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Strategy for energy efficient reconstruction of residential low-rise buildings

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ABSTRACT

Significant percent of population live in low-rise residential buildings. Energy efficiency of new houses is embodied in national regulations; proves on adequate energy performance represent the prerequisite for construction permit obtaining. Achieving energy efficiency in existing low-rise residential building, on the other hand, is more complex and problematic. By reviewing existing legal framework and taking into account the state on field, this paper aims to propose new methodology for energy performance improvement in existing low-rise residential sector (on the example of Montenegro and Serbia) . Proposed problem solution is oriented towards both the additional legal actions and deeper understanding of social and economic impacts as barriers to energy efficiency achievement.

Contents

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1. Introduction

Achieving and constantly enhancing the energy end-use efficiency accounts for generally recognized objective and one of the key research topics in contemporary technical sciences.

The culmination of interest, however, did not significantly reflect on changes in construction practice of new developments in Serbia and Montenegro: apart from the obligatory fulfilment of minimal, regulated requirements, visible most of all in the increment of thickness of thermal insulation layer and in improved characteristics of glazed segments of thermal envelope, other energy efficient measures are still rarely applied [1]. United Nations Economic Commission for Europe puts housing sector as one of the priority areas with regard to energy efficiency "not only because it consumes a large amount of energy, but also because it remains remarkably wasteful. While the state of existing technology provides a high potential for drastically reduced energy use in housing, the sector currently maintains outdated inefficient practices, and is one of the drivers of high levels of consumption" [2, p. III]. "... it is the transition countries that especially lag behind. A specific challenge for these countries relates for overcoming what can be called the energy inefficiency trap, or a situation in which countries having lower energy efficiency are unable to change their respective status due to the lacks of funds, experience, technology, motivation and initiative" [2, p. 2].

In Serbia and Montenegro, existing single-family residential stock is considered as energy inefficient. While the regulations often remain unapplied, the operational energy consumption remains high. Most of the houses were built before the first regulations on thermal protection of buildings were introduced, thus without thermal insulation in the envelope. The use of thermal insulation started approximately twenty years ago, but its thickness, as well as the characteristics of glazed elements of envelope do not satisfy present regulations [3]. Both in Serbia and Montenegro, significant part of existing single-family residential stock is built without building permit, based on everyday practice and knowledge [3], [4]. Therefore, one of the main objectives in action plans for energy performance improvement, such as in *Action plan of Montenegro for energy efficient measures in housing sector*, is to improve energy efficiency in illegally built houses through the process of legalization.

In conditions of long lasting unfavorable economic situation, the main owners' motive for saving the energy in a house represent the result of an effort to save the money that should be given to pay the bills. Major retrofitting done at once and with the aim of improving energy performance is too economically demanding measure for many, and, beside this, hard to follow and control.

Energy efficiency in existing single-family residential stock, from all above noted, might be considered as a significant current challenge for the two subject countries, while at the same time, for comparison, in developed western countries the attention already moves to other aspects of ecological friendliness of buildings, such as building materials or embodied energy [5].

Untapped potential for energy savings through building renovation of existing buildings may also be observed in the light of recent intensive debate regarding adoption of the *2030 Climate & Energy Package*. Namely, three leading building industry associations called all the EU 28 Heads of State for adoption of ambitious but realistic binding energy efficiency target of 40% by 2030. They are convinced that present state of the art of technology solutions in building industry can guaranty improvement of energy efficiency by refurbishment of existing building stock, ensuring on that way achievement of mentioned 40% target [6]. Besides direct impact on phasing out of leaky buildings, several positive side effects like enhancing employment, improvement of energy security and alleviating energy poverty are expected to happen. These impacts would also be well appreciated in both our countries, expediting economic prosperity and facilitating overcoming of the consequences of crisis whose negative effect has not remedied yet [6-25].

2. Energy efficiency and national legislation

The energy performance of buildings is in an Energy Performance Certificate (Energy classified pass) on the energy efficiency classes A to I. The classification is carried out via the primary energy demand. This takes into account the thermal protection system, the hardware used and the environmental impact of the used energy carrier. Table 1.

Table 1. The energy performance of buildings

Energy efficiency class	Primary energy [kWh / (m ^{2} · a)]	Efficiency - Energetic Standard
A	0- 40	"KfW energy -saving house 40"; is about energetically equivalent to the passive house (according Passivhaus -Institut: heating demand <15 kWh / (m² WF a) + efficient plants)
B	> 40 - 60	"KfW energy -saving house 60"; is about equivalent to the "3-liter house" (3 liters of heating oil per square meter of living space for space heating)
C	> 60 - 80	corresponds approximately to the standard of the classic Low-energy house: 55 to 70 kWh per m² heating demand Living space or Heating demand 25% lower thermal protection regulation combined with efficient systems
D	> 80 - 110	typical of compact new buildings, the EnEV requirements comply with, or for quality modernized old buildings (20 to 25 cm insulation and efficient heating system)
E	> 110 - 150	typical of single-family homes, the EnEV minimum requirements just meet (multi-family homes usually already in D), or for higher quality modernized old buildings
F	> 150 - 200	typical of completely modernized buildings (to level the EnEV requirements for the stock)
G	> 200 - 300	typical of partially modernized buildings: Heat protection measures to subareas and / or new efficient central heating
H	> 300 - 400	typical of old buildings with double glazing and renewed heating
I	> 400 - 500	typical of old buildings in the original position with single glazing and inefficient central heating
J	> 500	typical of existing buildings with electric night storage heater or electric ovens or for old buildings in the original position with standard boilers and preinsulated distribution lines

With the entry into force of EnEV 2014 on. 1 In May 2014 to change the energy efficiency classes. According to the following table, it will be readily apparent from the final energy consumption or final energy demand (Table 2, Figure 1).

Table 2. Estimated annual energy costs per square meter of living space, final energy

Energy efficiency class	final energy [kWh / (m ^{2} · a)]	Estimated annual energy costs per square meter of living space
A +	<30	< 2 euro
A	<50	3 euro
B	<75	5 euro
C	<100	7 euro
D	<130	9 euro
e	<160	12 euro
F	<200	15 euro
G	<250	18 euro
H	> 250	> 20 euro

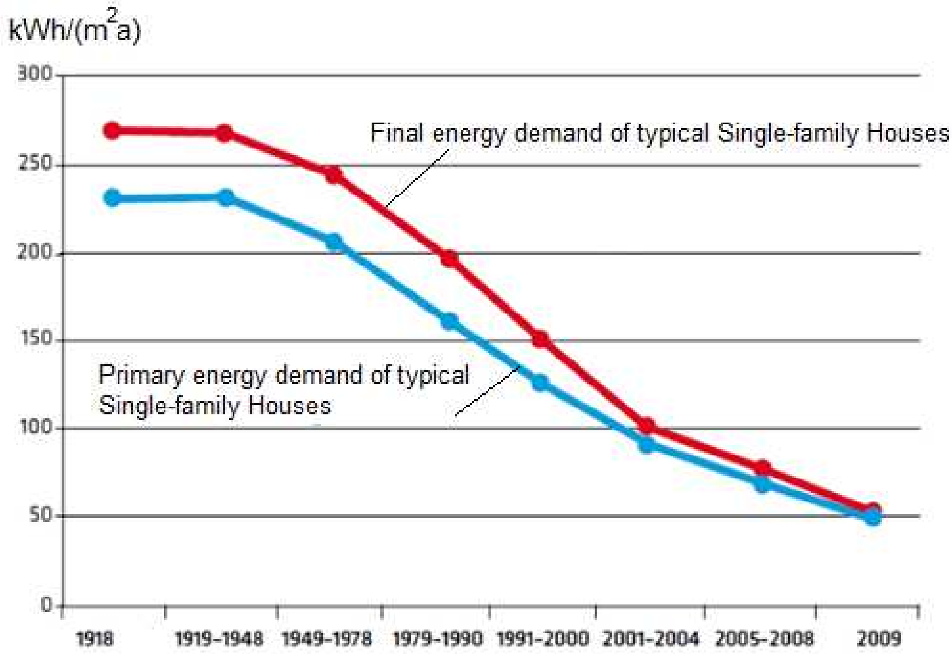

Figure 1. Final and primary energy demand of typical Single-family Houses by building age

Being the candidates for membership in European Union, both Serbia and Montenegro have transposed various European legal documents on energy efficiency and embodied them into national legislation. Thus, based on three Decisions of Ministerial Council of Energy Community, three main directives (*Energy Performance of Buildings Directive - EPBD 2010/31/EU* , *Energy Service Directive - ESD 2006/32/EC* and *Energy Labelling Directive - ELD 2010/30/EU*) and several related regulations have been transposed [7], forming harmonized national legal frameworks. However, national legislations require further synchronization with EU directives in the field, meaning further law reforms and, more important, law implementation [4]. Particularly high importance and great efforts will be necessary in the forthcoming adopted transposing of the recently adopted Energy Efficiency Directive according to the decision of the Energy Community Ministerial Council of October 2013[8].

In Serbia, the Law on Efficient Use of Energy accompanied by the Rulebook on energy efficiency of buildings which defines U-vales and other technical characteristics of the envelope and sets heating energy consumption levels [9], and Rulebook on terms, content and ways of issuing the certificates of energy performance of buildings which defines energy classes and energy passports [10] account for the most significant national legal documents regulating minimal conditions for the achievement of energy efficiency of different building types. A series of parameters defined in [9] relate to the achievement of energy efficiency of existing buildings, single-family houses among them. The same document sets value of 75 kWh/m 2 a as maximum allowed annual energy consumption for heating of existing houses.

Montenegrin Rulebook on minimal requirements for energy efficiency of buildings [11] determines maximum U-values, obtained after renovation of structural parts of existing single- family houses, with regard to belonging climatic zone. Houses with surface less than 50 m 2 as well as those under heritage protection (mostly present in coastal and capital areas) are exempted from the regulations due to the specific architectural and historic significance and sensitivity to changes.

The document prescribes mandatory instalment of solar collectors for water heating (internal use and swimming pool), but just on new structures located in coastal or capital area. *The Rulebook on certification of energy performance buildings* [12] defines eight energy classes of buildings in Montenegro, including residential type.

In order to provide smooth enforcement of adopted legislation both countries will make significant efforts especially in the area of building certification, where Serbia made initial steps, while this process in Montenegro is still lagging behind. Even recently prepared the new Montenegrin *Law on Efficient Use of Energy* (which will repeal existing *Law on Energy Efficiency*) provides through its transitional provisions postponed enforcement of obligations related to building certification. According to this, building owners are exempted of obligation to provide certificate on energy performance of buildings until 1 January 2018. On the other hand, the concept of "nearly zero energy buildings" defined in the *Energy Performance of Buildings Directive* (*EPBD 2010/31/EU*) is until recently not been considered in national legislation of both countries.

In Dec 2015, following provisions of the Law on Efficient Use of Energy (OG of Montenegro 57/2014), Ministry of Economy prepared new or updated package of rulebooks.

Energy Efficiency State of Compliance	
Directive 2006/32/EC	The Directive 2006/32/EC was already transposed by the Law on Energy Efficiency of 2010. The adoption of the new Law on Efficient Use of Energy in Dec 2014 further improved implementation by setting clearer procedures for measurement and verification of energy savings, establishing a new register of large energy consumers, improving energy performance certification procedures, defining energy-related products and obligations for market players, and setting clearer procedures for inspection and penalties, etc. It includes also provisions from the Energy Efficiency Directive 2012/27/EU, namely on energy services, energy management, as well as inventory, plans and dynamics of renovation of central government buildings. The exemplary role of the public sector is promoted well by the Law and the second EEAP. This is compliant with Directive 2006/32/EC. Following provisions of the Law on Efficient Use of Energy (OG of Montenegro 57/2014), Ministry of Economy prepared new or updated package of rulebooks in Dec 2015. These include: - Rulebook on methodology for determining annual consumption of primary energy, the content of the energy efficiency improvement plan and the report on implementation of the plan of big consumers - Rulebook on the content of the energy efficiency improvement program and plan as well as report on the implementation of the plan of local self-governing unit - Rulebook on information systems of energy efficiency and on the manner of submission of data - Rulebook on minimal energy efficiency requirements in buildings - Rulebook on certification of energy performance of buildings - Rulebook on performing energy audits of buildings - Rulebook on conditions for performing training, obtaining of authorization and manner of the managing of the registry for energy audits - Rulebook on regular energy audits of heating systems and air-conditioning systems - Rulebook on methodology for determining the level of energy efficiency in the procedure for public procurement
Directive 2010/30/EU	With regards to the labelling, the Law on Efficient Use of Energy of 2014 transposed key requirements of the recast Directive 2010/30/EU. However, the adoption of the Rulebook on Labelling of Energy-Related Products, which will enable full compliance with the Labelling Directive and Delegated Acts, is still pending
Directive 2010/31/EU	The requirements of Directive 2010/31/EU are transposed in general through the Law on Efficient Use of Energy and further implemented through the set of rulebooks adopted in May 2013. The implementation of certain requirements (i.e. certification of buildings and inspection of heating and air conditioning systems) is delayed as the entry into force was postponed until January 2016

3. Proposal for energy performance improvement

The size of existing single-family residential stock that should go under energy revision and upgrade raises the question on organization of proposed strategy implementation. Figure 2.

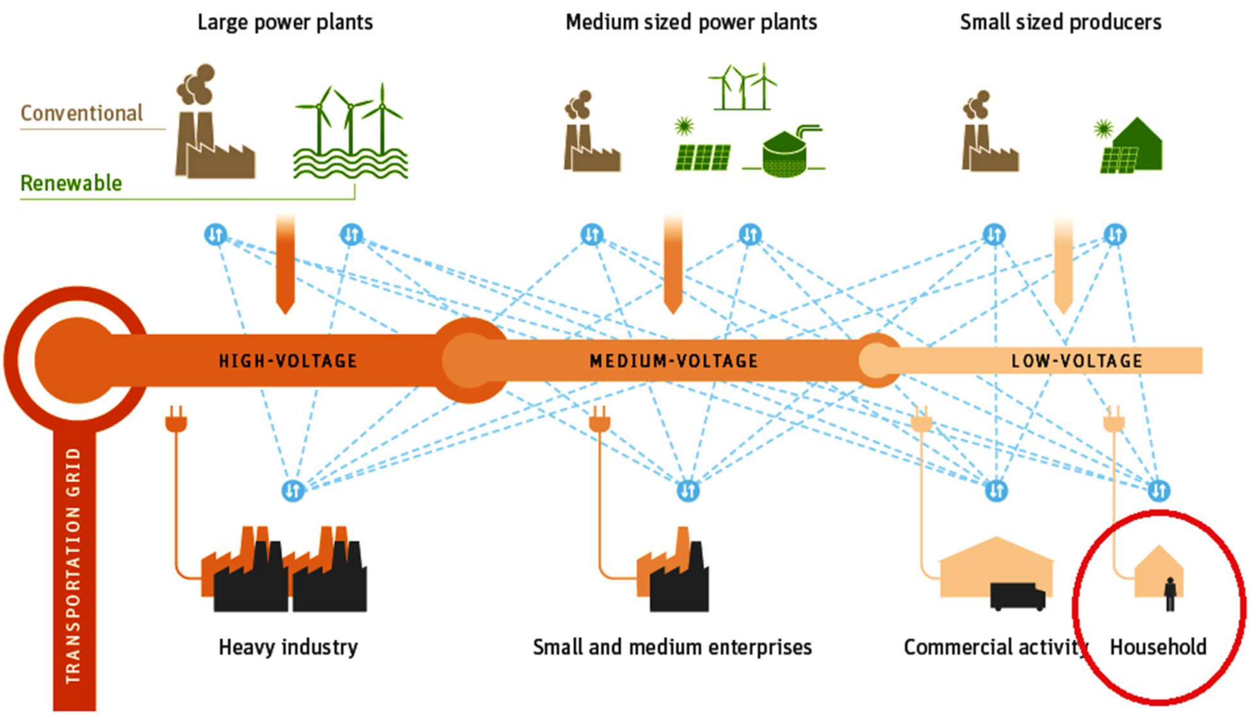

Figure 2. Possible energy resources of low-rise residential building

What people want is not energy, but energy services – the things we do with energy. In other words, we do not want gallons of gas, but mobility; not electricity and fuel oil, but cold food storage and well-lit, comfortable homes. In our buildings, we can provide a comfortable indoor climate with not only energy-intensive air conditioning and heating systems, but also properly filtered air and low concentrations of carbon dioxide. In other words, buildings of the future will provide even greater comfort than the ones today even though they consume less energy [16].

Collection of statistical data and creation of databases with typological structural and energy characteristics of houses would facilitate the process significantly. In Serbia, a sort of database is already formed: within the *Tabula international project*, two basic national types of single-family houses and several subtypes based on the year of construction were derived, and the possibilities for their energy improvement were given [14]. Another option, which could be elaborated in both counties, is to collect data and form bases on local level, by taking into consideration existing architectural, geographical and socio-cultural differences. This may especially be beneficial to Montenegrin conditions, where significant variations among different parts of the country exist.

Mandatory energy audit for all existing single-family residential structures (and not just those under major renovation, entering the estate market or passing through legalizing procedure) should be introduced in both Serbia and Montenegro. Extended (in comparison with the current) scope of duties of professional energy auditors-advisors should be regulated on national level in both countries. General new task for these professionals would relate to the creation of *the plan of energy performance improvement* for separate households, up to the achievement of energy efficiency, desirably above regulated minimum.

Energy improvements should be monitored through repeated audits.

The plan of improvement may be brought into relation with the energy management plan, at the beginning led exclusively by professional and gradually shifted towards the house owner who will at the end become the only responsible for energy consumption (and eventually production) monitoring.

Beside proposing technical measures and creating a plan for energy performance improvement, the role of energy advisors would also be to educate the residents/owners of the houses about energy efficiency (at every stage of the plan implementation!), and to provide them with information about the possible ways for obtaining the financial incentives for upcoming works on energy improvement. Financial support through the banking system must be solved on national level [3].

Due to the scope of action and specificities in existing geographical and social conditions, whole process of introducing the energy efficiency in existing single-family residential sector could be done at local level, under municipal guidance.

4. Measures and implementation stages

In single-family houses, operational energy is used for space heating, cooling, ventilation (rarely), artificial lighting, water heating and operation of various electrical machines, appliances and equipment. The quantity of consumed energy depends on size and characteristics of built structure, climatic and seasonal conditions, efficiency of all systems and units, which consume energy, as well as on the habits, standard and health conditions of occupants.

During the first visit to a subject single-family house, energy auditor/advisor should collect the data about energy consumption for every mentioned activity, total energy consumption, type of fuel used, possibilities for renewable energy resources use, as well as about the behavior and habits of tenants. After collecting and processing of all necessary data, the plan for energy performance improvement should be made.

Implementation of the plan for energy performance improvement should be conducted in stages (Tab. 1).

Stage 1 of the implementation relates to the fulfilment of minimal requirements that must be set differently from those standing in national regulations. Defining the minimum threshold, however, is recognized as a complex task. To fulfil the prerequisites set in regulations, large financial investment at once is demanded; for the majority of house owners, due to the current average economic conditions existing in both countries, it seems to be hardly achievable objective. Approach based on the implementation of passive (low-tech, bioclimatic) measures therefore arises as the optimal solution for stage 1 of energy performance improvement. Main efforts should be directed towards the reduction of energy demand for heating and cooling, as the two are the most energy consuming activities. Challenge of the task for energy expert in this stage lays in the fact that bioclimatic measures are more difficult to implement in existing structures than in new design.

Stage 2 should be composed in a way to be stand-alone or incorporable to any other stage.

Hence, the measures belonging to this stage may be implemented at any other, as well.

Stage 3 of the implementation of plan for energy performance improvement relates to comprehensive house renovation. Only in this stage, most likely, it is possible to achieve values set in regulations or to overcome them.

Finally, *stage 4* of energy efficiency enhancement implies the exceeding of regulated minimum and the application of advanced technologies, such as hybrid solar lighting, heliostat mirror systems, or heat recovery systems, for example. Some of the measures belonging to this stage, such as super insulation, may overlap with the stage 3 interventions.

In general, climatic conditions of an area represent the important factor and hence are embodied in regulations. On the other hand, climate change manifestations, predicted for the same territory, are not taken into consideration in legal documents. To maintain once achieved positive energy conditions in a house, possible impact of climate change should also be taken into account while creating and implementing the plan for energy performance improvement. Achieving energy efficiency means at the same time the contribution to climate change adaptation measures in the housing sector [15, 17]

Table 1. Measures and implementation stages of the energy performance improvement plan for single-family houses

ISSUE	*STAGE 1*	*STAGE 2*	*STAGE 3*	*STAGE 4*
THERMAL PROTECTION	Greening / vegetation Basic solar protection Interventions on the lot Repairs to prevent ventilation heat loss	Additional layer on glazed segments of thermal envelope Porch Overhang Veranda	Thermal protection in line with national regulations (thermal insulation, air layer and glazed segments) Solar protection in line with the orientation and characteristic of glazed segments Optimal ratio between glazed and solid segments of	Advanced thermal protection: super insulation, super windows, intelligent glass application, etc.

HEATING	Inspection of existing heating system Energy source Position , size and type of heating bodies Adequacy of system capacity Passive solar heating (direct gain) enhancement Interventions on the lot Habits	Passive solar heating (isolated heat gain) Heat storage Connection to public heat and gas networks Whole-house heating system with local regulation Biomass as a heat source for individual household Exclusion of air- conditioning unit (Montenegro)	Passive solar heating (indirect solar gain)	Active solar heating Geothermal pump Heat recovery systems
COOLING	Passive night cooling Interventions on the lot, including water bodies Habits	Cold storage Chimney effect Exclusion of air-conditioning unit Ceiling fans		Geothermal pump Cold recovery systems
VENTILATION	Cross ventilation Interventions on the lot Habits	Chimney effect	Wall wings Wind towers	
LIGHTING	Maximum daylight Energy efficient bulbs Spot lights Habits	Colours in interior	Optimal window position and size Light shelves Light pipes, wells, etc. for basement space	Hybrid solar lighting Sensors Heliostat mirror systems
WATER HEATING	Inspection and repairs of existing water heating system Adequacy of system capacity Energy source	Passive solar water heating Connection to public gas network Combined air and water heating systems (with heat recovery) Water efficient faucets	Pipe insulation Bath insulation Optimal length of horizontal hot water distribution branches	Solar water collectors Geothermal heat pump Heat recovery systems
ELECTRIC ENERGY	Inspection and repairs of existing equipment, machines and devices	New energy efficient equipment, machines and devices, in line with regulations		Micro turbines Photovoltaic systems Intelligent systems Energy management
ADAPTATION TO CLIMATE CHANGE	Risk assessment	Methods for additional heat load removal Individual potential for heat energy generation		Micro turbines Photovoltaic systems

5. Summary

The implementation of the system for certification of energy performance of buildings and inspection of heating and air conditioning systems should start without any further delay.

Current socio-economic situation in Serbia and Montenegro raises the need to redefine existing strategies for the achievement of energy end-user efficiency, especially in existing building stock within which single family-houses take significant share in both countries. Even in engineering sphere of activity, the focus of sustainable development is gradually shifting from technical towards societal and economic aspects. It was proved many times that, despite offered technical solutions to improve energy efficiency, existing unfavorable societal conditions did not allow their implementation. New approach in problem solving is therefore necessary.

Proposed methodology for the enhancement of energy efficiency in existing single-family residential stock is presented in a form of implementation plan, which includes wider national conditions, and not just those existing in technical/energy field. At the base, the plan proposes gradual improvement and aims to finally achieve regulated standards or to, better, overcome them at certain point which also may be limited in time. The time period for achieving energy efficiency should be determined in line with general economic situation and expected standard improvements in close future. During four stages of energy improvement, measures shifting from low technological to high technological and advanced will be applied; the final result should be delivered in the form of retrofitted energy efficient, or even "nearly zero energy" single-family house.

The plan puts occupants/owners of a house in central position; hence, it should be custom designed. Understanding and accepting, however, demand knowledge; development of sustainability, environmental and energy literacy is one of the key objectives of proposed plan.

Sustainable architectural artefact is much more than energy efficient structure. This fact leads to the opening of new research debate on possible integration of other sustainability measures, such as water efficiency, for example, with the proposed plan for energy efficiency enhancement.

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Стратегия энергоэффективной реконструкции жилых малоэтажных зданий

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ИНФОРМАЦИЯ О СТАТЬЕ	ИСТОРИЯ	КЛЮЧЕВЫЕ СЛОВА
УДК	Подана в редакцию: 11 февраля 2016	энергоэффективность; реконструкция; малоэтажное жилое здание; энергосбережение; социально-экономический фактор;

АННОТАЦИЯ

Значительный процент населения живет в малоэтажных жилых зданиях. Соответствие нормам энергетической эффективности подразумевается при строительстве новых домов и является обязательным элементом для получения разрешения на строительство. Достижение же соответствия нормам энергоэффективности в существующих малоэтажных жилых зданиях является сложным и порой проблематичным процессом. Рассматривая существующие правовые нормы и принимая во внимание состояние вопроса в целом, данная статья предлагает новый подход для улучшения энергетической эффективности существующих малоэтажных жилых зданий (на примере Сербии и Черногории). Предлагаемые в статье решения ориентированы на принятие дополнительных юридических мер, а также на более глубокое понимание социально-экономических последствий на пути достижения высоких показателей энергетической эффективности.

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