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Considerations for limiting the contribution of buildings to climate change through efficient energy use

Considerații privind limitarea contribuției clădirilor la schimbările climatice prin utilizarea eficientă a energiei

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Abstract. *The incontestable evidence of climate change and extreme weather events has brought the entire world to the brink of a red code alert, which determined the need to establish targets for limiting greenhouse gas emissions and the other actions that can be taken to solve them. The paper presents aspects of limiting the contribution of buildings to climate change through energy efficiency measures with an emphasis on the importance of the nZEB concept. The need to reduce the consumption of energy from fossil sources and increase the contribution of energy renewable sources is discussed, in a realistic context.*

Key words: efficient energy, climate change, renewable sources, buildings

1. Introduction

Climate change, being one of the most alarming global problems, has determined the establishment of actions to limit global warming. As energy production and consumption are considered to be the main contributors to climate change, reducing energy demand and increasing energy efficiency are seen as key factors in solving this problem [1], [2], [3]. The worldwide concern regarding this subject has led to the appearance of various studies related to the increase in global temperature of which a study conducted in 2018 draws attention to the seriousness of the problem, a fact highlighted in Fig.1 [4], [5]

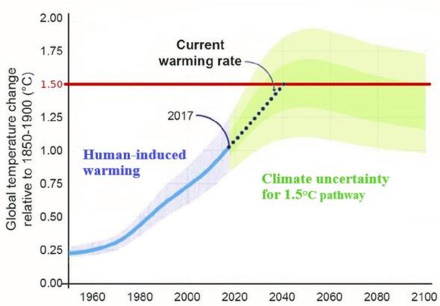

Fig. 1. Global temperature increase relative to the period 1850-1900 [5].

In Fig.1 the blue continue line corresponds to the actual observed temperature which continues dotted with black suggesting the predicted increase for the coming decades. This forecast is analysed under the impact of two trends marked by coloured bands: keeping CO_2 emissions at current levels and respectively decreasing them to the value 0. It is noted that at the current rate of global temperature increase, the alarmed value of 1.5 °C would be reached around 2040, and by stopping CO_2 emissions, a global temperature of about 1 °C could be reached by 2100 C. On the other hand, data published by Eurostat highlight the fact that in 2022 the civil residential buildings sector is the main responsible for greenhouse gas emissions - (24%), followed in relative similar percentages by the electricity and gas production and supply sector (21%) and respectively 20% - manufacturing industry [6]. What is worrying is that the residential building sector maintains a constant level of greenhouse gas emissions (about 245 million tons of CO_2-eq.) [6] compared to previous years (Fig. 2). This aspect highlights the fact that the effects of the transition to green energy are not observed in the main sector responsible for the highest percentage of greenhouse gas emissions.

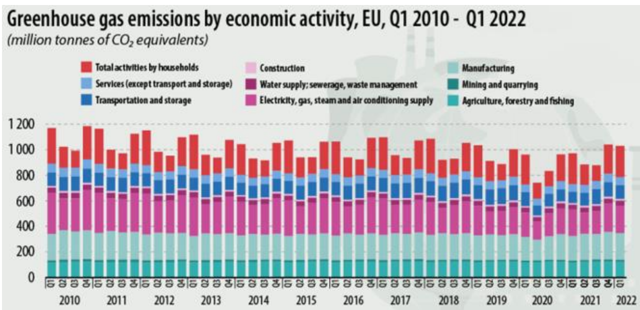

Fig. 2. Greenhouse gas emissions by economic activity in UE [6]

Therefore, immediate stopping measures are necessary, measures that involve reducing energy consumption simultaneously with the application of energy efficiency measures in the context of an energy mix with an increased weight in the direction of renewable energy sources (RES) [2], [6], [7], [8], [9], [10]

For this reason, the paper addresses aspects of limiting the contribution of buildings to climate change through the efficient use of energy, emphasizing the principles of nZEB (near zero energy building) buildings in terms of annual energy consumption (during operation). An important aspect, in this context, is the lack of a link in the design-execution-exploitation-post-use chain, namely the training of building operators. In principle, they are responsible for ensuring efficient energy consumption. No matter how efficient the design and execution phase is, the interaction between technology and users is not completed, and in this way the correct management and maintenance possibilities are not clarified [11], [12], [13]. Clearly, these aspects are much more visible in the non-residential sector, where building occupants are not directly affected by the costs of inefficient exploitation of systems that ensure environmental comfort [11], [12], [13]. If for this type of buildings there is staff dealing with building maintenance, for the residential sector, currently, there are no clear regulations [14]. Also under this aspect, the issues regarding the direction in which the construction sector is heading towards energy efficient buildings are addressed.

Even if there are regulations by which all new buildings must be built under nZEB principles, the decision makers in Romania do not make enough efforts to support their actual realization. On the other hand, the specialized literature shows that the implementation of these principles is very varied both at European level and at country levels or even in different areas within the same country [12].

2. Forecasting the evolution of RES integration to stop climate change

Reducing the consumption of energy from fossil sources is possible by integrating RES into the buildings services systems. According to the current legislation, the concept of nZEB buildings is closely related to this aspect, as it is mandatory to ensure a certain percentage of RES, from consumption. So, in the future, in order to keep the global temperature below the limit of 1.5°C, it is desired to limit and finally eliminate fossil fuel use. A forecast of the global evolution of the required energy sources is presented in Fig. 3 [15]. In order to keep the global temperature below this limit, it is observed that in the 2030s the percentage of RES energy should reach approximately 56%, 88% in 2040 and 100% by 2050 [15], [16], [17].

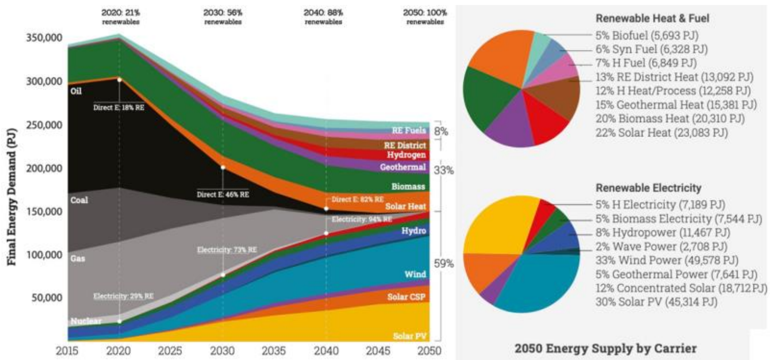

Fig. 3 Global evolution of energy sources regarding total energy demand [9]

The scientific specialized literature provides information regarding the upper limits of RES potential (solar and wind) and the maximum possible capacities to be installed (in GW) for global temperature limitation in the scenarios: 1.5°C and 2.0°C. [18]. In Europe, utility-scale solar photovoltaic sites (Fig. 4) are relatively small due to the density of buildings, and also relatively low solar radiation. As favourable areas stand out: southern Spain, southwestern Italy, the Asian part of Turkey, but also the southern part of the Alps (areas marked in red and yellow on the map in Fig. 4) [17]. However, suitable roof surface for installing solar panels is available in almost all of Europe, even in the northern parts.

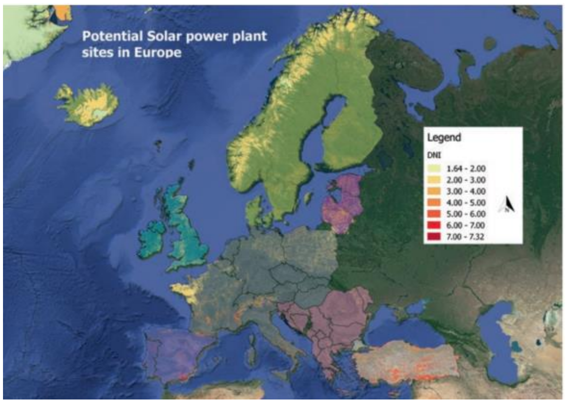

Fig. 4 Europe’s potential for utility-scale solar power plants [18]

The data available in the scientific specialized literature for the solar capacities that can be installed are established, taking into account the space requirements shown in Table 1 [18].

Table 1

Space requirements for calculating installed capacities

Type of renewable energy system	Installed capacity (MW)	The required surface (km^2)
Solar photovoltaic	1	0.04
Concentrated solar power	1	0.04
Onshore wind	1	0.2

3. Targets of increasing energy efficiency at UE level

The new EU objectives in terms of energy efficiency, proposed through the "Fit for 55" package, establish an 11.7% higher reduction for final energy consumption for 2030 compared to the targets set for 2020, increasing the minimum quota ford RES, by 2030, from 32% (Renewable Energy Directive-RED I [19]) to 40% (Renewable Energy Directive-RED II [20] and recently to 45% (REPowerEU 2022) [21]). The target of reducing greenhouse gases by at least 55% by 2030 compared to 1990 levels, set by the "Fit for 55" package, can be reached by respecting the RES share of at least 38-40% by 2030, which in the long term (at the level of 2050), will ensure climate neutrality. In this context, accelerated energy efficiency efforts by all countries are needed. Thus, updates were needed to both the minimum performance requirements for existing buildings and for new buildings in order to bring them into the near-zero energy category (nZEB). In Romania, the calculation methodology regarding the energy performance of buildings Mc 001-2022 [22] introduced flexibility and realistic targets in terms of ensuring the percentage of renewable energy in relation to nZEB standards. All these changes were necessary because, at the level of methodologies, the variety of approaches did not lead to uniform criteria regarding the implementation of nZEB buildings. So setting minimum performance requirements for existing buildings and new buildings with near-zero energy consumption (nZEB) is one of the requirements covered by the new regulation Mc 001-2022 [22].

Currently, for Romania, the Mc 001-2022 methodology [22] defines the nZEB building as the building whose consumption is covered by RES in a proportion of at least 30%, which is not consistent with the "Fit for 55" package of measures regarding compliance with the RES share of at least 38-40%. On the other hand, a study carried out in 2012 proposes for the year 2020, as a share of RES, a percentage higher than 40% for individual, collective and office buildings, and for public administration buildings a percentage higher than 50 is proposed % yet from the level of 2019 [23] .

4. Challenges of designing nZEB buildings in Romania

Even though the European Union has set targets for the new build sector to be carbon neutral by 2030, economic challenges and other equally important factors prevent the renovation of the existing residential building stock and the addition of high-performance buildings for newly built ones. From 2021, all new buildings in the EU should have been built as near-zero energy buildings (nZEBs), but many countries in Europe are still struggling to implement this concept. [24].

Practically, the nZEB building is characterized by low consumption of energy from fossil sources and using RES, in proportions established by minimum thermal and energy performance requirements, adopted for each country. For Romania, the Mc001/2022 methodology established these criteria for the categories of residential and non-residential buildings: new nZEB and existing renovated ones [22].

Although the "Fit for 55" package specifies that in order to limit climate change, a RES share of at least 38-40% is necessary until 2030, Mc001/2022 sets a realistic target of at least 30% for Romania, with the remark that after 2031 is necessary update the minimum proportion of energy from RES.

Depending on the climate zone, the maximum allowed values of total primary energy consumption (renewable and non-renewable) are established for nZEB buildings, which vary for collective residential buildings from 99.1 kWh/m^{2}y to 113.1 kWh/m^{2}y and respectively from 120.1 kWh/m^{2}y to 147.9 kWh/m^{2}y for buildings [22]. Thus, in order to obtain a high level of energy performance that to place the building within the nZEB consumption limits, must be met, in terms of design and execution the requirements regarding: compact geometry (ratio between surface and volume as small as possible), advantageous orientation of the building both on the site and in relation to the cardinal points, lighting strategies to ensure an adequate level of the proportion of natural light, strategies for adequate and efficient natural ventilation of the space, efficient constructive solutions for the building envelope (optimal level of thermal insulation) with the approach of minimizing the effects of thermal bridges, external windows with high thermal performance, properly adapted heating/cooling systems, energy storage systems for energy produced from RES (thermal/electrical), ecological materials conformable with to the principles of the circular economy or materials with phase change.

At the design stage, special attention must be paid to the optimal combination of different energy saving measures. Cost-optimal integration, control, and scheduling strategies of hybrid energy systems are crucial for improving the overall performance of nZEBs. The nZEB buildings subsequently connected to smart networks will play an important role in future smart cities.

Energy demand in buildings varies greatly depending on countries and climate zones, variation influenced by factors whose future evolution is uncertain (climate, income, user behaviour) [25] and therefore, practically, the great challenge of designing nZEB buildings requires a bold approach and clear actions. A series of studies they analysed x the evolution of energy demand in buildings in developing countries showed that in the long term an increase in consumption is expected despite the application of energy efficiency measures [25], [26], [27], [28], [29], [30]. However, these studies have not assessed the global implication of socio-economic uncertainty in a coherent framework.

As the construction sector in Romania still has a considerable percentage of buildings with high energy consumption, more attention should be paid to these categories of buildings through energy efficiency actions. Therefore, information that can be collected through continuous monitoring is needed in order to fully understand the key factors that influence the energy use of buildings.

Through the regulations and methodologies adopted at the level of each country, it is proven that the decision-makers are aware of the fact that one of the main ways to reduce energy consumption and CO_2 emissions is the increase in energy efficiency in the construction sector, which implies the acceleration of the implementation of the nZEB concept both for newly built and existing buildings, despite economic, social and political barriers [31].

5. Conclusions

Awareness of climate change and the evolution of greenhouse gas quantities has focused attention on energy efficiency in buildings in all sectors of activity. The medium and long-term objectives, but also the immediate priorities, will have to reflect actions on how energy is produced and the profiles of final consumers, with an emphasis on those actions that have the greatest impact at the level of each country.

On the other hand, in order to limit and finally eliminate carbon emissions, the transition to renewable sources in terms of energy production will not be sufficient, but measures and solutions aimed at reducing energy consumption will have to be adopted, which can achieve through energy efficiency, especially in the field of construction. And, on the other hand, even if energy efficiency can bring the construction sector very close to achieving sustainable development goals, it will not be able to solve some of the challenges of climate change without the transition to renewable sources and changing final consumers’ lifestyle behaviour.

At the same time, financing schemes to support the buildings construction of nZEB standards should be more accessible.

References

[1] P. Bertoldi, „The Paris Agreement 1.5°C goal: what it does mean for energy efficiency?”, in ACEEE Summer Study on Energy Efficiency in Buildings, 2018.

[2] M. Economidou, V. Todeschi, P. Bertoldi, D. D'Agostino, P. Zangheri, L. Castellazzi, „Review of 50 years of EU energy efficiency policies for buildings”, in Energy and Buildings, vol. 225, ID Article 110322, 2020.

[3] Curtea de Conturi Europeană, „Analiză panoramică. Acțiunile UE în domeniul energiei și al schimbărilor climatice”, in Curia Rationium, ISBN 978-92-872-7571-4, pp. 7-20, 2017.

[4] M.R. Allen, , O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, K. Zickfeld, „Global Warming of 1.5°C-Chapter 1: Framing and Context, IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty”, Cambridge University Press, pp. 49-92, 2018.

[5] F. Collart, „Predicting the dynamics of range shifts under climate change: assumptions and applications to the European bryophyte flora”, Thesis for: PhD, Advisor: Alain Vanderpoorten; Antoine Guisan, 2021.

[6] A. Loy, „Eurostat: Gazele cu efect de seră generate de activitățile economice din UE sunt încă sub nivelurile pre-pandemie”, August 16, https://www.caleaeuropeana.ro/, 2022.

[7] N. Bauer, K. Calvin, J. Emmerling, O. Fricko, S. Fujimori, J. Hilairea, J. Eom, V. Krey, E. Kriegler, I. Mouratiadou , H. Sytze de Boer, M. van den Berg, S. Carrara, V. Daioglou, L. Drouet, J.E. Edmonds, D. Gernaat , P. Havlik, N. Johnson, D.Klein, P. Kyle, G. Marangoni, T. Masui, R. C. Pietzcker, „Manfred Strubegger, Marshall Wise, Keywan Riahi, Detlef P. van Vuureni, Shared Socio-Economic Pathways of the Energy Sector – Quantifying the Narratives”, in Global Environmental Change, vol. 42, pp. 316–330, 2017.

[8] B. Hare, „No time to lose: the 1.5°C limit in the Paris Agreement”, in Climate Analytics, August 2016.

[9] K. Burkart, „$1.5T for 1.5°C: a ‘back of envelope’ budget to save the planet”, in One Earth, November 10, 2021.

[10] A. Revi, H. Coninck, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, J.-C. Hourcade, D. Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, T. Sugiyama, „Chapter 4-Strengthening and Implementing the Global Response”, in: Global Warming of 1.5°C.”, Publisher: Intergovernmental Panel on Climate Change, Cambridge University Press, pp. 313-444, 2018.

[11] M. Aune, T. Berker, R. Bye, „The missing link which was already there. Building operators and energy management in non-residential buildings”, in Facilities, vol. 27 No. 1/2, pp. 44-55, 2009.

[12] J. Niskanen, H. Rohracher, „Passive houses as affiliative objects: Investment calculations, energy modelling, and collaboration strategies of Swedish housing companies”, in Energy Research & Social Science, vol. 70, Article ID:101643, 2020.

[13] I. N. Pettersen, E. Verhulst, R. V. Kinloch, A. Junghans, T. Berker, „Ambitions at work: Professional practices and the energy performance of non-residential buildings in Norway”, in Energy Research & Social Science, vol. 32, pp. 112–120, 2017.

[14] J. Palm, K. Reindl, „Understanding energy efficiency in Swedish residential building renovation: A practice theory approach”, in Energy Research & Social Science, vol. 11, pp. 247–255, 2016.

[15] S. Scott, „Scientists chart a new course to reach ‘net zero’ emissions for all sectors of the global economy by 2050”, One Earth, https://www.oneearth.org/, 2023.

[16] V. A. Golubev, V.A. Verbnikova, I. A. Lopyrev, D. D. Voznesenskaya, R.N. Alimov, O. V. Novikova, E. A. Konnikov, „Energy Evolution: Forecasting the Development of Non-Conventional Renewable Energy Sources and Their Impact on the Conventional Electricity System", in Sustainability, vol. 13 (22), Article Number: 12919, 2021.

[17] S.B. Tsai, Y. Xue, J. Zhang, Q. Chen, Y. Liu, J. Zhou, W. Dong, „Models for forecasting growth trends in renewable energy", in Renewable and Sustainable Energy Reviews, vol. 77, pp. 1169–1178, 2017.

[18] S, Teske, K. Nagrath, T. Morris, K. Dooley, „Chapter 7 -Renewable Energy Resource" Assessment in book Achieving the Paris Climate Agreement Goals, pp. 161-173, 2019.

[19] EU, „Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC", in Official Journal of the European Union, 23 April 2009.

[20] EU, „Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)", in Official Journal of the European Union, 11 December 2018.

[21] A. Wilson, „European Parliament - Revision of the Renewable Energy Directive: Fit for 55 package-Briefing, PE 698.781", September 2022.

[22] MDLPA, „Methodology for calculating the energy performance of buildings, indicative Mc 001-2022", in Monitorul Oficial al României, Partea I, Nr.46bis/17.I.2023, 2023.

[23] A. Bogdan, „Implementation of buildings with almost zero energy consumption (NZEB) in Romania", in Buildings Performance Institute Europe (BPIE), August 2012.

[24] S. Attia, J. Kurnitski, P. Kosinski, A. Borodinecs, Z. Deme Belafi, K. István, H. Krstic, M. Moldovan, I. Visa, N. Mihailov, B. Evstatiev, K. Banionis, M. Cekon, S. Vilceková, K. Struhala, R. Brzon, O. Laurent, „Overview and future challenges of nearly zero-energy building (nZEB) design in Eastern Europe", in Energy & Buildings, Vol. 267, ID Article 11216, 2022.

[25] A. Levesque, R. C. Pietzcker, L. Baumstark, S. De Stercke, A. Grübler, G. Luderer, „How much energy will buildings consume in 2100? A global perspective within a scenario framework", in Energy, vol. 148, pp. 514-527, 2018.

[26] V. Daioglou, B.J. van Ruijven, D.P. van Vuuren, „Model projections for household energy use in developing countries", in Energy, Vol. 37, pp. 601-615, 2012.

[27] M. Isaac, D.P. van Vuuren, „Modeling global residential sector energy demand for heating and air conditioning in the context of climate change", in Energy Policy, vol. 37 (2), pp. 507-521, 2009.

[28] D. Urge-Vorsatz, K. Petrichenko, M. Staniec, J. Eom, „Energy use in buildings in a long-term perspective", in Current Opinion in Environmental Sustainability, vol. 5 (2), pp.141-151, 2013.

[29] S. Guo, D. Yan, S. Hu, J. An, „Global comparison of building energy use data within the context of climate change", in Energy and Buildings, vol. 226, Article ID: 110362, 2020.

[30] A. Allouhi, Y. El Fouih, T. Kousksou, A. Jamil, Y. Zeraouli, Y. Mourad, „Energy consumption and efficiency in buildings current status and future trend", in Journal of Cleaner Production, vol. 109, pp. 118-130, 2015.

[31] X. Cao, X. Dai, J. Liu, Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade, Energy and Buildings, vol. 128, pp. 198-213, 2016.