JOURNAL OF APPLIED ENGINEERING SCIENCES
ISSN: 2247-3769 / e-ISSN: 2284-7197

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VOL. 15(28), ISSUE 2/2025
ART.NO. 457 pp. 229-234

CONSIDERATIONS ON THE ENERGY EFFICIENCY OF NON-RESIDENTIAL BUILDINGS IN ROMANIA

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Received: 17.03.2025 / Accepted: 04.05.20 25/ Revised: 13.08.2025 / Available online: 15.12.2025

DOI:10.2478/jaes-2025-0027

KEY WORDS: energy efficiency, residential, buildings, energy exchange.

ABSTRACT:

Energetic performance regulations within Romania are handled by both domestic standards and European mandated ones both of which are aimed at not only regulating energy efficiency criteria of a given building but also at gradually increasing it nationally on a standard level. The contents presented herein showcase the methodology of how this is implemented within the various building sectors, taking into account both the legislative norms and the methodology behind maintaining a high degree of energy efficiency within constructions based on their particular nature.An important position, both in the EU agenda and in the used political instruments, is represented by the mitigation of the impact of climate change on the natural environment, at a regional level. It is well known that a main cause of climate change is found within the emissions of greenhouse gases into the atmospheric air, the most important source being the burning of fossil fuels. The general finding of scientists is that CO2 emissions are the main cause of the increase in temperature of Earth's atmosphere and that the lack of measures to control these emissions will lead to undesirable effects for humanity as a whole.

1. INTRODUCTION

The directives that comprise the fundamental strategies on climate change and on which the work of the United Nations Framework Convention on Climate Change (UNFCCC) is based, are mitigation and adaptation. The mitigation phenomenon is intended to limit greenhouse gas emissions, through a series of radical measures and adaptation is required through a wide range of specific measures and actions, designed to reduce the aggressive impact of the climate. In the context of climate change, an important direction of action is the adaptability of the built space. Constructions will have to comply with both future extreme weather events and climatic conditions, as they will face higher temperatures in summer, lower in winter, stronger winds, heavy snowfalls and other environmental changes that can become dangerous.

2. THEORETICAL CONSIDERATIONS

From a legislative point of view, we have a package of laws and regulations, both domestic and European, that regulate the energy performance of buildings in our country and at a European level. These legislative acts establish the method of calculating the optimal cost values, while respecting the minimum energy performance requirements of buildings, with their component elements. The most important normative acts are Directive 2010/31/EU and Law 372/2005 which establishes the energy performance criteria of buildings (European Commission, 2010, European Environment Agency, 2013, European Parliament, 2002).

Regarding the local legislation, we can say that the main sector targeted by the normative acts in force is the non-residential one, followed by individual, collective and heritage housing. For non-residential buildings, office buildings in general and then for those with large glazed surfaces in particular, there is still no clear concern regarding energy requirements and a concrete calculation methodology.

Normative C 107/2 of 2005 establishes the method for calculating the characteristics of the global thermal energy performance of non-residential buildings. The global thermal insulation coefficient is denoted by the symbol G1 with the unit of measurement $W/(m^3K)$. The relationship based on which the satisfaction of the global thermal energy performance level of a building, or only a part of that building, is verified is:

$$\leq G1ref \qquad (1)$$

where:

G1 – is the conventional indicator that measures the degree of overall energy performance of a building, or only a part of the construction, different in the cold period of a year from a functional point of view.

G1ref - is the global reference coefficient, with the role of establishing the thermo-energetic performance of the building, in accordance with the architectural design, the performances imposed by the execution design and monitored throughout the life of the building (C107/2, 2005), (Administrația Națională de Meteorologie, 2012).

The Heated volume consists of directly heated spaces (staircases, hallways, wall cabinets, pantries, elevators and common circulation spaces). These spaces will be considered "heated" even if they do not have heating elements and are connected to heated spaces or located at a level where most of the spaces are heated. The concept of heated volume also includes the volume occupied by a display case, if it is separated from it by glass, in which case it is taken into account that the outer wall of the heated volume is the outer glass of the display case (BPIE, 2012).

The concept of unheated volume refers to spaces that do not have heating elements and do not meet the requirements of a heated volume. These include: cellars, technical basements, garages, corridors, attics, etc. (C107/2, 2005, Moberg A, 2005), BPIE, 2012).

The C107/2 standard applied to non-residential buildings divides them into two categories:

- Category 1 buildings, consisting of buildings with "continuous occupancy" as well as buildings with "discontinuous occupancy" having a high inertia class (details can be found in Annex B of the C107/2 standard);
- Category 2 buildings, consisting of buildings with "discontinuous occupancy", excluding those in the high inertia class.

The category of buildings with "continuous occupancy" includes those buildings whose operating regime requires that the internal temperature does not fall more than 7°C below the value established for operation in the 0–7-hour interval. The buildings that are part of this category are: hospitals, boarding schools, nurseries, etc.

The category of buildings with "discontinuous occupancy" includes those buildings whose operating regime requires that the deviation from the temperature imposed in operation be greater than 7°C in a 10-hour interval of a day, of which at least 5 hours are found in the 0–7-hour interval. The buildings that are part of this category are: restaurants, administrative buildings, schools, performance halls, amphitheaters, industrial buildings that have a maximum of two shifts per day, etc., having the medium and low inertia class, in accordance with Annex B of the normative. (Moberg A., 2005)

The effective global coefficient of a building, G1, can be calculated with the relationship below:

$$G1 = \frac{1}{V} \cdot \left[\sum_j \frac{A_j \cdot \tau_j}{R'_{mj}} \right] \tag{2}$$

where:

V – represents the heated volume of the building or part of the building, calculated in accordance with Norms C107/3 and C107/1 and measured in m³;

Aj – represents the surface area j of the building element, through which a heat exchange occurs, calculated in accordance with Norms C107/1, C107/3 and C 107/5, and expressed in m²;

τj – is the correction factor of the temperature difference between the different environments with respect to the building element j, and is calculated in accordance with Norms C107/1, C107/3 and C 107/5;

Rmj – represents the corrected average specific thermal resistance of a building element j, and is calculated in accordance with Norms C107/3 and C 107/5, and expressed in m²0K/W (Stefanescu D., 2012);

The calculation relationship for the global reference coefficient, G1ref is the following:

$$G1ref = \frac{1}{V}\left[\frac{A_1}{a} + \frac{A_2}{b} + \frac{A_3}{c} + d \bullet P + \frac{A_4}{e}\right] \tag{3}$$

where:

A1 – represents the area of the surfaces with opaque components of the vertical walls and which make an angle greater than 600 with the horizontal plane. These surfaces are in direct contact with an unheated space or with the outside, and are expressed in m², taking into account the inter-ax dimensions;

A2 – represents the area of the surfaces of the last level, of the floors that make an angle less than 600 with the horizontal plane, and are in direct contact with an unheated space or with the outside. The calculation will be made, taking into account the inter-ax dimensions, and is expressed in m²;

A3 – represents the area of the surfaces of the lower floors, which are in direct contact with the outside or with an unheated room. The calculation will be made, also taking into account the inter-ax dimensions, and is expressed in m²;

P – represents the external perimeter of the heated space of the building, which is buried, or in contact with the ground, and is expressed in m;

A4 – represents the area of the surfaces of translucent or even transparent walls, in contact with an unheated space or with the outside. The calculation will be made, in accordance with the nominal dimensions of the wall gap, and will be expressed in m²;

V – represents the heated volume, which will be calculated taking into account the internal dimensions of the building, and will be expressed in m³;

a,b,c,d,e – represent the control coefficients of the construction elements described above, whose values are in tables 1 and 2, depending on:

- category 1 or category 2 of the building;
- type of building;
- climatic zone in which it falls, in accordance with the C107/3 standard (Balota R.S., 2012).

Type of building	Climate zone	a [m²K/W]	b [m²K/W]	c [m²K/W]	d [W /mK]	e [m²K/W]
Offices, commercial buildings and hotels	I	0,80	2,10	0,90	1,30	0,30
	II	0,90	2,30	1,00	1,30	0,30
	III	1,00	2,50	1,10	1,30	0,30
Other buildings (industrial with regular operations or exploitation)	I	0,65	1,80	0,90	1,30	0,25
	II	0,70	2,00	1,00	1,30	0,25
	III	0,75	2,20	1,10	1,30	0,25

Table 1. Values of control coefficients of construction elements for category 1 buildings

Type of building	Climate zone	a [m²K/W]	b [m²K/W]	c [m²K/W]	d [W/ mK]	e [m²K/W]
Clinics, dispensaries, nurseries	I	1,05	2,45	1,30	1,40	0,39
	II	1,15	2,70	1,40	1,40	0,39
	III	1,25	2,95	1,50	1,40	0,43
Schools and sports buildings	I	0,75	2,00	0,90	1,40	0,39
	II	0,80	2,25	1,00	1,40	0,39
	III	0,85	2,45	1,10	1,40	0,43
Offices, commercial buildings and hotels	I	0,75	2,00	0,90	1,40	0,30
	II	0,80	2,25	1,00	1,40	0,30
	III	0,85	2,45	1,10	1,40	0,30
Other buildings (industrial with regular exploitation)	I	0,55	1,40	0,85	1,40	0,25
	II	0,60	1,50	0,90	1,40	0,25
	III	0,65	1,60	0,95	1,40	0,25

Table 2. Values of control coefficients of construction elements for category 2 buildings

In the case of buildings with large glazed surfaces, as is the case of the building studied in this paper, the C107/2 standard proposes to increase the global reference coefficient G1ref by a certain amount, ΔG1ref, having the values mentioned in Table 3, in correlation with the building category and the solar index, Is, calculated according to Annex C and, in certain situations, with the thermal inertia of the building (determined according to Annex B of the standard (C107/2, 2005).

Building category	Building type	Thermal inertia	Solar index $[m^{-1}]$		
			until 0.009	from 0.010 to 0.019	over 0.020
Category 1 buildings	Sport buildings	Some	0	0,06	0,12
	Other buildings	Small	0	0,03	0,06
		Medium	0	0,05	0,10
		Large	0	0,06	0,12
	Buildings	Some	0	0,03	0,06
Category 2 buildings	For sports and schools				
	Other buildings	Some	0	0,04	0,08

Table 3. ΔG1ref values, in W/(m³K)

In order to establish the thermal inertia class of non-residential buildings, it is necessary to mention the classification category (1 or 2).

The inertia class is determined by taking into account the following situations:

- If the surface area of the heated space of the building under analysis is less than or equal to 200 m², the calculation will be made for the entire building;
- If the respective surface area exceeds 200 m², the calculation will be made on a smaller portion, which can be considered representative for that building.

Depending on the value obtained from equation 1.4. the thermal inertia class of the building or part of it will be established and is mentioned in Table 4.

$$\frac{\sum_j m_j \bullet A_j}{A_d} \qquad (4)$$

where:

mj – represents the unit mass of each component building element j, which influences its thermal inertia, being expressed in kg/m²;

Aj – represents the useful area of each building element j, is determined in correlation with its internal dimensions, being expressed in m²;

Ad – represents the developed area of the building or part of the building analyzed, in m². The calculations will take into account the provisions of STAS 4908.

$\frac{\sum_j m_j \bullet A_j}{A_d}$ kg/m²	Thermal inertia
up to 149	Small
from 150 to 399	Medium
over 400	Large

Table 4. Criteria for determining the thermal inertia class

The capacity of a building or part of a building to capture solar energy is defined by the solar index, Is, calculated with the relationship:

$$I_s = \frac{\sum_j \left(A_j \bullet S_j \bullet \sigma_j\right)}{V} \left[m^{-1}\right] \qquad (5)$$

where:

$\sum_j$ - represents the sum of the products, the sum calculated for each of the vertical translucent or transparent walls, or which make an angle greater than 600 with the horizontal plane;

Aj - represents the area of the translucent or transparent wall, area calculated in m², of the projection on a plane parallel to the respective element;

Sj - represents the solar factor of the transparent or translucent wall, and is the result of the ratio between the value of solar energy transmitted through this wall and the value of incident solar energy. This factor is determined in accordance with the indicated standard;

σj - represents the coefficient illustrating the degree of solar energy reception on a given facade, also determined in accordance with the indicated standard;

V - represents the heated volume of the building or part of that building, measured in m³,

also determined in accordance with the indicated standard (Ionescu Gh.C., 2014, Iancău, M., 2012).

Depending on the carpentry model, its nature, the type of glazed element, the building category and the location of the glazed element, the solar factor will be calculated, in relation to the wall (Table 5).

Carpenting nature	Glazed element type	Carpenting type	Buildings with constant occupation		Buildings with intermitent occupation	
			Position		Position	
			On the inner face of the wall	On the outer face of the wall	On the inner face of the wall	On the outer face of the wall
Wooden joinery with hinged or sliding opening	Window	simple	0,51	0,56	0,53	0,59
		coupled	0,44	0,48	0,46	0,51
		double	0,44	0,44	0,46	0,46
	Glass door without panel	simple	0,53	0,59	0,56	0,62
		coupled	0,46	0,51	0,48	0,53
		double	0,46	0,46	0,48	0,48
	Glass door with panel	simple	0,46	0,51	0,49	0,54
		coupled	0,40	0,44	0,42	0,46
		double	0,40	0,40	0,42	0,42
Sliding metal joinery	Window	simple	0,58	0,64	0,60	0,67
		coupled	0,50	0,55	0,52	0,58
		double	0,50	0,50	0,52	0,52
	Glass door without panel	simple	0,60	0,67	0,64	0,71
		coupled	0,52	0,58	0,55	0,61
		double	0,52	0,52	0,55	0,55
Metal joinery with hinged opening	Window	simple	0,54	0,60	0,57	0,63
		coupled	0,47	0,52	0,49	0,54
		double	0,47	0,47	0,49	0,49
	Glass door without panel	simple	0,56	0,62	0,59	0,65
		coupled	0,48	0,53	0,51	0,56
		double	0,48	0,48	0,51	0,51
Metal joinery for industrial halls		simple	-	-	0,62	0,69
		double	-	-	0,53	0,53

Table 5. Determining the positioning of the glazed element in relation to the wall

The values indicated in the table refer to the currently used glazed elements, provided with transparent glass panes. In the case of non-traditional glazed elements, provided with special glass, the determination of the solar factor values will be made in accordance with the mentions in the certification documents of the analyzed products. When establishing the solar factor values, the existence of any shading due to lintels or vertical slats will be taken into account. This explains the reason why the solar factor value calculated for a glazed element located on the outer face of the wall is higher than that of a glazed element located on the inner face of the wall.

All glazed elements that are mounted in walls whose thickness is identical to the thickness of the glazed element will be considered as mounted on the external face of the wall.In calculating the σ coefficient for a glazed element, both its orientation and the height of obstacles that could shade the element will be taken into account.

The σ coefficient in the case of a western orientation depends on the purpose of the building, without neglecting in the calculations the fact that the solar energy captured on a particular facade will be recovered more efficiently in spaces that have a permanent occupancy, unlike spaces with an occasional occupancy. The values obtained for the coefficient σ are mentioned in Table 6, depending on the orientation of the element, the height of the obstacles, and for a westward orientation, the values take into account the occupancy mode of the building.

The weighted average height of the obstacles is the result obtained by summing the average heights related to the four azimuth sectors, denoted 1, 2, 3, 4 (Figure 7 and Table 8), and is determined according to the example in the regulations (INCD URBAN - INCERC, 2012, Buildings Performance Institute Europe, 2012).

Weighted average height of obstacles	Element orientation				
	From SW to SE	From SE to NE	From SW to NW		From NE to NW
			Continuous occupation	Intermittent occupation	
up to 15°	1	0,6	0,6	0,4	0,3
from 15° to 25°	0,8	0,4	0,4	0,3	0,2
25° and more	0	0	0	0	0

Table 6. Values of the coefficient σ

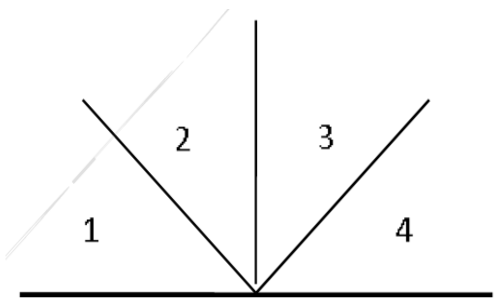

Figure 7. Illustration of the four azimuth sectors, denoted 1, 2, 3, 4

Element orientation	Azimuth sector			
	1	2	3	4
from SW to SE	0,10	0,40	0,40	0,10
from SE to NE	0,05	0,20	0,45	0,30
from SW to NW	0,30	0,45	0,20	0,05
from NE to NW	0,20	0,30	0,30	0,20

Table 8. Height weighting coefficients according to the four azimuth zones

3. EXISTING BUILDINGS

According to the information extracted from the database with the results of the "Energy Performance Certificates", managed by INCD URBAN INCERC, the graph in Figure 9 was created, which represents a current picture of the energy performance of existing buildings in the non-residential sector. The aforementioned graph was created based on the analysis of a number of 7000 energy performance certificates.

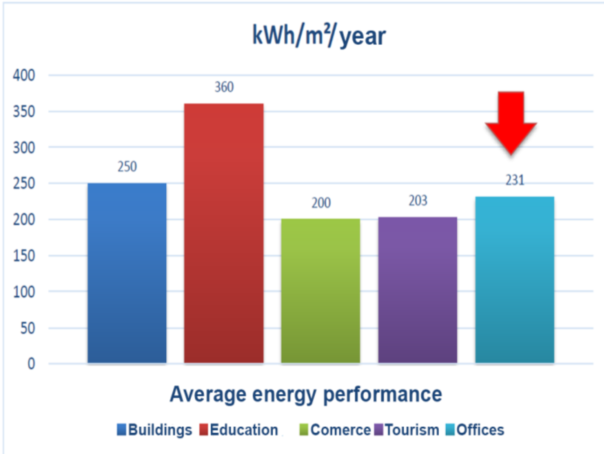

Figure 9. Energy performance values for existing buildings

The graph in Figure 10 shows the values of the average CO2 Emission Index for several types of buildings in the non-residential sector. We note that, among non-residential buildings, office buildings are in 3rd place in terms of average energy performance. The consumption value (231 kWh/m²/year) (5) is, however, well above the current requirements for energy efficiency of buildings. Also, the level of emissions for office buildings is at a high level according to Table 11 (Ionescu G.C., 2021, Cziszter K., 2022).

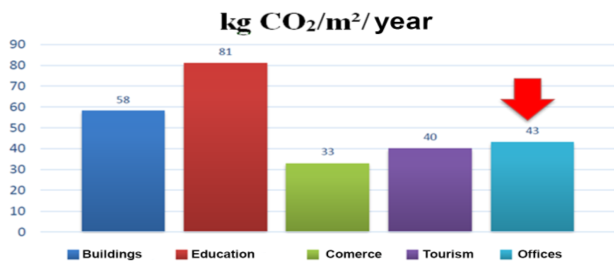

Figure 10. Average CO_2 emission index

Construction year	Thermal transmission U [W/(m²K)]		Final energy consumption (kWh/m²yr)
	Vertical	Horizontal	
Offices	0.70 – 1.50	0.35 – 1.30	120 – 250

Table 11. Energy performance characteristics – office buildings

4. CONDITIONS IMPOSED ON NEW OFFICE BUILDINGS

At best, for this type of building, there are a few studies by economic agents and a few scientific papers. In 2011, BPIE conducted a study on the definition of “Principles for Nearly Zero Energy Buildings” 1 (nZEB), with the aim of analyzing the main challenges in the implementation of nZEB and proposed a new set of general principles that will be taken into account when developing technically and economically reliable nZEB definitions at national level and will align with long-term political objectives. Following an analysis of the technical and economic implications of the proposed principles, the study established a series of general proposals for support measures, with a view to a transition to "Nearly Zero Energy Buildings" in Europe. The study was carried out, taking into account the 3 main categories of buildings, namely: Office Buildings, Collective Residential Buildings and Individual Residential Buildings.

The current technical regulatory framework provides minimum requirements only for newly constructed buildings, and the minimum energy performance requirements are not represented in the form of a global consumption indicator in either of the 2 cases (new buildings/existing buildings).

The technical regulations in our country generally contain thermal insulation criteria for each individual building element, ultimately summing up all the energy performance of the building in an overall thermal insulation coefficient G3. There is an overall heat transfer coefficient G, measured in (W/m^{2}K) which is related to the volume needed to be heated. It varies depending on the number of floors of the building and the compactness index, calculated as a ratio between area and volume.

	Walls	Roof/Terrace	Lower Floor	Windows	Global demand
Residential Buildings (demand)	0,56 W/m²K	0,20 W/m²K	0,35 W/m² K	1.30 W/m²K	Global thermal transmittance coefficient, G (W/m³K).
Residential Buildings (standard)	0,56 W/m²K	0,20 W/m²K	0,22 W/m² K	1,30 W/m²K	
Office Buildings (demand)	based on climate zone and size U = 0,56…0,67 W/ m² K	based on climate zone U = 0,22…0,29 W/ m² K	based on climate zone and size U = 0,34…0,50 W/ m² K	2,0 W/m²K	Global thermal transmittance coefficient
Office Buildings (standard)	0,6 W/m² K	0,25 W/m² K	0,35 W/m² K	1,30 W/m² K	

Table 12. Requirements specified in technical regulations and characteristic values for new buildings (in W/m^{2}K) – Comparison between residential and non-residential buildings

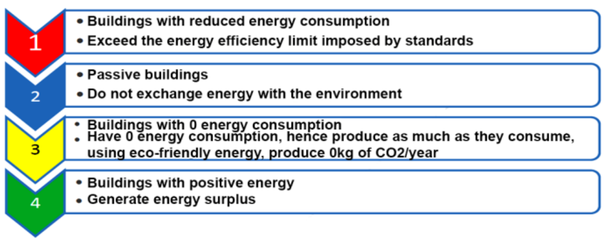

Figure 13. Categories of low-energy buildings

The last 2 categories in the figure above (Table 12 and Figure 13) are those that provide for the use of renewable energy sources. Unfortunately, the use of these energy sources is not yet a common practice in our country. Several pilot projects in the field of renewable energies have been launched in the private sector. The most widely used solution is the use of solar panels to generate domestic hot water for use in homes. Photovoltaic solar panel parks that provide electricity and geothermal heat pump systems have also been built (Szabo S., 2022).

Although the European market has the capacity to provide adequate technical solutions for the collection and use of energy from renewable sources, the legislative framework does not sufficiently encourage their implementation in the non-residential sector. Financial support schemes for the implementation of energy efficiency technologies in buildings are mainly oriented towards buildings in the residential sector (Ionescu Gh.C., 2013). The specialized literature does not mention works that study the energy behavior of office buildings in the northwest of Romania, with a large glazed surface. Although this work does not contain all the studies necessary to obtain reliable solutions regarding this type of buildings, the studies carried out aimed to obtain an efficient result in the case of non-residential buildings.

5. CONCLUSIONS

This work, through its content, analyzed in detail all building elements that have an energy impact, and with the help of the case study conducted, identified most of the problems that arose in different areas of the construction. Following these steps, a series of solution proposals were made by using analysis programs and software tools dedicated to this purpose.

The proposed solutions are recommended to be implemented through close collaboration with companies that produce envelope elements, such as: the utilized construction materials, insulating materials, facade systems, etc. This approach would lead to the validation of the proposed solutions as simulated by the computational programs approached.

Following theoretical and practical analyses, an attempt was made to correlate the energy transfer phenomena from the interior and exterior environments, as well as the environmental parameter regulation systems, with the aim of identifying new calculation algorithms that, in turn, can be implemented in various programs for the most efficient optimization of buildings in terms of energy consumption.

Due to the latest achievements in the technical field, a series of new products necessary for air conditioning systems have been obtained. The concept of "Self Aware Building" constitutes a new research direction regarding the notion of "smart building". By implementing this concept, an efficient optimization of energy consumption is desired. Appropriate equipment is required, with a varied range of solar collectors, capable of significantly reducing the building's energy consumption.

As for buildings that are part of the non-residential sector, they represent approx. 18% of the total built-up area and approximately 4% of the total real estate stock. Of these buildings, the ones with commercial purpose represent 31%, followed by educational institutions at a rate of 29%, then16% healthcare and 13% office spaces.

Directive 2010/31/EU on the energy performance of buildings was amended in 2018 by Directive (EU) 2018/844. The basic idea was to accelerate the cost-effective renovation of existing buildings, as well as to promote smart technologies in buildings. As part of the Clean Energy Package, the amending directive comes as a complement to the legislative acts on energy efficiency.

This new Directive required EU member states to develop long-term renovation strategies by 2050, in order to accelerate renovations in both the residential and non-residential building sectors, achieving a high level of energy efficiency and decarbonization. The adopted strategies aimed to establish a roadmap containing measurable measures and indicators of progress, taking into account the EU's long-term objective in 2050 of reducing greenhouse gas emissions by 80-95% compared to 1990. The roadmap was to include indicative benchmarks for 2030, 2040 and 2050 and to specify how they will contribute to achieving the EU's energy efficiency objectives, in accordance with Directive 2012/27/EU on energy efficiency. Regarding the National Thermal Rehabilitation of Buildings Programme, the Government of Romania approved and issued a Government Decision on 17 December 2020 on the National Long-Term Renovation Strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, and its gradual transformation into a high-energy-efficient and decarbonised real estate stock by 2050.

The building energy retrofit policies were defined in the ENTRANZE assessment, based on an initial assessment of buildings in Romania, as well as the results obtained from the cost-optimal calculations carried out in the project, which included balanced solutions for energy efficiency and the large-scale use of renewable energy sources.

The greatest benefits in terms of energy savings, sustainable transformation of the building sector, as well as macroeconomic impact, are brought by policy sets PS2 and PS3, by describing and analyzing the possibilities for sustainable transformation of the building sector in Romania. Although these sets of measures can be improved, they can constitute an ambitious plan for the renovation of buildings in Romania, directly contributing to an increase in living standards and sustainable economic development.

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