THEORETICAL SUBSTANTIATION OF THE STRATEGY OF MAJOR RENOVATION OF COLLECTIVE HOUSING BUILDINGS IN THE URBAN AREA

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***Abstract**: The new social phenomenon of associations of people converted into prosumers (on grid) is analyzed in terms of energy efficiency. The consequences of promoting the quality of prosumers for CRB (current representative building) (especially in urban areas) and for RRB (renovated representative buildings) (which have benefited from thermal renovation) are analyzed. The real purpose of the associations is to reduce the costs of energy utilities (and not only) and to benefit to a small extent from the electricity consumed in the building. It is demonstrated, on the basis of dynamic simulation of the energy response of buildings to climate and anthropogenic requirements, that converting CRB buildings exclusively into prosumers with no other purpose than minimizing utility costs keeps the energy and environmental performance of buildings away from the quality of nZEB buildings. On the other hand, the transformation of renovated RRB into nZEB buildings is ensured by equipping them with photovoltaic solar panels and thus acquiring the quality of prosumer.*

***Keywords:** prosumer; energy performance; medium performance; dynamic simulation*

1. Introduction

The aim of paper is an analysis of the impact of existing buildings equipped with photovoltaic (on-grid) solar panels on the energy and environmental performance of urban areas (Bucharest area). The geometric support of the energy analysis of buildings of the block of flats type is proper to the Representative Building (R.B.) and the climatic support, referring to the Municipality of Bucharest, is the type climatic year. Energy performance is defined by the specific value of primary energy associated with building utilities, called the Energy Performance of the Building [kWh/m^{2}year] (EPB) and the Environmental Performance of the Building (Env.PB) associated with the EPB is defined by the specific value of CO_2 emissions [kg/m^{2}year]. The reporting element is the useful area of the occupied spaces of the building. EPB and Env.PB values are determined based on the energy balance of the building (occupied spaces and secondary spaces used). It is basically determined by dynamic simulation with hourly step according to the mathematical model of the energy balance of the building during the climate year type. The energetic and environmental dimensioning of a building results in the identification of the package of technical solutions that lead to the energy performance of the building and the environmental performance of the building. With reference to the City of Bucharest (Climate Zone II), the accepted energy characteristics (optimal cost, nZEB) and associated environmental characteristics (nZEB) are presented in Tables 1 and 2.

Table 1

Optimal Global cost range – specific primary energy [kWh/m²year] [1] , [2]

Climate Zone / Build.Type	Zone I	**Zone II**	Zone III	Zone IV	Zone V
Offices	50 - 90	62 - 100	75 - 112	88 - 125	102 - 139
Collective house	48 - 102	56 - **112**	70 - 124	83 - 137	97 - 152
Individual house	142 - 214	155 - 230	178 - 247	198 - 262	229 - 288

Table 2

nZEB – specific primary energy [kWh/m²year] [1], [2]

Climate Zone	Time horizon	Collective house	Collective house
		Primary Energey [kWh/m²y]	CO_2 emissions [kg/m²y]
II	2030	74	19
	2050	43	9

The buildings that have photovoltaic solar panels connected to the Urban electricity network acquire the quality of *prosumer* if the excess electricity produced by the photovoltaic panels is injected into the Urban electricity network. Currently, technical solutions of the type prosumer are encouraged, regardless of the category of energy performance of buildings. The following is the energy response of the Representative Buildings of type Current RB (CRB) and Renovated RB (RRB) that meet the prosumer condition. The mentioned types of buildings are landmarks of the typology of buildings in urban areas. Most buildings in urban settlements (including Bucharest Municipality) are part of the CRB class. CRB buildings are characterized by low energy and environmental performance. At the opposite pole, the buildings of type nZEB [3] are included in the class with maximum energy and environmental performance. These buildings are currently exceptions in the national urban area. The analysis that led to the energy classes of buildings presented in Table 2 is the result of the application of the methodology for determining the building energy response to the dynamic climatic solicitation. The calculation method includes mathematical modeling of the processes of transfer of ownership at the level of the envelope and of the technical systems in the endowment of buildings and solving the system of algebraic and differential equations by dynamic simulation with hourly time step.[4], [5] This specification is necessary in order to ensure the criterion of energy comparison of any type of buildings. The technical systems are presented in Table 3. The presence of photovoltaic solar panels is imposed exclusively by the criterion of *climatic resilience* (summer season associated with heat waves) [6]. The buildings that hold the status of prosumer (on-grid) have photovoltaic solar panels whose surface *is not conditioned by energy performance*.

2. CRB building type prosumer

2.1 Energy performance of the prosumer type CRB

The energy diagrams (heating and cooling living spaces) related to CRB are shown in Fig.1 (required hourly values of heat and sensitive cold) and Fig.2 (required monthly heat and sensitive cold values).

The PV surface of the building involves two different functions as follows:

- The power minimization function provided by the Urban network (*energy-only function*) in order to provide the utilities necessary for the operation of the CRB;
- The function of injecting electricity into the Urban network (on grid) (*financial profit function*)

The graph in Fig.3 shows the variation of Primary Energy characteristic CRB located in Bucharest, depending on the surface of the solar photovoltaic panels available.

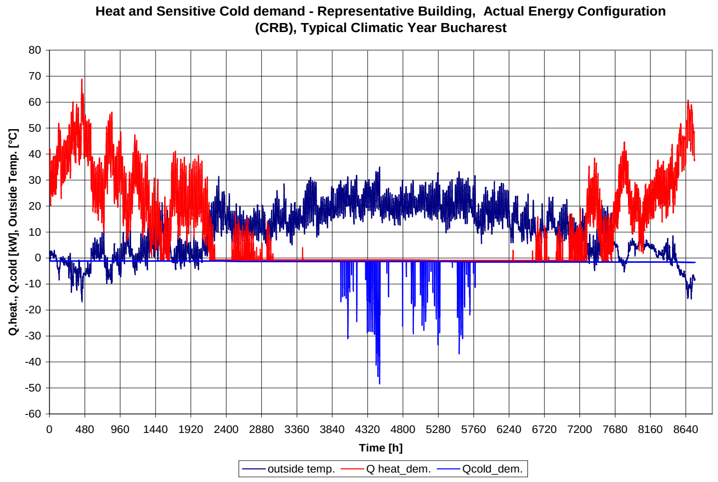

Fig. 1 The heat demand for heating and the sensitive cold demand – Current RB. Dynamic simulation with time step (INVAR – SID)

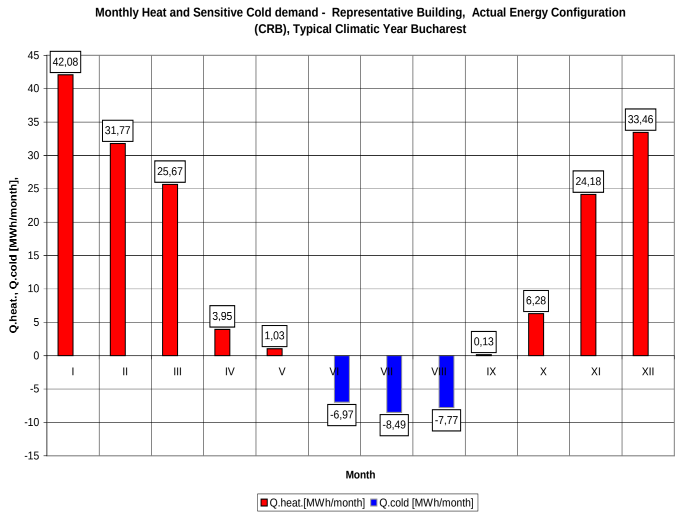

Fig.2. The value of the monthly heat and cold needs – Current RB

The common denominator of all the systems presented is the endowment of the representative building with photovoltaic (monocrystalline) solar panels with the maximum allowed area of 300 m^2 (geometrical limitation of the Representative Building). From the graph (representation of the thermal and energy balance of the building, including technical systems), it follows that no matter how generous the building is equipped with photovoltaic solar panels, the energy performance of the building is far from both the optimal cost domain and (implicitly) the nZEB domain (Fig.3). The expansion of the PV > PV_M (PV_M - surface the energy dimensioning area proper to the electricity demand in case of heat wave type climatic demand in the summer season – a condition imposed by the climatic resilience of the building) is useful to the tenants strictly from an economic point of view. The electricity (surplus) produced by the PV – PV_M surface is injected into the public electricity network, for a fee, by virtue of the prosumer quality of the Owners Association. Consequently, the (theoretically) infinite expansion of the PV – PV_M surface has no favorable energy impact on the energy quality of the CRB building, but “produces” significant amounts that decrease or even cancel the costs of the energy utilities (and not only) of the housing units. Basically by equipping CRB buildings with PV, depending on the *technical systems* available, maximum limited and fixed reductions of primary energy compared to the current state (PV = 0), regardless of the surface of PV, PV_M, as follows:

- Urban heating (Cogeneration): 17.53% (from 207.49 kWh/m^{2}year to 171.11 kWh/m^{2}year equipped with 126 m^2 PV_M area. Any increase in the PV surface has no impact on the energy quality of the CRB)
- Air – water heat pumps: 26.92% (from 186.40 kWh/m^{2}year to 136.21 kWh/m^{2}year equipped with 172 m^2 PV_M area. Any increase in the PV surface has no impact on the energy quality of the CRB)
- Air – water heat pumps and Cogeneration: 26.17% (from 193.69 kWh/m^{2}year to 143.00 kWh/m^{2}year equipped with 174 m^2 PV_M area. Any increase in the PV surface has no impact on the energy quality of the CRB)

Consequently, CRB buildings with the quality of prosumer *are not acceptable solutions like EPB*, with reference to the classes of buildings recommended in the European Directives, even if it benefits from considerable PV surfaces mounted on the roof or on the ground in the area that belongs to the building. The *energy-only function* is performed by photovoltaic solar panels which, within the CRB, climatic Zone II, have different maximum areas depending on the technical system provided by the CRB (Table 3). The minimum values of the EPB indicator in Table 3 correspond to the maximum areas of PV_M to be taken in the calculation of EPB and implicitly of EnvPB. The calculation model also involves determining the monthly amounts of electricity produced by $PV_{INJ} > PV_M$, which are exclusively injected into the public electricity grid. This function is materialized by collecting the equivalent of the electricity, additionally produced by the photovoltaic panels mounted inside the property perimeter of the owners’ association and injected into the public electricity network.

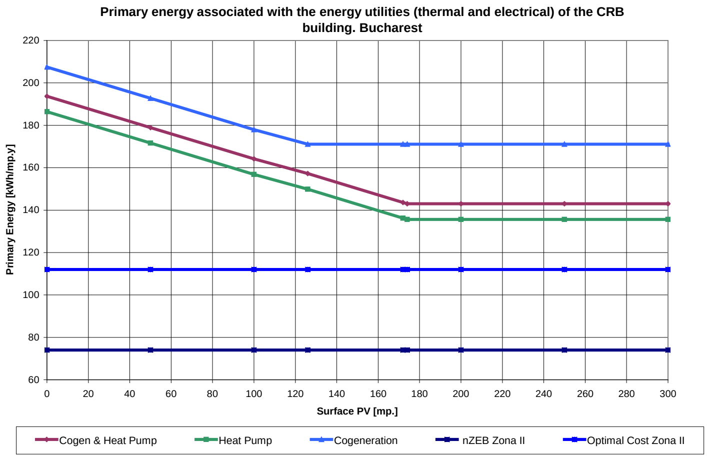

Fig.3 Primary Energy variation by PV surface – performance benchmarks:
The optimal cost range (max. 112 kWh/m2year), n ZEB (max. 74 kWh/m2yr)

Therefore, the real energy characteristic EPB and implicitly EnvPB of the building equipped with any of the three representative technical systems and photovoltaic panels is determined strictly according to the PV surfaces that participate in the energy balance of CRB (and any building that benefits from PV). The mathematical model is unitary both for the determination of EPB and EnvPB and for the determination of the economic characteristic of the endowment of a building with the surface $PV \geq PV_M$ (*energetic sizing area*). According to Table 3, the energy dimensioning of the CRB building, with regard to the technical systems and the surface of photovoltaic panels (PV), leads to distinct maximum values of PV surfaces > 0 corresponding to the minimum values of the energy and environmental indicators EPB and EnvPB

Tabel nr.3

Primary energy of CRB equipped with different technical systems and PV [kWh/m²year]

A.PV [m²] / System	0	126	172	174
Cogeneration (actualy)	207,49	171,11		
Air water heat pump	186,40	149,85	136,21	
Cogeneration & heat pump	93,69	157,23	143,59	143,00

The coefficient of conversion of heat produced into primary energy, c_T results from the relationship:

$$c_T = \eta_{CET}^{-1} + y \cdot (\eta_{CET}^{-1} - \eta_{El}^{-1}) \quad (1)$$

The cogeneration index is determined as the ratio between the electricity supplied by the Central of Cogeneration and the heat supplied:

$$y = \frac{En.el}{Q} \quad (2)$$

in which:
Q – heat produced by Cogeneration system and supplied to buildings [kWh/year]
En.el. – electricity produced by Cogeneration system and supplied to buildings [kWh/year]
η_{CET} - the efficiency of the Cogeneration system [-]
η_{El} - electricity production efficiency [-]

The denominator value of the fraction (2) represents, at the urban area level, the heat consumption of buildings, including the yields of distribution and transport networks. In the case of the existence of CRB buildings only, the denominator value is high, which leads to a low value of the cogeneration index. Currently, the value of $y_{CRB} \approx 0.1764$ (in case of nZEB should be $y_{nZEB} \approx 0.50$) For the current values $\eta_{CET} = 0.74$ and $\eta_{El} = 0.38$ results the value $c_{T.CRB} = 1.125$. Therefore, the current Cogeneration heating system (strictly referring to the beneficial residential buildings CRB) leads to primary energy (thermal vector) with the value of $1.125 \cdot Q_{CRB}$. The values of Q_{HEAT} (based on Fig.2) = 96.88 kWh/m²year, $Q_{WARM\ WATER}$= 28.00 kWh/m²year generate value of primary energy (*heat vector*), Q_{CRB} = 140.56 kWh/m²year. The value of primary energy En.el. (*electric vector*) is 66,93 kWh/m²year. Primary Energy value (PV=0) is 207,49 kWh/m²year. Based on elementary (*wrong*) *energy balance*, the final primary energy of CRB Building is 125,62 kWh/m²an (Fig.3, PV = 300 m² and cogeneration system). In reality, based on the real *energy balance* of the CRB, results the value of 171.11 kWh/m²year (PV_M=126 m², Table 3), value by 36.2% higher than that associated with the surface of 300 m² solar panels (Fig.3). The error comes from the fact that it correlates PEB with the energy produced by the total surface of PV (300 m²) and not of the usable PV_M surface resulting from the energy balance of the building (PV_M =126 m2) (Fig.3). This correlation also includes the PV surface that strictly fulfills the function of injecting electricity into the public network, *without any energy benefit for the support building*. The risk of developing the prosumer system is that of *neglecting the real energy renovation of buildings in favor of reducing the costs of the buildings utilities* (Chap.2.2)

2.2 The costs of CRB’s own energy (prosumer) utilities.

The cost of building utilities results from the metering of the electricity supplied to the public network by the CRB building. This value reduces the costs incurred by the association in the absence of PV and the on-grid system. Therefore, the advantage of the prosumatory system is of a financial nature, but the energy characteristic of buildings is overvalued (see the final of Chap. 2.1).The graph in Fig.4 shows the average monthly energy cost of energy utilities per apartment depending on the PV surface that the CRB building is equipped with, and the type of technical systems that are equipped.

- With air - water heat pump equipped but without PV, the utility cost indicator is 518 lei/ap.month. The inclusion of photovoltaic panels with a surface of 300 m^2 leads to the reduced cost of 280 lei/ap.month,
- The connection of CRB to the urban district heating system leads, in the absence of photovoltaic panels, to the cost indicator of 340 lei/ap. month. The endowment with PV with a surface of 300 m^2 leads to the cost of 117 lei/ap.month.
- The urban heating system and the air-water heat pump lead to the pair of energy cost values of 342 lei/ap.month (PV = 0 m^2) and 117 lei/ap.month (PV = 300 m^2).

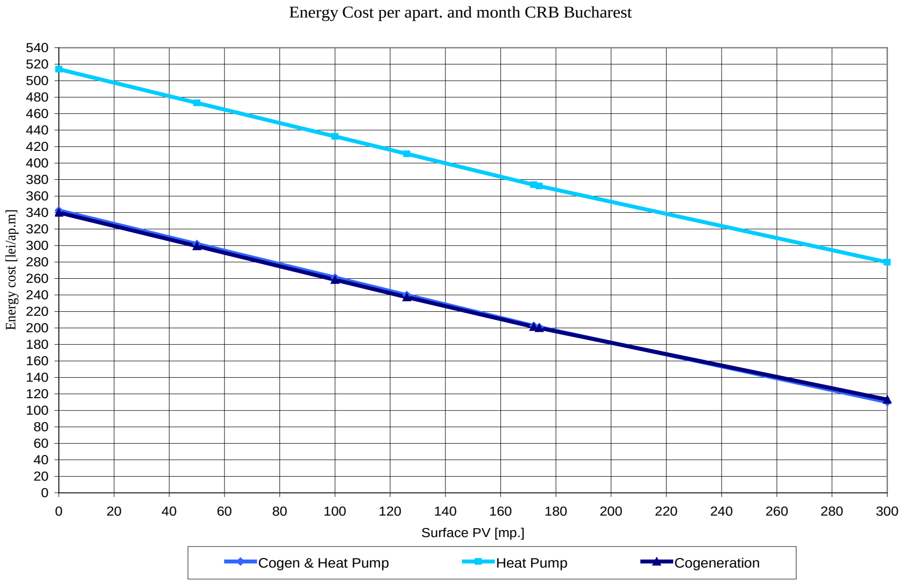

Fig. 4 The variation in the cost of energy according to the PV surface

3. RRB - HR building type prosumer

RRB – HR is a Renovated Representative Building (which benefited from thermal renovation), represents the second significant category as a presence in the urban landscape of Bucharest. The additional renovation required by the nZEB building requirement consists in the endowment with Heat Recoveries for use in the cold season and in the transition seasons.

The energy diagrams (heating and cooling living spaces) related to the RRB - HR are presented in Fig.5 (hourly values of heat and sensitive cold) and in Fig.6 (monthly values of heat and sensitive cold). The graph in Fig.7 shows that equipping RRB – HR buildings with photovoltaic solar panels leads to a significant reduction in the cost of utilities. The costs of RRB’s own energy (prosumer) utilities (*financial profit function*) is presented in Fig.8.

4. Conclusions

Turning CRB buildings into prosumatory buildings is a strategy that hinges on the natural expansion of the rational type of nZEB building.

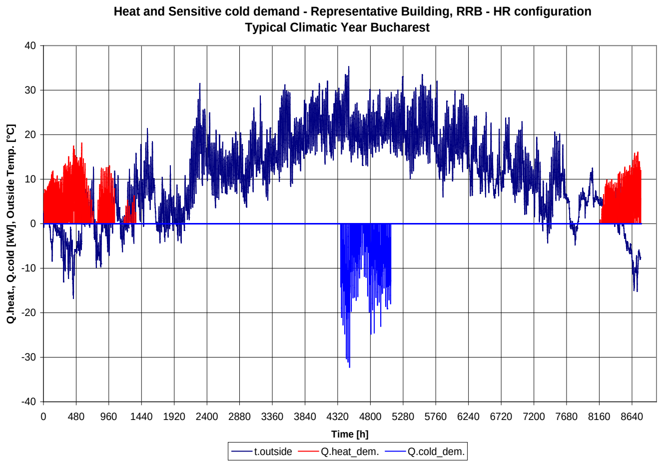

Fig.5 The heat demand for heating and the sensitive cold demand – RRB – HR. Dynamic simulation with time step (INVAR – SID)

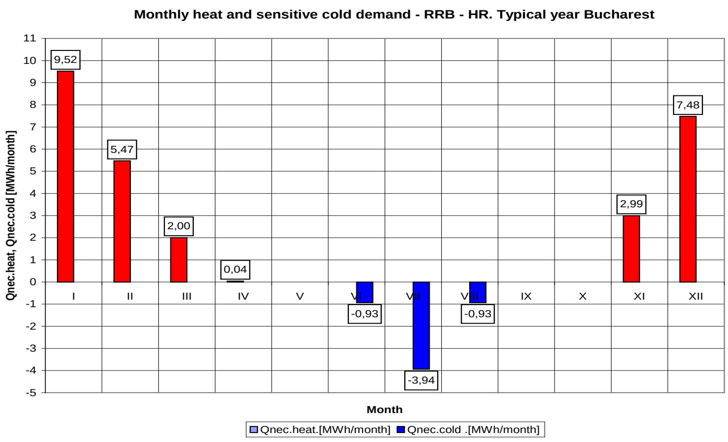

Fig.6 The value of the monthly heat and cold needs – RRB – HR

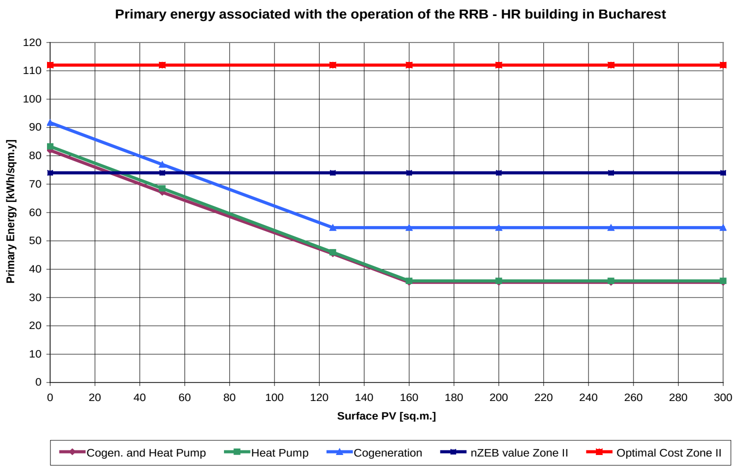

Fig.7 Primary Energy variation by PV surface – performance benchmarks: The optimal cost range (max. 112 kWh/m^{2}year), n ZEB (max. 74 kWh/m^{2}year)

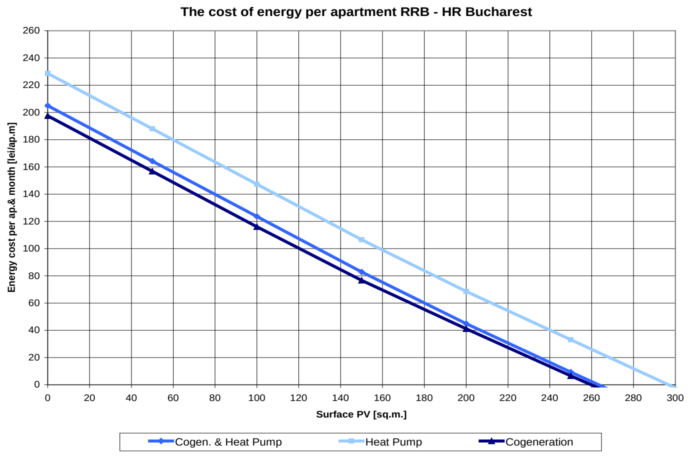

Fig.8 The variation in the cost of energy according to the PV surface

The conversion of CRR buildings into nZEB buildings is possible by equipping them with heat recoveries and photovoltaic solar panels that give them the quality of prosumers (Fig.7).

A consequence of the impact of the surface of the photovoltaic panels on the climate of the urban settlement is represented by the surface temperature of the photovoltaic panels, significantly higher than the temperature of the outside air. This increase leads to a significant intensity of the urban heat island associated with the summer season [7]. This involves a rational approach in the sizing of solar photovoltaic surfaces and weather alert measures in situations of major climate risk. [4]

5. Acknowledgement

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