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Nearly Zero-Energy Regulation and Buildings Built with Prefabricated Technology: The Case of Hungary

András Horkai, Attila Talamon, Viktória Sugár

***Abstract*—**There is an urgent need nowadays to reduce energy demand and the current level of greenhouse gas emission and use renewable energy sources increase in energy efficiency. On the other hand, the European Union (EU) countries are largely dependent on energy imports and are vulnerable to disruption in energy supply, which may, in turn, threaten the functioning of their current economic structure. Residential buildings represent a significant part of the energy consumption of the building stock. Only a small part of the building stock is exchanged every year, thus it is essential to increase the energy efficiency of the existing buildings. Present paper focuses on the buildings built with industrialized technology only, and their opportunities in the boundaries of nearly zero-energy regulation. Current paper shows the emergence of panel construction method, and past and present of the 'panel' problem in Hungary with a short outlook to Europe. The study shows as well as the possibilities for meeting the nearly zero and cost optimized requirements for residential buildings by analyzing the renovation scenarios of an existing residential typology.

***Keywords*—**Budapest, energy consumption, industrialized technology, nearly zero-energy buildings.

I. Introduction

THIS study presents the situation of prefabricated, reinforced concrete – so called 'panel' – residential buildings in the light of cost-optimized and nearly zero-energy requirements.

In order to reduce the energy dependence of the countries and the emission of greenhouse gases, it is of the utmost importance to address the energy consumption of this existing building stock. As only1.5-2% is the ratio of new buildings even in the case of an ideal economic environment in Hungary [4], so the existing housing stock will play a decisive role for decades.

The building energy regulations became stricter, as of 1st January 2018, in case of all new buildings and the renovation or extension of existing buildings will be compulsory to at least meet the cost-optimized level of requirements, which is expected to be further tightened [9].

As part of a study on the building stock of the Hungarian capital, Budapest, the authors analyze the prefabricated sandwich panel residential buildings and the related energy policies and regulations in Europe and Hungary. By comparing the existing buildings' spatial and renovation scenarios with current requirements, the authors aim to assess the situation of the stock in a cost-optimized and nearly zero-energy requirements.

II. The Panel Construction Method

In Europe, after World War II, there was a large lack of housing, due to the war destruction, which hit most of the housing stock in most countries. To solve the housing shortage, the experts saw the solution in the industrialization of construction: in Germany, in the middle of the 1940s, brick material in post-war debris was utilized, medium and large wall blocks were produced, and slab structures were made with prefabricated reinforced concrete beams and liner bodies [3].

In Hungary, block construction started to spread in the middle of the 1950s: first, medium-sized blocks (which made of concrete or brick and has half a floor height and 25 cm thickness), then big blocks (full floor height and 30 cm thickness) were used.

The outlines of the more developed industrialized construction have emerged from the 1930s and began to expand after World War II. In France at the beginning of the 1950s, large-panel manufacturing started, which became the first panel factory the technology later adopted by the Soviet Union and also further developed by the Danes. The systems initially designed for the construction of five-story buildings, which were used in France, the Soviet Union, as well as in Denmark, here, with 10 stories [2], [3].

In Hungary, at the beginning of the 1950s, the first structure of reinforced concrete frameworks was first made in 1955, the first panels were fabricated, then the first real panel residential buildings were constructed in Dunaújváros and Pécs, in 1958.

In the first half of the 1960s, the Hungarian government announced the housing program, which meant that 1 million homes should be built in 15 years, with at least one third of them being highly industrialized the so-called 'house-factory' technology. It was decided that these domestic developments should be carried out on using Soviet technology. The first Hungarian house-factory in Budapest (BHK I. – I. Budapest House Combine) started manufacturing in 1965, using the production technology of the Soviet Union I.464/A, where panel structure was based on the French 'Camus' system [1].

The decision to use Soviet system can be justified given its structural design and the efficiency of construction. However, the system had disadvantages: the 3.20-m span of the system was a step backwards compared to the 3.60-m span already used for block construction. The Soviet solution however was

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criticized by domestic experts. They instead suggested the Danish (Larsen-Nielsen) solution at the time, which was well known in the literature, and considered to be much better, especially because of the greater layout flexibility. Architects gave their opinions in several places, so the government at that time allowed only one Hungarian house-factory to be of a Danish type (II. Budapest House Combine) to realize its experiences on the further Soviet-style house-factories [1], [3].

Fig. 1 First 'panel' building in Hungary [14]

Fig. 2 Prefabricated sandwich panel factory in Hungary, 1974 [15]

III. The Residential Building Stock of Europe and Hungary

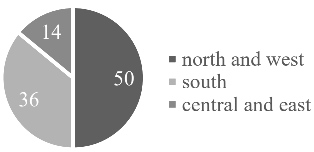


Fig. 3 The distribution of built-in floor areas per region in Europe [11]

Based on estimates, in the EU-27, Switzerland and Norway, there are about 25 billion usable square meter built-in m2 area, which is shown by region in Fig. 3. Based on this, half of the floor area is located in the northern and western regions.

The annual growth rate in the residential sector is around 1-1.5% even in ideal economic conditions [4].

75% of the European real estate hold single or multi-dwelling residential buildings, the remaining 25% of the largest share being small and wholesale buildings, the second is offices and educational buildings.

A large part of the European building stock is over 50 years old, and many buildings have been in use for more than 100 years. Approximately 40% of the residential buildings were built before 1960, during which time energy requirements were practically not yet.

During the period 1961-1990, with the expansion of the industrialization of the building technologies, explosive growth happened in the building stock of the countries, at this time the number of residential buildings doubled [11].

In case of Hungary, 46% of the building stock was built before 1960, and in the three decades after 1960 the housing stock was more than doubled. Since the second half of the 1980s, the construction of apartments has slowed down, and also drastically decreased in the years following the change of regime (1989). This has particularly affected the housing estates, as small-scale (brick) housing construction was not conducted in housing estates. 62% of the housing estates were made of prefabricated (panel) houses using reinforced concrete.

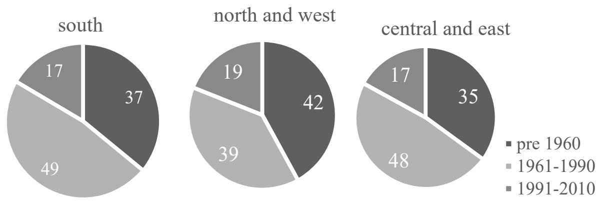


Fig. 4 Age categorisation of housing stock per region in Europe [11]

Between 1967 and 1990, on average 30-35.000 constructions a year, approximately 510.000 prefabricated reinforced concrete panel flats were constructed in Hungary, which is nearly 13% of the flat stock. [1].

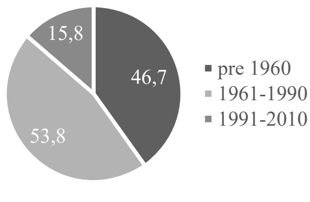


Fig. 5 Distribution of dwellings per construction time in Hungary [4]

TABLE I
Distribution of Dwellings per Time in Hungary [4]

	pre 1960	1961–1990	1991–2010	SUM
total number of dwelling	1 827 928	2 104 927	619 574	**3 912 429**
number of dwellings built with prefabricated technology	0	511 364	8 315	**519 679**
percentage of dwellings built with prefabricated technology	0	24%	1%	**13%**

IV. 'The Panel Problem'

A. Functional Obsolescence

The residential and public buildings had been uniformed to be able to manufacture by industrialized technology, which is cost-effective.

Although several types were designed, only 3-4 types were allowed for the execution of a housing estate (mainly for crane-run housing estates) due to economics and construction technology reasons.

Most of the apartments contain one or two, rarely three rooms. The Soviet structural system (3.20 m span) did not allow the establishment of rooms larger than 18 m^2. Nowadays, the small size of rooms, the small bathroom, and the small kitchen do not meet the modern living requirements (no space for washing machine, tumble dryer, fridge, dishwasher, etc.)

Functional problems include high noise level in dwellings, which are due to the good low sound-proofing ability of reinforced concrete structures and the lack of mechanical equipment (wiring, ventilators, lifts).

It is possible to improve and modernize the obsolete technical and industrial gaps, but the possibility to change the size and function of the rooms in the apartments is limited. For block buildings, structural change is almost impossible, in panel buildings opportunities depending on the static possibilities [3].

B. Technical Obsolescence

The primary load-bearing structures have a long lifecycle (approx. 150 years), in contrast the service-life of the secondary structure is much less: for example, paintings are exceptionally short-lived structures; there is a longer lifespan for roofs and roof insulation, and they have a varied lifetime in electrical and sanitary engineering, radiators, ventilators, and elevators.

Energy requirements have been tightened since the construction of buildings, and the structures surrounding the heated building block do not meet today's requirements. On the other hand, panel-type residential buildings, have a low surface-to-volume (A/V) ratio, they are architecturally and energetically compact buildings, which is highly sustainable. During their renovation, their geometry characteristics (A/V ratio, glazing ratio, ceiling height, etc.) and their structural design properties, which cannot or can only be slightly modified (e.g. exterior thermal insulation), mechanical system can be renewed with higher cost investment [2], [3].

C. Energetic State

The large number of panel house is a serious problem especially in Eastern European countries, where the stock is physically and morally obsolete. Here, usually the demolition of buildings is unrealistic in a short and medium term and is not justified either from an environmental point of view. Detailed lifecycle analyzes [13] have already proven that energy efficient renovation is clearly a better alternative than dismantling panel buildings and replacing with new residential buildings.

99% of panel type residential buildings are heated by district heating. One of the biggest problems is high operating cost. In Hungary, it is common assumption that these buildings have the highest heating costs. The reason for this is, in fact, not the low energy efficiency, or the high district heating costs, in general, but the poor efficiency of outdated technologies and the high losses of mechanical systems.

The energy quality of the residential buildings is not as bad as the general belief holds. In the Energy City project of the Central Europe Program, a comparative analysis of different building types was carried out. The results show that the heating energy consumption of a panel house built in the seventies is nearly the same as a typical 10-year-old family house, and less than half of a 30-year-old family house. The reason for this is believed to be that the prefabricated sandwich panels originally have a 5-8 cm insulating layer, which results in a better U-value than an uninsulated brick wall. This finding can, however, be partly questioned by the extremely high heat losses of the sandwich panel hubs and by the evaporation of the insulation layer over the last decades. The real reason for a more efficient use of energy is more obvious: the surface-to-volume ratio, thus the losses of the heated floor area can be up to three times more in case of a family house compared to the compact geometry of panel buildings. Of course, this does not mean that panel buildings are energy efficient, but it also points out that the panel problem is sometimes overblown [5], [6].

V. Energy Policy of the EU

In 2007, the European Council laid down its legal bases for an integrated European energy and climate policy (Energy Policy of Europe).

In March 2010, the European Commission issued the Europe 2020 Strategy, where main objectives include a 20% reduction in greenhouse gas emissions compared to 1990 levels, a 20% share of renewable energy sources in the final energy use and 20% energy efficiency increase.

The main objective of the 2010/31/EU EPBD Directive [8] is to promote the improvement of energy efficiency of buildings within the EU. According to the EPBD Directive, the minimum energy performance requirements for buildings should be defined in such a way as to provide an optimal balance between cost and investment between the required investments and energy cost savings over the lifetime of the building. This cost-optimized level is the level of energy efficiency that results in the lowest cost during a specified building period during the specified calculation period (30 years) where the lowest cost is associated with energy-related investment costs, maintenance and operating costs and, where appropriate, disposal costs should be determined.

The Directive also requires Member States to ensure that all new buildings are nearly zero-energy after 31 December 2020, and Member States will have to draw up national plans to achieve this level.

One of the major impacts of the Directive is, that in the case of modernization of all buildings, Member States should set minimum building energy and building engineering requirements, thus improving the energy efficiency of existing building stock [7].

VI. Energy Regulations in Hungary

The definition of the energy characteristics of buildings must be based on Minister without Portfolio Decree No. 7/2006. (V. 24.) TNM [9] on the establishment of energy characteristics of buildings, which is intended to comply with Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. The decree sets and mandates the cost-optimized energy requirement values from January 1, 2015 in the case of the use of domestic or EU funding sources or central budget support, from 1 January 2018 in every other case.

Levels and requirements of building energy regulation:

I. Requirements for the heat transfer coefficient (U_R) of the building envelope: for all limiting structures that delineate the heated building volume: $Ú_R < U_m$ (where U_m is the standard value for the investigated building structure)

II. The requirements for specific heat loss coefficient (q): for the whole building $q < q_m$ (where q_m is the standard value dependent on the surface-to-volume ratio for the building under investigation)

III. The total requirements of the primary energy use (E_p) for the whole building $E_p < E_{pm}$ (where E_{pm} is the standard value dependent on the surface-to-volume ratio of the investigated building and the function of the building)

The decree specifies these requirement values for residential buildings, office buildings, educational buildings, other functions for commercial buildings. Given that the climate of each region does not differ significantly in Hungary, the requirements are the same throughout the country.

A. Requirement Levels

There were currently three requirements in force in the Regulation, parallel to each other, at the same time depending on the nature of the building and the form of financing, but from January 01, 2018 the cost-optimized requirements are in force:

- Basic Requirement Level (BASIC)
- Cost-Optimized Requirement Level (CO)
- Nearly zero requirement level (NZ)

It is important that the level of requirements must be met at the time of use of the building, so during the planning process it is necessary to know the planned time of use and to construct the building accordingly.

TABLE II
Current Requirements in Hungary [9]

type of the building	funding	the year of entry into force of the requirement						
		2015	2016	2017	2018	2019	2020	2021
new building	by private funding		BASIC			CO		NZ
	by government/ EU funding			CO				NZ
	for official use		BASIC		CO		NZ	
	for official use by government/ EU funding		CO				NZ	
renovation/ extension of an existing building	private funding		BASIC			CO		
	by government/ EU funding				CO			

TABLE III
Required Heat Transfer Coefficient of the Main Elements of the Building Envelope [9]

Element of the building envelope	Requirements for the heat transfer coefficient U_R [W/m2K] BASIC	CO; NZ
External wall	0.45	0.24
Flat roof	0.25	0.17
Attic slab	0.30	0.17
Arcade ceiling	0.25	0.17
Cellar ceiling	0.50	0.26
Facade glazed doors and windows (with wood or PVC frame)	1.60	1.15
Façade glazing	1.50	1.40
Wall between adjacent heated buildings	1,50	1,50

B. Nearly Zero-Energy Requirements

Nearly Zero-Energy Building (NZEB): a cost-optimized or energy-efficient building according to the Government Decree on the certification of energy performance of buildings, where at least 25% of the annual energy demand expressed in primary energy is supplied from a renewable energy source, which is generated in the building, comes from or is produced in the vicinity of the building [8].

The requirement values for nearly zero requirement levels for heat transfer coefficient are the same as those for the cost-optimized level. In the case of renovation of existing buildings, only the heat transfer coefficient of the structure affected by the renovation must meet the relevant requirements.

One of the most important requirements is that the energy demand of the building must be at least 25% of the renewable energy source which is generated in the building, comes from or is produced in the vicinity of the building. Generated energy is close to produce if:

- the energy production facility was created and licensed for the purpose of supplying building,
- it is covered by district heating or cooling which uses only the following energy sources outside the electricity used to transfer energy: electricity from the national grid, renewable energy (firewood, biomass, energy produced directly or indirectly from biomass, biogas energy, wood pellet, agripellet), renewable (solar, wind, hydropower, geothermal, hydrothermal, atmospheric) and beyond no other energy carrier can be used in the district heating or

district cooling system [9].

C. Requirements for Rehabilitation of Panel Buildings

Regarding the renovation of existing buildings (like panel building stock), the regulation states:

- expenditures for existing buildings that have been upgraded or renewed for energy saving since 31 December 2017 must meet cost-optimized requirements;
- the significant renovation of an existing building should document and record the possibility of using alternative systems technically, environmentally and economically
- when upgrading an existing heating system, it is recommended to set room temperature control based on economical calculation. If there are several different parts of the building, it is recommended to measure the heat quantity per building;
- when converting an existing building into a voluntary nearly zero-energy rating, only the structure affected by the renovation is covered [9].

VII. Renovation Possibilities

In Hungary, the National Building Energy Strategy 1073/2015. (II.25.), for the year of 2020, 49 PJ / year of primary energy saving is the goal of which:

- renovation of residential and public buildings: 40 PJ;
- renovation of business premises: 4 PJ;
- other energy savings for buildings: 5 PJ

the government intended to save energy. This also demonstrates that the greatest potential lies in modernizing existing residential and public buildings [7].

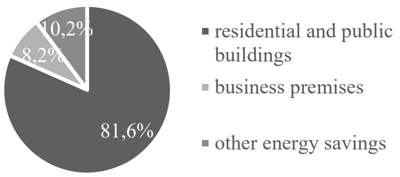


Fig. 6 Planned primary energy savings according to the National Building Energy Strategy [7]

In the case of existing buildings, there is a wide range of tools to reduce energy demand, which can be categorized from a financial perspective into the following categories:

- Non-purchase of equipment, e.g. planned (preventive) maintenance, strategy change in operator-consumer behavior;
- Low cost, e.g. control of mechanical engineering equipment, comprehensive mechanical adjustment, installation of individual meters and cost distributors;
- Moderate cost, e.g. thermal insulation of flat roof or attic slab, heat generating or ventilation engineer development;
- High cost, e.g. complete facade insulation (walls, flat roof, cellar ceiling), replacement of facade doors and windows, replacement of the complete engineering system, complex renovation [12].

In Hungary, a large part of panel residential buildings have already participated in a state-funded renovation program: in PANEL I, program mainly replaces façade joinery, insulation of building envelopes, modernization of interior utilities (heating), use of renewable energies (solar cells, solar collectors); in the framework of ÖKO-PROGRAM, individual regulation of heat dissipators, individual measurement of heat consumption and conversion of the heating system; upgrades similar to PANEL I were carried out under ZBR-PANEL. At present, there is no program for energy reconstruction of residential buildings built with industrialized technology, the residents carry out such work with self-government or local government support.

In previous energy modernization, the requirements for the heat transfer coefficient of the building envelope have been dimensioned to the level of the BASIC, which as outlined above does not meet today's cost-optimized requirements.

VIII. Building Typology and Energy

For the planning of the future renovation scenarios, it was necessary to determine the stock and the energetic characteristics of the domestic buildings, in particular the dwellings and public buildings. Within the TABULA EPISCOPE project [10], building types and models were developed in 2014, based on statistical data: a total of 15 types of buildings were modeled for the modeling of the existing building stock, resulting in a multi-step modeling process, essentially separate from building technology, building structures and construction time. The 15 types of buildings cover the entire home-dwelling stock and provide an opportunity to make the building energetic analyzes of the residential building sector well-founded.

Types, which included panel residential buildings:

- Type 13. /AB.02.Ind (apartment block, built between 1945-1979, built with panel technology);
- Type 14. /AB.03.Ind (apartment block, built between 1980-1989, built with panel technology).

The characteristics are according to the TABULA: Mid-rise housing estate, built between 1945-1989 with panel technology. The outer walls are reinforced concrete sandwich panels. Mostly basement + ground floor + 10 stories, with a flat roof.

Two renewal scenarios were defined in the TABULA project: 'standard' and 'ambitious'. The purpose of the general renovation is to develop the average insulation and systems according to the building energy regulation in force in 2014. The ambitious scenarios include technology solutions for nearly zero-energy consumption standards.

Standard refurbishment scenario: the planned refurbishment includes the insulation of the building envelope (walls, flat roof and slabs) together with the replacement of old doors and windows. A variable speed-control circulation pump and thermostatic valves will also be installed as a step of modernisation.

Ambitious refurbishment scenario: the refurbishment aiming for nearly zero energy use will include extensive insulation for the building envelope, doors and windows will be changed. In addition to the circulation pump and thermostatic valves, solar collectors will be installed.

It should be noted that the requirements for nearly zero-energy buildings have not yet been introduced in Hungary at the time of writing, so these measures are merely a prognosis [10].

Fig. 7 Example building for Type 'AB.02.Ind' [10]

Fig. 8 Example building for Type 'AB.03.Ind' [10]

In the case of modernization of buildings for energy efficiency, the solutions can be classified into two main groups according to the levels of Hungarian energy regulation: architectural interventions and energy modernization solutions of mechanical systems.

In case of panel buildings, one of the most commonly used solution is the energy modernization of building envelope (structures around heated volume): exterior insulation, replacement of doors and windows.

In the following, we will examine whether the structural reconstruction (regulation LEVEL 1.) of Types AB.02.Ind and AB.03.Ind defined by the TABULA EPICOPE project meets the cost-optimized requirements currently in force.

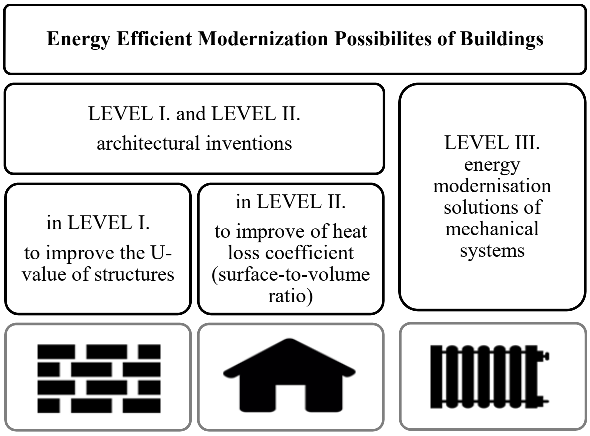


Fig. 9 Modernization of buildings for energy efficiency [9], [16]

TABLE IV
STRUCTURAL RENOVATION SCENARIOS OF 'AB.02.IND' TYPE BY TABULA PROJECT [10]

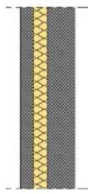
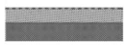
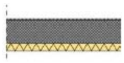
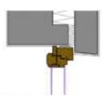
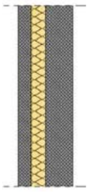
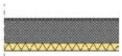
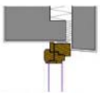
	Elements of the building envelope and their U-values [W/m^{2}K]		Meet the cost-optimized requirements?
	Wall		
	Existing state	0.80	✕
	Sandwich panel: reinforced concrete (15cm); polystyrene insulation (8cm); reinforced concrete (7cm)		
	Standard refurbishment	0.40	✕
	Additional 5 cm external insulation on existing structure		
	Ambitious refurbishment	0.19	✔
	Additional 16 cm external insulation on existing structure		
	Flat roof		
	Existing state	0.91	✕
	waterproofing; lightweight concrete (10 cm); reinforced concrete (15 cm)		
	Standard refurbishment	0.27	✕
	Additional 10 cm insulation on top of existing structure		
	Ambitious refurbishment	0.14	✔
	Additional 24 cm insulation on top of existing structure		
	Cellar ceiling		
	Existing state	0.55	✕
	linoleum (0.5cm); reinforced concrete (15cm); polystyrene insulation (5 cm)		
	Standard refurbishment	0.24	✕
	Additional 10 cm insulation on the underside of existing structure		
	Ambitious refurbishment	0.15	✔
	Additional 20 cm insulation on the underside of existing structure		
	Window		
	Existing state	3.30	✕
	Double-pane wooden casement windows		
	Standard refurbishment	1.60	✕
	Window with double-glazing, low-e coating and argon gas filling		
	Ambitious refurbishment	1.00	✔
	Window with triple-glazing, low-e coating and argon gas filling		

TABLE V
STRUCTURAL RENOVATION SCENARIOS OF 'AB.03.IND' TYPE BY TABULA PROJECT [10]

	Elements of the building envelope and their U-values [W/m^{2}K]		Meet the cost-optimized requirements?
	Wall		
	Existing state	0.70	✗
	Sandwich panel: reinforced concrete (15 cm); polystyrene insulation (8 cm); reinforced concrete (7 cm)		
	Standard refurbishment	0.40	✗
	Additional 5 cm external insulation on existing structure		
	Ambitious refurbishment	0.19	✓
	Additional 16 cm external insulation on existing structure		
	Flat roof		
	Existing state	0.43	✗
	waterproofing; concrete (7 cm); mineral wool insulation (8 cm); reinforced concrete (15 cm)		
	Standard refurbishment	0.21	✗
	Additional 10 cm insulation on top of existing structure		
	Ambitious refurbishment	0.12	✓
	Additional 24 cm insulation on top of existing structure		
	Cellar ceiling		
	Existing state	0.55	✗
	linoleum (0.5 cm); reinforced concrete (15 cm); polystyrene insulation (5 cm)		
	Standard refurbishment	0.27	✗
	Additional 10 cm insulation on the underside of existing structure		
	Ambitious refurbishment	0.17	✓
	Additional 20 cm insulation on the underside of existing structure		
	Window		
	Existing state	2.50	✗
	Wooden window with double-glazing		
	Standard refurbishment	1.60	✗
	Window with double-glazing. low-e coating and argon gas filling		
	Ambitious refurbishment	1.00	✓
	Window with triple-glazing, low-e coating and argon gas filling		

Figs. 10 and 11 show how the U values of the elements of the building envelope of 'AB.02.Ind' and 'AB.03.Ind' types of buildings in existing state and in each refurbishment scenarios, and dotted lines indicate the values of the cost-optimized requirement level for each structure. It can be stated that in the existing state the heat transfer coefficients of the structures are far below the requirement level, in case of standard scenario approaching (but not achieving) the requirements, and in case of ambitious renovation all four selected structures meet the requirements.

In the case of buildings reconstruction for energy modernization, this scenario can serve as a guideline [10].

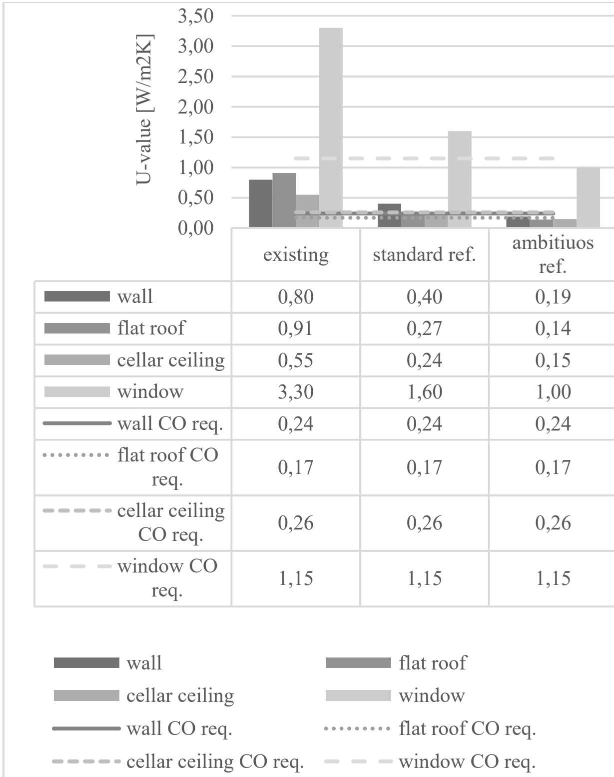


Fig. 10 Renovation scenarios at U-values and the cost-optimised (CO) requirements at 'AB.02.Ind' Type

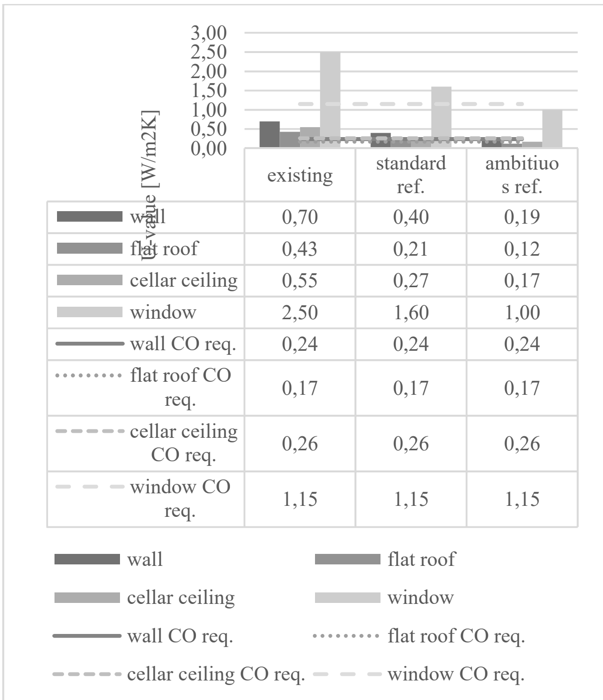


Fig. 11 Renovation scenarios at U-values and the cost-optimised (CO) requirements at 'AB.03.Ind' Type

In Tables VI and VII the differences between the U-values of the structures and the U-values defined in the cost-optimized requirement level were compared. The cost-optimized requirements level - depending on the structure - is approx. 2.5-3x higher than the U-values of the existing structures of panel residential buildings. With the structural modernization of the TABULA standard scenario, these differences will be approx. halved and the ambitious scenario can meet the values set in the requirement.

TABLE VI
DIFFERENCES BETWEEN THE U-VALUES OF RENOVATION SCENARIOS IN CASE OF 'AB.02.IND' TYPE COMPARED TO THE COST-OPTIMIZED REQUIREMENTS [10]

Elements of the building envelope	Refurbishment	Construction U-value [W/m2K]	cost-optimized requirements [W/m2K]	Difference to the cost-optimized requirements (const. U-value / CO req.)
	- (existing)	0.8	0.24	3.33
wall	standard	0.4	0.24	1.67
	ambitious	0.19	0.24	0.79
	- (existing)	0.91	0.17	5.35
flat roof	standard	0.27	0.17	1.59
	ambitious	0.14	0.17	0.82
	- (existing)	0.55	0.26	2.12
cellar ceiling	standard	0.24	0.26	0.92
	ambitious	0.15	0.26	0.58
	- (existing)	3.3	1.15	2.87
window	standard	1.6	1.15	1.39
	ambitious	1	1.15	0.87

TABLE VII
DIFFERENCES BETWEEN THE U-VALUES OF RENOVATION SCEANRIOS IN CASE OF 'AB.03.IND' TYPE COMPARED TO THE COST-OPTIMIZED REQUIREMENTS [10]

Elements of the building envelope	Refurbishment	Construction U-value [W/m2K]	cost-optimized requirements [W/m2K]	Difference to the cost-optimized requirements (const. U-value / CO req.)
	- (existing)	0.7	0.24	2.92
wall	standard	0.4	0.24	1.67
	ambitious	0.19	0.24	0.79
	- (existing)	0.43	0.17	2.53
flat roof	standard	0.21	0.17	1.24
	ambitious	0.12	0.17	0.71
	- (existing)	0.55	0.26	2.12
cellar ceiling	standard	0.27	0.26	1.04
	ambitious	0.17	0.26	0.65
	- (existing)	2.5	1.15	2.17
window	standard	1.6	1.15	1.39
	ambitious	1	1.15	0.87

The II. level of the Hungarian energy regulation is the test for compliance with the requirement for the specific heat loss coefficient (q). In nearly zero-energy regulation, this value is also tightened. This coefficient is a standard value dependent on the A/V (surface/volume) ratio of the investigated building, which is low in value due to the compactness of the panel buildings and the energetically favorable geometric design, so compliance with the regulations is not a problem.

In the case of these refurbishment scenarios, the calculation of energy demand was also done according to the TABULA methodology. The heating energy demand for buildings in standard cases is approx. 50%, in case of ambitious renovation approx. 32% of the original energy demand, which is a major factor in energy demand as well as modernization of the building envelope.

IX. CONCLUSIONS

In Europe, in many countries and in Hungary, residential buildings built with industrialized technology, including panel buildings, represent a significant proportion of the building stock. The energetic properties of these buildings are not worse than an average family house, but with more levels of modernization their energy consumption can be significantly reduced.

In the case of upgrading existing buildings, the use of the cost-optimized requirement level is mandatory, the application of a nearly zero requirement is voluntary, but only an opportunity.

Requirements for the heat transfer coefficients of nearly zero requirement level are the same as those for the cost-optimized level. In the case of renovation of existing buildings, only the heat transfer coefficients of the structure affected by the renovation must meet the relevant requirements. By examining the renovation scenarios defined by the TABULA project, it can be seen that these requirements can easily be met in the case of 'ambitious' refurbishment (significant exterior thermal insulation and exchange of doors and windows). However, our buildings are different in one type, so the technical solutions required to meet the requirements are not uniform and they have to be modified to the needs of the building.

The renovation of the building envelope is only the first step towards a nearly zero requirement level, the 'very high energy efficiency'. The aim is a complex: architectural and mechanical modernization for energy efficiency. The following are to be considered: the possibilities for modernizing mechanical engineering and the part of the requirement that the nearly zero-energy buildings must provide for at least 25% of the annual energy demand expressed in primary energy from renewable energy, generated in the building comes from or is produced in the vicinity of the building.

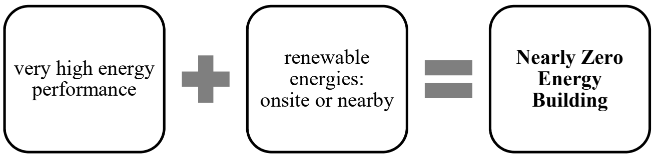


Fig. 12 The Nearly Zero-Energy Building Schema [8]

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