INFLUENCE OF RENEWABLE ENERGY SOURCES ON THE ENERGY BALANCE IN URBAN AREAS RECONFIGURED USING THE nZEB ENERGY ATLAS TOOL

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***Abstract**: Considering the climate change, the medium and long-term energy objectives of the European Union, regarding climate neutrality require significant reductions in energy consumption and implicitly in CO_2 emissions related to the exploitation of buildings, and at the same time the promotion of energy production technologies from renewable source; the building envelope can become the support for the placement of these technologies both in the case of new constructions and in major energy renovation projects.*

The tools used for the purpose of sustainable urban planning with the objective of promoting new buildings with nearly-zero energy consumption but also with reference to the energetic reconfiguration of the existing built stock, such as the nZEB Urban Energy Atlas (Izabella Marin Lazăr 2022) include the possibility simulation in accordance with the proposed intervention scenarios and specific climatic conditions of the amount of energy from renewable sources that can be produced on site and the contribution of these sources to the energy balance of the urban area.

***Keywords:** nZEB-nearly Zero Energy Buildings, Energy Atlas, Heat Island Mitigation, energy efficiency, renewable energy sources, urban retrofitting, integrated solutions*

1. Introduction

The current legislative requirements impose the obligation to build new high-performance buildings characterized by "nearly zero" energy consumption (Directive 2010/31/EU), their definition referring to "a building with a very high energy performance for which the energy requirement is almost equal to zero or very low should be covered to a very large extent with energy from renewable sources including energy produced on site". Thus, the basic principles in the definition of nZEB aim at a maximum threshold of primary energy from conventional sources (fossil fuels) and implicitly a maximum threshold of CO2 emissions, and a minimum threshold of energy from renewable sources.

In the Romanian legislation, Law 101/2020 for the amendment and completion of Law 372/2005 provides, by amending art.3, point 15 of chapter II, that in the case of buildings with near-zero energy consumption, the energy required to ensure energy performance must be covered in proportion of at least 30% with energy from renewable sources, including energy from renewable sources produced on site or nearby within a radius of 30 km from the GPS coordinates of the building, starting with the year 2021.

We can also signal as a key point of the current energy debates a trend of future growth in the energy requirement for air conditioning. The International Energy Agency (IEA) identifies among the listed main causes/ climate changes in the sense of increasing average temperatures but also the frequency of extreme temperatures due to local effects caused by the heat island phenomenon and climate change. In the Report of the European

Environment Agency "Climate change impacts and vulnerability in Europe 2016" this mention is made regarding the increase in electricity consumption for air conditioning in correlation with increases in extreme temperatures in the summer season for the Central and Eastern European area, with an implicit impact on the level of the territory of Romania, especially in the extra-Carpathian area.

All the presented previously converge towards the need to include in the applications for urban energy planning the simulations regarding the impact at the level of the analysed urban areas of the exploitation of the local potential for the production of energy from renewable sources. The "Energy and Climatic Atlas of the City of Helsinki" is such a public 3D application that on the basis of three-dimensional models of buildings presents their energy performance and allows by calculating the solar radiation incident on the envelope and determining the shaded surfaces, the evaluation of the zonal potential for electricity production by equipping with photovoltaic panels.

2. Materials and Methods

It is important to mention the need to use as support the numerical simulations regarding the relevant urban energy reconfiguration scenarios, the dynamic energy modelling algorithm with an hourly time step having as climatic support the specific values of the typical climatic year for the analysed area (Constantinescu Dan – Tratat de Inginerie Termică, Termotehnica în construcții, vol.2 Ed.AGIR 2020).

Additionally, the urban environment is characterized by an increase in temperatures in densely built areas generated by the structure of compact, impermeable surfaces with high thermal conductivity (Helmuth Erich Landesberrg - 1981) due to the urban heat island effect (UHI) defined as a temperature difference between urban areas and the rural ones where the percentage of vegetal areas with permeable soils is predominant. This phenomenon increases the vulnerability of the urban environment in the context of increasing the duration and intensity of heat waves due to climate change.

The urban microclimate and the built environment are in an interdependent relationship influencing each other. The energy consumption of the building intended to ensure the internal thermal comfort is influenced by the external temperatures amplified by the urban heat island effect and in the same time the consequence of the use of air conditioning equipment is the re-sending of hot fluids into the external environment which causes an "uncontrolled" increase in external temperatures through this building becoming itself an anthropic factor that produces the increase of the UHI effect.

It is therefore necessary for new nZEB buildings to adopt "design solutions sized to cope with the forecasted climatic conditions" (https://www.resilientdesign.org/ the-resilient-design-principles) thus determining their energy and environmental performances follows the same evaluation method as in the case of existing buildings described in the previously cited work with the difference of using it as a support for modelling the energy behaviour of the residential units of new buildings, it will be done on the basis of a virtual climatic year with a higher potential for climatic demand.

The role of efficient buildings goes beyond the conventional approach of the static envelope that delimits the interior environment from the exterior environment, being a step forward towards the adoption of project solutions that give the envelope adaptability to climatic demands. The envelope elements play an essential role in ensuring the interior comfort parameters, which requires their energy optimization both by implementing passive architectural solutions and by integrating active energy production systems from renewable sources that will influence the energy balance of the building and its performance.

3. Results and Discussion

Graphical and numerical results are presented with reference to the quantification of the energy production potential from renewable sources by equipping with photovoltaic (PV) panels. These were obtained through the use of the nZEB Energy Atlas decision-making tool for the analysis of real and proposed energy and environmental performances within the analysed representative Urban Areas. (Izabella Marin Lazar 2022).

This study highlights values of Primary Energy (kWh/m^2 year) and CO_2 emissions (kg/m^2 year) compensated by equipping with photovoltaic panels a significant percentage, approximately 65%, of the surface of the terraces of the 283 block stairs analyzed in the delimited area located in the City of Bucharest (climate zone II).

For the two representative energy typologies of analyzed buildings, CRA (buildings in the current initial condition "thermally unrehabilitated") and CRR (renovated buildings "thermally rehabilitated"), the current energy consumption, respectively values of Primary Energy (kWh/ m^2 year) and associated CO_2 emissions (kg/ m^2 year) are presented with the highlighting of the thermal and electrical vector. Significant results are presented regarding the impact on the energy balance of the buildings and at the average zonal level of the inclusion in the proposed solution packages of technologies for the production of energy from renewable sources, being evaluated Primary Energy values and CO_2 emissions compensated by equipping the building with PV panels.

The resulting energy saving at the regional average level by harnessing the solar potential is approx. 11%, (24.9 kWh/m^2 year), for CRA type buildings, respectively 17.7% (28.22 kWh/m^2 year) for CRR type buildings and a reduction in CO_2 emissions of approx. 8, respectively 8.6 (Kg / m^2 year) with reference to the current energy status.

The implementation of all the measures included in the package of solutions proposed for the energy reconfiguration of the analysed area will cause a significant decrease in the energy consumption of the buildings compared to the current state, which implies an increase in the energy balance of the percentage related to the input of the energy produced by the photovoltaic panels.

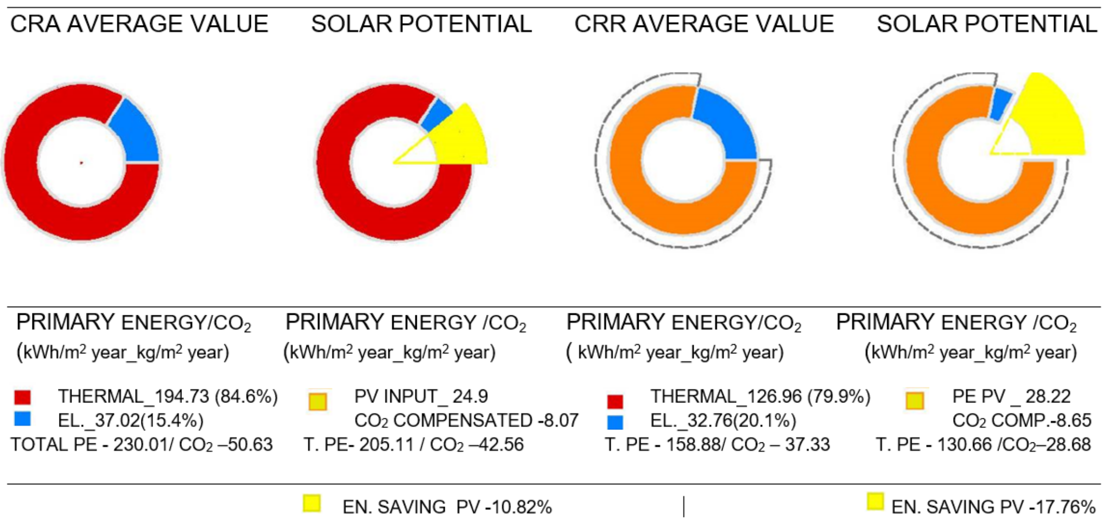

Figure 1: Share of compensated energy by equipping CRA and CRR type buildings with photovoltaic panels – the values of Primary Energy (kWh/m^2 year) and CO_2 emissions (kg/m^2 year) compensated

By correlating the proposed capture surface with the heated surfaces, resulted the capacity for reducing Primary Energy of approx. 28.08 kWh/m^2 year respectively a reduction in CO_2 emissions of approx. 8.4-6.18 kg/m^2 year.

The current energy status of the analysed buildings is characterized by much higher values of primary energy and CO_2 emissions associated with them compared to the nZEB classification thresholds. This fact requires the testing through successive energy simulations using the nZEB Energy Atlas type tool of cumulative solutions that include measures applicable at the level of buildings but also the modernization of urban thermal energy supply systems as well as the capitalization of the potential of energy production from renewable sources in order to identify packages of optimal solutions applicable to achieve the proposed objectives.

The graphic modelling on the support of cadastral maps represents a transposition of the numerical values resulting from the analysis of the proposed scenarios by assigning a zonal plan to each energy scenario or the three-dimensional energy scale modelling of the buildings.

Below is a plan extracted from the sequence of energy simulations carried out in order to classify the analysed area in the nZEB classification with reference to the time horizon 2030-2050, which highlights the cumulative effect of the solution of connecting the buildings to a modernized heating system of the cogeneration type high efficiency and equipping them with photovoltaic panels located on the terrace.

Average zonal values EP= 49.54 kWh/m^2 year-CO_2 = 10.25 kg/m^2 year / Reference - nZEB 2030-2050

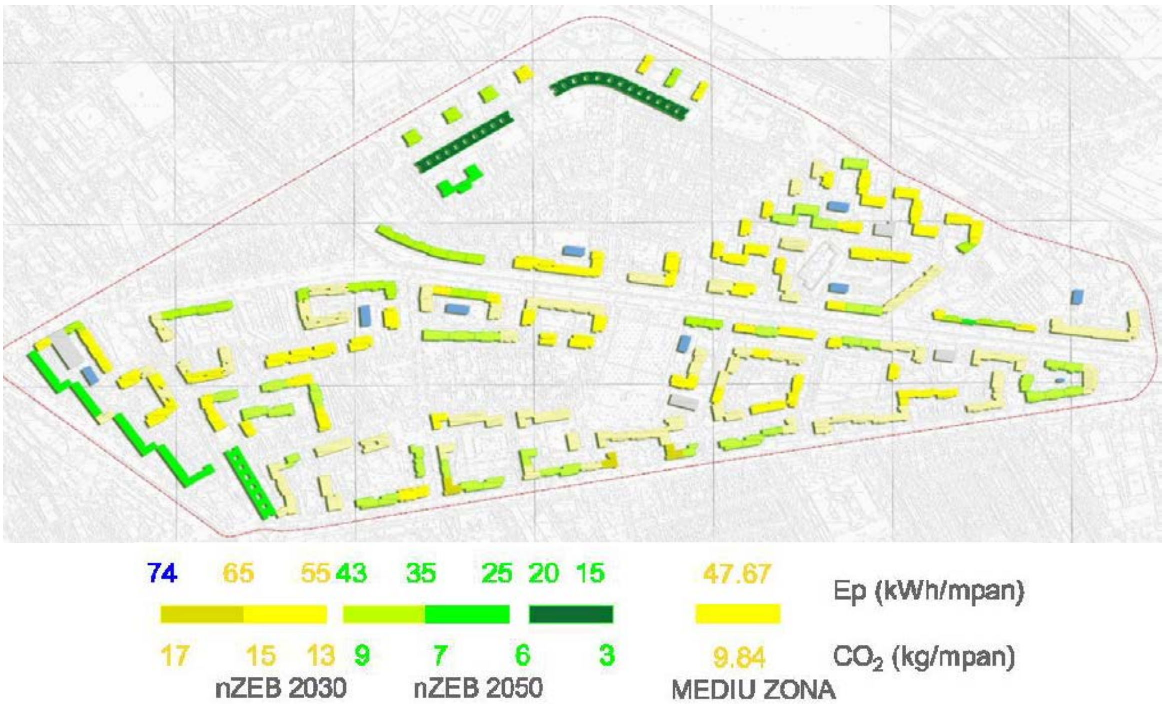

Figure 2: modernized energy source high efficiency co/tri-generation _CTIE _current buildings_CRA/CRR _ SRE impact _PV

4. Conclusions

Taking into account the increase in intensity and duration of heat waves in the context of climate change, the importance of the complementarity of energy renovation solutions with measures aimed at ensuring the conditions for resilience within major renovated housing units is noted. The conclusion of the specialized studies (Research project - ”*Reducerea Efectelor Insulei Termice Urbane pentru îmbunătățirea Confortului Urban Şi echilibrarea Consumului Energetic în București*”) - with reference to the degree of vulnerability of the residential units in the current state highlights, through the simulation of the Natural Thermal Regime, values of indoor temperatures that can endanger the health of the occupants, mainly vulnerable people, in the absence of the functioning of the technical systems due to the interruption of the electricity / thermal energy supply. From this perspective the provision of photovoltaic panels can constitute a source of electricity supply for residential units that ensures the operation of air conditioning systems in the event of interruption of the energy supply due to overloading of the network during heat waves.

A significant conclusion that emerges on the basis of the presented analysis refers to the approach of systemic solutions for the energetic re-configuration of urban areas, in which the exploitation of the zonal potential for energy production from renewable sources plays an important role in the energy balance alongside measures applicable to buildings and promoting the modernization of urban heating systems. It is also possible to study, in order to optimize the environmental performance, a set of complementary solutions based on e-mobility and integration of the natural component (green spaces, alignments of trees, wooded areas) placed inside the analysed areas or even on sites close to the city, obtaining a set of extended decisions necessary for developing sustainable urban planning.

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