for improving architectural and construction building parts and measures for improving heating systems and domestic hot water systems for 29 selected typical buildings, in accordance with the methodology of the European project TABULA.

Typologies provide insight into the most important characteristics of buildings but also contain a lot of data for numerous further scientific research projects (e.g., the National Typology of residential buildings in Serbia [4] was used in the papers [5] - [7], the Typology of residential buildings in Bosnia and Herzegovina in papers [8] – [11], etc). In [5], a comparative analysis of residential indoor air pollutant concentration change is presented through different mitigation scenarios by implementing building physical and thermal retrofit measures for existing Belgrade and Niš housing stock up to 2050. For modelling the overall residential stock, appropriate data from [4] (i.e., building construction, building age, etc., and thermal i.e., heating system, envelope thermal performances, etc.) were used.

Ćuković – Ignjatović et al, [6] investigated the potential for improving the energy performance of multifamily housing blocks connected to the district heating system. The national Typology of residential buildings in Serbia [4] was used as a tool for assessment of current building performance and savings through different retrofit scenarios.

The reduction of energy demand in the residential building sector by a bottom-up simulation model through three different scenarios was analysed in [7]. The bottom-up simulation model was developed based on the national Typology of residential buildings in Serbia [4] as an input.

Gajić at all, [8] analysed the potential savings of the energy need for heating the existing single-family houses in the residential stock in urban and rural areas of Bosnia and Herzegovina, based on data from [3].

The representative shape factors of residential houses and buildings in Bosnia and Herzegovina were analysed in [9]. The paper is based on the data from the Typology of residential buildings in Bosnia and Herzegovina [3].

Kadrić, et al, [10] performed a comparison of methodologies for calculating the energy demands of residential buildings from the national typologies of Bosnia and Herzegovina [3] and Serbia [4]. In addition, the comparison of the data obtained from the two national typologies and the necessary corrections were proposed that would enable a more accurate assessment of energy consumption for heating in the residential sector of the two countries.

Gvero et al. [11], analysed the urban air pollution caused by the emission of PM10 from small household devices and abatement measures in one part of the Banja Luka city area. For prediction and quantification of the influence of the household's appliances, the results of the project the Typology of residential buildings in Bosnia and Herzegovina were used.

The Typology of residential buildings in Bosnia and Herzegovina is also used for the preparation of the Integral Building Renovation Strategy in Bosnia and Herzegovina until 2050 [12].

According to [3], the number of buildings of single-family housing (97.63%) compared to collective housing (2.37%) is significantly higher. Also, 73.71% of the gross surface area of residential space belongs to single-family houses. From this percent, almost 90% (i.e. 90.42% according to the gross surface of residential space) of single-family houses were built in the period 1971-2014.

In the absence of other data, the Typology of residential buildings in Bosnia and Herzegovina [3] is used today to assess the energy characteristics of the building stock in most municipalities and cities in Bosnia and Herzegovina.

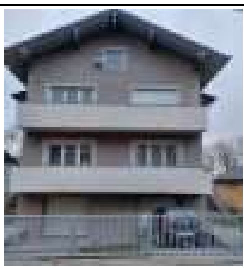
Having in mind that the national typology was created as a result of a comprehensive analysis of the building stock at the national level, this paper attempts to answer whether the data from [3] are applicable at the local (municipality or city) level, where the building stock is much smaller. Single-family houses built in the period 1971-2014 were selected for this analysis because they are the most represented type of building in Bosnia and Herzegovina and in the City Derventa.

2. ANALYSES AND DISCUSSION

The Typology of residential buildings in the City Derventa [13] was created within the framework of the INER project (Intelligent energy management and promotion of renewable energy sources) within the framework of INTERREG IPA as a result of two-year research (2020-2022). The Typology of the City Derventa contains data about typical buildings, building envelope construction, energy calculations, heating and hot water preparation systems, possibilities for improving energy efficiency with the aim of reducing energy consumption for two scenarios (standard and improved scenario), etc. according to the type and period of construction of building stock.

According to the 2013 Census, the City Derventa has 27,404 inhabitants and 13,748 housing units [13]. A significant increase in the number of residential buildings in the City Derventa began in the 1960s of the 20th century and was caused by industrialization, which required a large workforce. In the City Derventa around 14,500 building units were destroyed or damaged as a result of the last war. In the first post-war years, the majority of multi-family buildings and single-family houses underwent partial renovation. The matrix overview of characteristic single-family houses in the period 1971-2014, from the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina is given in Table 1.

Table 1. Matrix overview of characteristic single-family houses in the period 1971-2014, from the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina

	The "Typology of residential buildings in the City Derventa" [13]	*The "Typology of residential buildings in Bosnia and Herzegovina" [3]*
1971-1980		
1981-1992		
1992-2014		

The data about the net area of heating space, heated space volume, and shape factor of the characteristic buildings in booth typologies are presented in Table 2, and the heat transfer coefficient (U values) of the basic elements of the envelope are presented in Table 3. As can be seen from Table 1, the net area and heating volume of characteristic single-family houses in the City Derventa, by period of construction, are higher than in the national typology.

Table 2. The area of heating space, heated space volume and shape factor of the characteristically single family houses in the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina

Types	*Periods*	*Typology*	*Net area of the heated spaces*	*Heated space volume*	*Shape factor -f_0= A/V ratio*
Building category	*Built in*		*m²*	*m³*	-
Single family houses (SH)	*1971-1980*	*Derventa*	*165.6*	*558.9*	*0.802*
		Bosnia and Herzegovina	*67.8*	*149.2*	*1.04*
	1981-1992	*Derventa*	*125.22*	*374.40*	*0.93*
		Bosnia and Herzegovina	*101.4*	*250.2*	*0.83*
	1992-2014	*Derventa*	*168.42*	*499.2*	*1.04*
		Bosnia and Herzegovina	*121.1*	*298.7*	*0.92*

As it can be seen from Table 2, the shape factor of the characteristic single-family house in the City Derventa in the construction period 1971–1980 is smaller than the shape factor of the characteristic single-family house in the national typology. The opposite situation is in the construction periods of 1980–1992 and 1992–2014. The heat transfer coefficients of characteristically single-family houses, (Table 3) according to the construction periods considered, are generally similar in both typologies. A few significant differences are noticeable in the construction period 1981–1992, where the coefficients of characteristically single-family houses in the City Derventa, in most cases, are higher than in the national typology.

Table 3. Heat transfer coefficient (U values) elements of envelope of the characteristically single family houses in the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina

Types	*Periods*	*Typology*	*U external wall*	*U windows*	*U ground floor*	*U floor construction to unheated attic*
Building category	*Built in*		*W/(m²K)*	*W/(m²K)*	*W/(m²K)*	*W/(m²K)*
Single family houses (SH)	*1971-1980*	*Derventa*	*1.664*	*3.00*	*3.38*	*2.522*
		Bosnia and Herzegovina	*1.64*	*3.00*	*3.63*	*1.75*
	1981-1992	*Derventa*	*1.612*	*2.9*	*3.22*	*2.36*
		Bosnia and Herzegovina	*0.5*	*2.93*	*0.43*	*0.34*
	1992-2014	*Derventa*	*0.517*	*2.85*	*0.693*	*2.98*
		Bosnia and Herzegovina	*0.52*	*2.85*	*0.578*	*0.34*

Energy calculation (annual energy need for heating, delivery energy, primary energy, and emission of CO_2) of characteristic single-family houses by different periods of construction is presented in Table 4, and was carried out according to appropriate rulebooks [14] – [16]. The identified typical heating systems and the system for preparing domestic hot water, as well as their efficiency, are identical in both typologies. For the purposes of this analysis, energy calculations for all characteristic single-family houses were performed using the same meteorological data (the "North Zone" [14]) as in the national typology.

Table 4. Energy characteristic of single-family houses by different period of construction from the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina.

Types	*Periods*	*Typology*	*Specific energy need for heating $Q_{h,nd,cont}$ (continuous heating, annual)*	*Specific energy need for heating $Q_{h,nd,interm}$ (intermittent heating, annual)*	*Specific delivered energy for heating $E_{h,del,interm}$ (annual)*	*Specific primary energy for heating $E_{prim,interm}$ (annual)*	*Specific emission CO_2 (annual)*
Building category	*Built in*		*kWh/(m^{2}a)*	*kWh/(m^{2}a)*	*kWh/(m^{2}a)*	*kWh/(m^{2}a)*	*kg/(m^{2}a)*
Single family houses (SH)	*1971-1980*	*Derventa*	*349.69*	*263.35*	*526.7*	*589.90*	*35.70*
		Bosnia and Herzegovina	*484.58*	*381.59*	*763.19*	*854.77*	*51.73*
	1981-1992	*Derventa*	*347.51*	*247.91*	*495.82*	*555.32*	*33.61*
		Bosnia and Herzegovina	*176.45*	*135.93*	*271.86*	*304.47*	*18.43*
	1992-2014	*Derventa*	*224.04*	*162.71*	*325.42*	*555.32*	*22.06*
		Bosnia and Herzegovina	*149.89*	*127.61*	*255.25*	*285.86*	*17.30*

According to Table 4, the specific energy consumption (need, deliver, and primary) and CO_2 emissions of characteristically single-family houses in the City Derventa are higher in two construction periods (1981–1992 and 1992–2014) and lower in one construction period (1971–1988). Obviously, differences in energy consumption are mostly caused by the difference in the shape factor of characteristically single-family houses and less by the difference in the values of the U values of the envelope elements. These differences are not negligible, as shown in Figure 1, and amount from 21.27% in the case of energy need for heating (intermittent heating) and CO_2 emissions (construction period 1992–2014) up to 45.17% for the same parameters in the construction period 1981–1992.

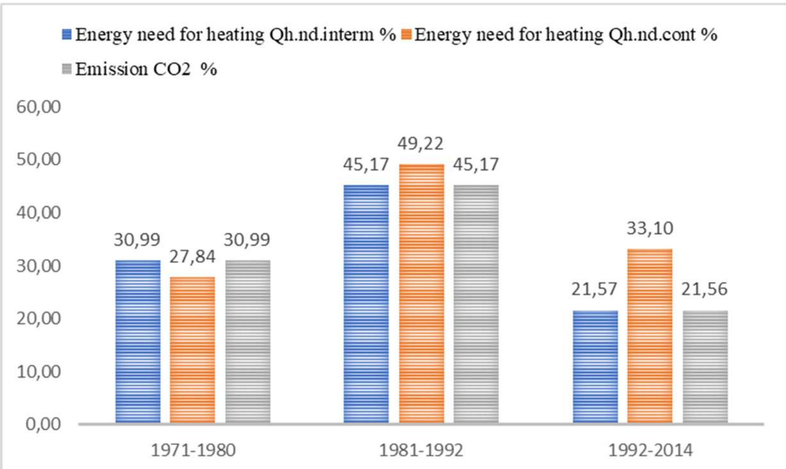


Figure 1. Difference in energy need for heating and emission CO_2 of single-family houses by different period of construction from the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina"

As already mentioned, energy calculations for all characteristic single-family houses in the City Derventa were performed using the same meteorological data as in the national typology. Taking into account that average monthly temperatures for the City Derventa prescribed by [14] are higher than those for the "North Zone," the identified difference in energy consumption (Figure 1) will be less expressed for the characteristic single-family houses in the construction periods 1981–1992 and 1992–2014 and more for the construction period 1971–1980.

The values of the heat transfer coefficient (U value) elements of the envelope of characteristically single-family houses and energy needs for heating after implementation of the first set of standard improvement measures are presented in Table 5. As can be seen from Table 5, the use of data from national typologies for the estimation of energy savings by implementation of the first set of standard improvement measures, instead of data from the local typology, would also lead to wrong estimations, although now these differences are much smaller and are in the range of 3.35% for the period of construction in 1992–2014 to 29.99% for the construction period 1971–1980. In this case, it is also important to stress that calculations with local meteorological data would cause the correction of the obtained results in the same way as already mentioned. At the City level, these differences will be further increased due to the differences in the surfaces of the characteristic single-family houses in different typologies.

Table 5. Heat transfer coefficient (U values) elements of envelope and specific energy need for heating (annual) of the characteristically single-family houses after implementation of the first set of standard improvement measures in the Typology of residential buildings in the City Derventa and the Typology of residential buildings in Bosnia and Herzegovina

Types	*Periods*	*Typology*	*U external wall*	*U windows*	*U floor construction to unheated attic*	*Specific energy need for heating $Q_{h,nd,interm}$ (annual)*
Building category	*Built in*		*W/(m²K)*	*W/(m²K)*	*W/(m²K)*	*kWh/(m²a)*
Single family houses (SH)	*1971-1980*	*Derventa*	*0.285*	*1.60*	*0.289*	*93.89*
		Bosnia and Herzegovina	*0.32*	*1.60*	*0.33*	*134.11*
	1981-1992	*Derventa*	*0.28*	*1.60*	*0.289*	*90.51*
		Bosnia and Herzegovina	*0.22*	*1.60*	*0.19*	*72.71*
	1992-2014	*Derventa*	*0.284*	*1.60*	*0.28*	*89.02*
		Bosnia and Herzegovina	*0.22*	*1.60*	*0.18*	*86.04*

3. CONCLUSION

In order to make correct estimates of energy consumption for heating in the residential building sector, reducing energy consumption and CO_2 emissions by applying energy efficiency measures in a municipality or city, but also at the entity and state level, it is necessary to know the structure and characteristics of the building stock as realistically as possible. Strategic planning is much easier if exist appropriate typologies of residential buildings at different levels. Conducted analyses show that if the data from the national typology in local communities were used, for the purposes of implementing energy efficiency measures, reducing emissions of CO_2, etc., in the case of single-family houses, it could lead to wrong estimates at the local level.

Table 4 and Figure 1 indicate, that the assessment of the energy characteristics of building stock at the municipality or city level, in the case of single-family houses should be based on local typologies (if they exist). Otherwise, the national typology can be used but taking into account its limitations caused by local characteristics of building stock.

Local typologies should also contain data about energy consumption calculated using local meteorological data. This would further improve the estimation of consumption and potential energy savings and, of course, cause additional differences between the calculated energies in local typologies and national typologies.

LITERATURE

[1] M. González-Torres, L. Pérez-Lombard, J. F. Coronel, I. R. Maestre, and D. Yan, "A review on buildings energy information: Trends, end-uses, fuels and drivers," Energy Reports, vol. 8, pp. 626–637, Nov. 2022, doi: https://doi.org/10.1016/j.egyr.2021.11.280.

[2] "Bosnia And Herzegovina First National Energy Efficiency Action Plan 2010-2018, final draft," Sarajevo, 2012.

[3] D. Arnautović-Aksić et al., Tipologija stambenih zgrada Bosne i Hercegovine, Arhitektonski fakultet Univerziteta u Sarajevu, Arhitektonsko građevinski fakultet u Banjoj Luci, 2016. Accessed: Feb. 09, 2024. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://af.unsa.ba/publikacije/Typology_of_Residential_Buildings_in_Bosnia_and_Herzegovina.pdf

[4] M. Jovanović-Popović, D. Ignjatović, A. Radivojević, and A. Rajčić, National Typology of residential buildings in Serbia. Belgrade: Faculty of Architecture, University of Belgrade and GIZ - Deutsche Gesellschaft fur internationale Zusammenarbeit, 2013. Accessed: Feb. 09, 2024. [Online]. Available: http://eeplatforma.arh.bg.ac.rs/en/publications/national-typology-of-residential-buildings-in-serbia

[5] S. P. Stefanovic, M. Stevanovic, Borislav Grubor, Z Zana Stevanovic, M. Živković, and Maja Djurovic-Petrovic, "Comparative analyses of built environment exposures relevant to health of greenhouse gas emissions reduction strategies in Serbia," Thermal Science, vol. 18, no. 3, pp. 903–914, Jan. 2014, doi: https://doi.org/10.2298/tsci1403903s.

[6] N. Ćukovic-Ignjatovic, D. Ignjatovic, and B. Sudimac, "Potentials for improving energy performance of multifamily housing blocks connected to the district heating system," Thermal Science, vol. 22, no. Suppl. 4, pp. 1183–1193, 2018, doi: https://doi.org/10.2298/tsci170612228c.

[7] A. Novikova, T. Csoknyai, M. Jovanovic-Popovic, B. Stankovic, and Z. Szalay, "Assessment of decarbonisation scenarios for the residential buildings of Serbia," Thermal Science, vol. 22, no. Suppl. 4, pp. 1231–1247, 2018, doi: https://doi.org/10.2298/tsci171221229n.

[8] D. Gajić, E. Salihović, and N. Zagora, "Energy Saving Potential of the Refurbishment of Building Envelope of the Existing Single-Family Houses in Urban and Rural Areas of Bosnia and Herzegovina," presented at the PLACES AND TECHNOLOGIES 2017, Sarajevo, 2017. Accessed: Feb. 09, 2024. [Online]. Available: https://www.researchgate.net/publication/319623865_ENERGY_SAVING_POTENTIAL_OF_THE_REFURBISHMENT_OF_BUILDING_ENVELOPE_OF_THE_EXISTING_SINGLE-FAMILY_HOUSES_IN_URBAN_AND_RURAL_AREAS_OF_BOSNIA_AND_HERZEGOVINA

[9] D. Gajić, D. Todorović, and N. Zagora, "Reprezentativni faktori oblika stambenih kuća i zgrada Bosne i Hercegovine za određivanje referentnih energetskih razreda," in ENEF 2017, B. Blanuša, Č. Zeljković, and P. Matić, Eds., Banja Luka, Nov. 2017, pp. 9–14.

[10] D. Kadrić, B. Živković, N. Delalić, B. Delalić, and I. Bešović, "The residential building national typology in the Republic of Serbia and in Bosnia and Herzegovina in the function of determination of needed and delivered energy for the residential sector heating," KGH – Klimatizacija, grejanje, hlađenje, vol. 47, pp. 67–78, Feb. 2018. Accessed: Feb. 09, 2024. [Online]. Available: https://izdanja.smeits.rs/index.php/kgh/article/view/3335

[11] P. Gvero, R. Radic, M. Kotur, and D. Kardas, "Urban air pollution caused by the emission of PM10 from the small household devices and abatement measures," Thermal Science, vol. 22, no. 6 Part A, pp. 2325–2333, 2018, doi: https://doi.org/10.2298/tsci180119152g.

[12] ENOVA, "Integral Building Renovation Strategy in Bosnia and Herzegovina up to 2050." Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://usaideia.ba/wp-content/uploads/2021/08/building-renovation-strategy-in-bih-by-2050.pdf

[13] Tipologija stambenih zgrada grada Dervente. Accessed: Feb. 09, 2024. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://lir.ba/wp-content/uploads/2021/11/D.T1.1.1-Local-building-typology-Derventa-LIR-Evolution-FINAL.pdf

[14] Ministarstvo za prostorno uređenje, građevinarstvo i ekologiju Republike Srpske, "Pravilnik o minimalnim zahtjevima za energetske karakteristike zgrada," Apr. 2015. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://ekofondrs.org/sadrzaj/dokumenti/ee/Pravilnik_o_minimalnim_zahtjevima_za_energetske_karakteristike_zgrada.pdf(accessed Feb. 09, 2024).

[15] Ministarstvo za prostorno uređenje, građevinarstvo i ekologiju Republike Srpske, "Pravilnik o vršenju energetskog pregleda zgrada i izdavanju energetskog certifikata." Apr. 2015. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ekofondrs.org/sadrzaj/dokumenti/ee/Pravilnik_o_vrsenju_energetskog_pregleda_zgrada_i_izdavanju_energetskog_certifikata.pdf (accessed Feb. 09, 2024).

[16] Ministarstvo za prostorno uređenje, građevinarstvo i ekologiju Republiek Srpske, "Pravilnik o metodologiji izračunavanja energetskih karakteristika zgrada." Apr. 2015. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ekofondrs.org/sadrzaj/dokumenti/ee/Pravilnik_o_metodologiji_za_izracunavanje_energetskih_karakteristika_zgrada.pdf (accessed Feb. 09, 2024).