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OFFICE BUILDINGS IN DIFFERENT CLIMATE ZONES FROM ROMANIA - COMPARATIVE STUDY ON ENERGY EFFICIENCY INDICATORS

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Summary: *This study represents an analysis of the applicable technical solutions for the energy rehabilitation for an office building, so that the rehabilitation project can be financed through the POR/2016/3/3.1/b/1/BI program regardless of the climatic zone in which the building is located. In this article are analysed the thermal rehabilitation solutions of the building's tire without interventions on the energy sources compared to the energy rehabilitation that includes interventions on the energy sources. The article purpose is to determine the necessity of interventions on energy sources in the context of energetic rehabilitation in the case of POR/2016/3/3.1/b/1/BI application.*

Key words: *energy audit, greenhouse gas rehabilitation, renewable energies, energy efficiency indicators*

1. Introduction

It is well known that reducing energy consumption for heating is the most effective action that can be taken in a building to protect natural resources and reduce greenhouse gas emissions in the atmosphere. The major objective of all states, both European Union and non-EU, is to increase the energy performance of buildings by reducing energy consumption. The reducing energy consumption objective are set out in the Directive no. 91/2002/EEC on energy performance transposed into national legislation by means of Law no. 372/2005 on the energy performance of buildings. National legislation on energy efficiency of buildings has undergone some changes since its appearance, in the sense of improving the level of energy performance to be achieved for the new buildings and for the ones which will be rehabilitated. Currently there are a lot of energy indicators which must be fulfilled for an audit project in order that the proposed solution by an auditor to be eligible for projects funded by European funds. If different forms of energy (eg. electricity, gas, solar energy) are used to provide utilities in a building, quantities from each one of these energy must be converted into primary energy consumption, which takes into account production, transport and distribution yields.

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Given the importance of high energy efficiency, the measures and the strategies of the European Union are focus on cost and energy consumption reduction. So, until 2020's, the European Union Proposes a 20% reduction in primary energy and 20% increase in the share of energy renewable.[3]

2. Objectives

This study aims at assessing the energy performance of an office building in Romania in different climatic zones by determining the thermal protection level of the building and the energy efficiency of heating, hot water and lighting installations, so that in the four climatic zones, the energy efficiency indicators of the building to be within the limits established by the current technical legislation. At national level, the technical regulation "Calculation of Energy Performance of Buildings MC001 / 1-2006", approved by the Order of the Minister of Transports, Constructions and Tourism no. 157/2007, published in the Official Gazette of Romania, Part I, no. 126 and 126 bis of 21 February 2007, as subsequently amended and supplemented, was amended and supplemented by Order no. 2641/2017. Both for the rehabilitation of the existing buildings and for the new buildings it is mandatory to observe this Order regarding the energy efficiency of the buildings.

Due to the fact that investments for energy rehabilitation are made by accessing European funds, in case of rehabilitation of existing buildings it is necessary to observe the conditions stipulated in the Applicant's Guidelines, so that the projects are eligible for financing. The main objective of the present study is to establish the minimum necessary technical solutions for the Romanian climate zones, so that the office building fulfils the minimum requirements stipulated in the current Romanian legislation and in the Applicant's Guide POR/2016/3/3.1/b /1/ BI which is currently the main source of financing for the energy rehabilitation of buildings.

Through the Applicant Guidelines for POR/2016/3/3.1/b/1/BI funding, the following energy performance conditions for the building are required: [1]

- respect of minimally corrected thermal resistance;
- the inclusion in the maximum annual consumption q_{an}, max of primary energy;
- incorporation in the $C0_2$ equivalent emission level;
- achieving a minimum of 10% of total primary energy consumption from renewable energy sources at project level.

It should be noted that observance of minimally corrected tempered resistances is not a mandatory condition if the requirements cannot be met, but it is mandatory to respect the condition $qan \leq qan, max$. [1]

3. Methods and Procedures

In order to determine the normal yearly heat consumption for building heating, domestic hot water and artificial lighting, the geometrical characteristics of the building and the entire energy performance calculation methodology MC001/1-4/2006 with subsequent modifications will be used.

The steps for calculating the energy performance of the building consists of:

- Determination of the corrected thermal resistances of the building elements of the building envelope;
- Determination of annual energy consumption for space heating at the energy source

of the building:
- Determining the annual energy consumption for artificial lighting at the energy source of the building;
- Determination of annual energy consumption for the preparation of hot water at the energy level of the building.

The analysis of the energy rehabilitation solutions of the building consists in comparing the resulting indicators based on the proposals of the rehabilitation solutions with the energy efficiency indicators to be met and this activity consists of:
- Establishment of technical solutions aimed at the energy rehabilitation of the building;
- Comparing the obtained results with the reference values so that the technical legislation in the field is respected;
- Disclaimer / remove technical solutions whose energy efficiency indicators do not meet the minimum values;
- Calculation of energy efficiency indicators for eligible technical solutions;
- Carrying out the economic analysis of the technical solutions eligible for the project financing;
- Calculation of economic efficiency indicators for eligible technical solutions.

For this case study, the studied building has the following general characteristics:
- Main destination: office building;
- Heights: Ground floor;
- Built-up area: 659.00 m2;
- Usable heated area: 481.95 m2;
- Superstructure: Brick masonry walls;
- Heat source for heating: Gas-fired boiler;

Taking into account the building's destination, the internal calculation temperature, the occupancy period of the building, the specific consumption of hot water, the time of use and the installed power of the luminaires were determined. Considering the complexity of a study on the energy efficiency of the building, we will focus on establishing technical solutions for the energy rehabilitation of the building so that it complies with the technical legislation in force, focusing on the comparison of the minimum technical solutions needed for the rehabilitation / modernization of the building so that it is eligible under POR/2016/3/3.1/b/1/BI for extreme climatic zones from Romania.

The most efficient reduction of total energy consumption is achieved by observing the Trias Energetica principle. This principle shows how to prioritize actions of efficiency:[2]
- energy consumption must be reduced;
- the amount of energy needed must be provided as much as possible from renewable sources;
- the rest of the energy needed must be taken from less polluting fossil sources if it is possible.

4. Results and Discussions

The calculation of energy efficiency was done with specialized software.

For fitting the indicators resulted from the application of the energy rehabilitation solutions into the required indicators through the Guide, different energy rehabilitation solutions were set up, as follows:

a) The same energy rehabilitation solution for all climatic zones consists of:

Thermal rehabilitation works of the building envelope:

- thermal insulation of the facade - glazing - windows: energy efficient joinery Uf ≤1,1 W / m^2K, Ug ≤1,1 W / m^2K;
- thermal insulation of the facade - opaque part - exterior walls: 15 cm thick thermal system, λ = 0.038W / mK;
- thermal insulation of the floor over the last level - Roof roof: 30 cm thick thermal system, λ = 0.038W / mK;
- thermal insulation of the building socket: 10 cm thick thermal system, λ = 0.038W / mK;

Rehabilitation works related to the building:

- replacement of all indoor (thermal, sanitary, electrical) installations including boiler in condensation and lighting with LED lighting;

Energy efficiency indicators Table 1

CLIMATE ZONE V	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	98.00	**157.44**	kWh/m^2year
- CO_2 equivalent emission:	28.00	**19.65**	kgCO_2/m^2year
CLIMATE ZONE IV	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	89.00	**144.66**	kWh/m^2year
- CO_2 equivalent emission:	24.00	**17.42**	kgCO_2/m^2year
CLIMATE ZONE III	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	69.00	**128.07**	kWh/m^2year
- CO_2 equivalent emission:	19.00	**14.51**	kgCO_2/m^2year
CLIMATE ZONE II	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	57.00	**111.41**	kWh/m^2year
- CO_2 equivalent emission:	15.00	**11.59**	kgCO_2/m^2year
CLIMATE ZONE I	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	50.00	**95.54**	kWh/m^2year
- CO_2 equivalent emission:	13.00	**8.81**	kgCO_2/m^2year

As a result of the analysis indicators, for each climatic zone, it can be noticed that the building energy rehabilitation solutions is not correctly chosen, the resulting indicators regarding the annual specific consumption of primary energy from non-renewable energy is higher than the indicators required to be achieved. As a result, measures are needed to reduce the annual consumption of primary energy from non-renewable fossil sources.

b) The same energy rehabilitation solution for all climatic zones consists of:

Thermal rehabilitation works of the building envelope:

- thermal insulation of the facade - glazing - windows: energy efficient joinery Uf ≤1,1 W

/ m^2K, Ug ≤1,1 W / m^2K;
- thermal insulation of the facade - opaque part - exterior walls: 15 cm thick thermal system, λ = 0.038W / mK;
- thermal insulation of the floor over the last level - Roof roof: 30 cm thick thermal system, λ = 0.038W / mK;
- thermal insulation of the building socket: 10 cm thick thermal system, λ = 0.038W / mK;

oRehabilitation works related to the building:
- replacement of all indoor (thermal, sanitary, electrical) installations including boiler in condensation and lighting with LED lighting;
- thermal solar collectors: thermal solar collector - 1 piece, installed power P = 3.02 kW;
- photovoltaic solar panels: photovoltaic panels - 35 pieces, photovoltaic system installed P = 9.98 kW.

Because there is no boiler room inside the building, the boiler displacement with a pellet / biomass boiler or heat pump options have been excluded, for these variants is required space for the equipment placement. Of course, these variants may represent energy rehabilitation solutions for the building, but building and fitting works are also needed to make sure the equipment can be used. The lifetime of the materials and equipment proposed for the energy rehabilitation of the building is at least 15 years.

By applying the measures described above, the following energy efficiency indicators, differentiated according to the climatic zones, are obtained:

Energy efficiency indicators Table 2

CLIMATE ZONE V	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	98.00	**97.72**	kWh/m^2year
- CO_2 equivalent emission:	28.00	**16.78**	$kgCO_2/m^2year$
- specific annual consumption of final energy using renewable sources is:	-	**24.64**	kWh/m^2year
- the percentage of renewable sources use:	min. 10 %	**16.10**	%

CLIMATE ZONE IV	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	89.00	**84.94**	kWh/m^2year
- CO_2 equivalent emission:	24.00	**14.54**	$kgCO_2/m^2year$
- specific annual consumption of final energy using renewable sources is:	-	**24.64**	kWh/m^2year
- the percentage of renewable sources use:	min. 10 %	**17.56**	%

CLIMATE ZONE III	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	69.00	**68.35**	kWh/m^2year
- CO_2 equivalent emission:	19.00	**11.64**	$kgCO_2/m^2year$
- specific annual consumption of final energy using renewable sources is:	-	**24.64**	kWh/m^2year
- the percentage of renewable sources use:	min. 10 %	**19.90**	%

CLIMATE ZONE II	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	57.00	**51.69**	kWh/m^{2}an
- CO_2 equivalent emission:	15.00	**8.72**	kgCO_2/m^{2}year
- specific annual consumption of final energy using renewable sources is:	-	**24.64**	kWh/m^{2}an
- the percentage of renewable sources use:	min. 10 %	**23.00**	%

CLIMATE ZONE I	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	50.00	**35.82**	kWh/m^{2}an
- CO_2 equivalent emission:	13.00	**5.94**	kgCO_2/m^{2}year
- specific annual consumption of final energy using renewable sources is:	-	**24.64**	kWh/m^{2}an
- the percentage of renewable sources use:	min. 10 %	**27.00**	%

Following the analysis of the resulting indicators, it can be noticed that the energy rehabilitation solution of the building is correctly chosen, the resulting indicators being included in the indicators to be achieved. It can also be noticed that for the climatic zone III and V, the specific annual primary energy consumption from fossil non-renewable sources for the proposed energy rehabilitation solution (68.35 kWh/m^{2}an respectively 97.72 kWh/m^{2}an) is close to the maximum value of the required indicator (69.00 kWh/m^{2}an respectively 98.00 kWh/m^{2}an respectively) while for the other climatic zones, respecting the same energy rehabilitation solution, the values for the energy efficiency indicators are much better than the values to be achieved, the biggest difference being for the climatic zone I. Taking into account the values obtained for the climatic zone I, for the energy rehabilitation without intervention on the energy sources and for the rehabilitation with interventions on the energy sources, the question is whether the energy rehabilitation measure with interventions on the energy sources is minimum, taking into account the difference between the resulting indicators for the specific annual energy consumption and the indicators to be achieved, according to the technical legislation.

For this, respecting the same degree of thermal insulation of the building, the minimum necessary equipment with renewable energies for the climatic zone it will be determined so that the building meets the technical norms in force and the project can be financed.

- retrofit of the building only with the renewable energy source - photovoltaic solar panels(PV) where 31 pieces are needed, installed photovoltaic system P=8.83kW, the result indicators is in Table 3:
- retrofit the building with a renewable energy source - PV panels 26 pieces, installed photovoltaic system P=8.83 kW, and thermal solar panels - 1 piece, installed power P=3.02 kW, the result indicators is in Table 4:
- retrofit the building with a renewable energy source - thermal solar panels - 1 piece, installed power P=3.02 kW, the result indicators is in Table 5:

It is worth to remark that for the climatic zone I, the office building only with a renewable energy source for the preparation of hot water is not a technical solution leading to the necessary indicators, so that the project does not meet the technical legislation in force, as can be seen from the analysis of Table 5, where the result indicators is higher than the indicators to be achieved.

Energy efficiency indicators for Climate I using PV Table 3

CLIMATE ZONE I	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	50.00	**48.53**	kWh/m^{2}year
- CO_2 equivalent emission:	13.00	**7.30**	kgCO2/m^{2}year
- specific annual consumption of final energy using renewable sources is:	-	**16.79**	kWh/m^{2}year
- the percentage of renewable sources use:	min. 10 %	**18.10**	%

Energy efficiency indicators for Climate I using PV and solar panels Table 4

CLIMATE ZONE I	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	50.00	**49.46**	kWh/m^{2}year
- CO_2 equivalent emission:	13.00	**6.38**	kgCO2/m^{2}year
- specific annual consumption of final energy using renewable sources is:	-	**19.76**	kWh/m^{2}year
- the percentage of renewable sources use:	min. 10 %	**21.50**	%

Energy efficiency indicators for Climate I using solar panels Table 5

CLIMATE ZONE I	Indicators to be achieved	**Result indicators**	u.m.
- specific annual consumption of primary energy from non-renewable fossil sources is:	50.00	**88.89**	kWh/m^{2}year

Taking into account the results obtained for the energy rehabilitation solutions, it should be mentioned that for this case study, from the installations point of view, the achievement of the necessary values for the energy efficiency indicators can be achieved only by rehabilitating the lighting installations (replacing the bodies of Lighting and provision of renewable energy sources - electric solar panels), without the need for interventions on the energy source for heating or the preparation of hot water for Romanian - Climatic Zone I.

Economic efficiency indicators for the 5 Climate Zones in Romania Table 6

Economic indicators	Climate zone V	Climate zone IV	Climate zone III	Climate zone II	Climate zone I	u.m.
The estimated cost of the investment	122.561,79					[euro]
	558.391,51					[lei]
Annual energy savings	224,459.22	229,722.12	236,557.05	243,420.14	249,957.11	[kWh/year]
Value of energy economy	37,528.46	38,408.39	39,551.16	40,698.63	41,791.58	[lei/year]
Net updated value (ΔVNA)	-106,397.90	-111,069.96	-117,137.56	-123,230.16	-129,033.25	[lei]
Additional Investment Recovery Duration (NR)	12.95	12.69	12.37	12.06	11.78	[year]
Cost of energy savings (e)	0.035	0.034	0.033	0.032	0.031	[euro/kwh]
	0.158	0.154	0.150	0.146	0.142	[lei/kwh]

From the point of the **economic analysis** view, for the assumption that price of energy and fuel is the same for all climatic zones, and the energy rehabilitation solutions do not differ from one climate zone to another, the results obtained are presented in Table 6.

5. Conclusions

For an energy rehabilitation project to be funded, the technical rehabilitation solutions to be implemented for the building in question, the following requirements must be observed simultaneously: energetic efficiency, thermal comfort, financial efficiency and others. Analysing the values of the energy efficiency indicators presented in Table 1 and Table 2, we can state that the energy rehabilitation of the office building without interventions related to the energy sources (thermal, electrical) does not lead to values of the indicators that comply with the energy efficiency legislation of the buildings, in particular annual primary energy consumption from fossil non-renewable sources.

The thermoset thicknesses used in the calculation are the usual ones, which lead to corrected thermal resistances above the minimum. The value of the CO_2 emissions is an easy-to-reach indicator that can be respected without any intervention on the energy sources for this office building. For the case of the studied building, regardless of the Romania climatic, there is at least one feasible rehabilitation building option for all 5 climatic zones, for which both the economic indicator values and the resulting financial indicators lead to results that respect technical legislation for efficiency energy. Renewable energy sources represent the viable technical solution for reducing the consumption of primary energy and greenhouse gas emissions (CO_2 equivalents), interventions on energy sources in buildings lead to the possibility of fitting the indicators to the indicators required.

The values of the economic efficiency indicators presented in Table 3, ΔVNA, NR and (e) lead to economically acceptable results for the energy rehabilitation of the building for all 5 climatic zones. Regardless of the rehabilitation option chosen to increase the energy performance for the building it is necessary to observe the energy and economic efficiency indicators in the technical legislation existing or those imposed by the financier.

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