Nearly zero-energy buildings in Central and Eastern EU: Possible definitions and implementation roadmaps for Poland, Romania and Bulgaria

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Abstract
The recast Energy Performance of Buildings Directive (EPBD) requires EU Member States (MSs) to construct only nearly Zero-Energy Buildings (nZEB) from 2019 for public buildings and from 2021 for all new buildings. Acknowledging Europe's diversity and adding flexibility, EPBD requires MSs to draw up specifically national nZEB definitions and national plans reflecting national, regional or local conditions. These plans must translate the nZEB requirement into practical and applicable measures and definitions to steadily increase the number of nZEB. Several EU MSs have already started to do so, others not. The current economic crisis and related budgetary constriction have resulted in the nZEB requirement no longer being a political priority for many of these latter countries.

This paper shows the main findings of three country studies released in autumn 2012 and aims to support the national efforts to draw up affordable yet ambitious nZEB definitions and implementation roadmaps for Poland, Romania and Bulgaria, see BPIE(2012)-1, BPIE(2012)-2, BPIE(2012)-3.

Starting from the analysis of current construction rates and standards, economic conditions and existing policies, relevant reference buildings are defined for the actual practices in construction of offices, single- and multi-family buildings. Therefore, different improved thermal insulation variants and heating options are simulated in order to determine the impact of these improved nZEB solutions in terms of energy performance, CO_2 emissions, renewable energy share and additional annualised costs. To improve the CO_2 balance and the renewable energy share of the building, the simulation was also performed on improved basic nZEB solutions by using additional photovoltaic rooftop systems. The macro-economic implications of the nZEB solutions are also evaluated.

Based on the simulation of the selected nZEB solutions, nZEB definitions, policy recommendations and implementation roadmaps are proposed for each of these three countries.

Introduction
The recast Directive on the energy performance of buildings (EPBD) stipulates that by 2020 all new buildings constructed within the European Union after 2020 should reach nearly zero energy levels. This means that in less than one decade, all new buildings will demonstrate very high energy performance and their reduced or very low energy needs will be significantly covered by renewable energy sources. The Energy Performance of Buildings Directive requires EU Member States to elaborate national definitions and to draw up national plans for nearly Zero-Energy Buildings, reflecting specific national and regional conditions. Therefore, it is critical to have sustainable, robust and feasible country definitions and EU standards to support the successful implementation of the Directive, for achieving the savings potential and for maximizing the socio-economic benefits.

In 2011, BPIE released a study proposing general principles to be followed when implementing nZEB in the EU Member States [1]. Following-up this study, BPIE launched three studies for Poland, Romania and Bulgaria in November 2012, which evaluate through indicative simulations whether these principles hold true for the actual status-quo in these countries. The objective was to offer an independent and research-based opinion proactively supporting national efforts to draw up affordable yet ambitious definitions and implementation roadmaps for nearly Zero-Energy Buildings (nZEBs).

Based on an extensive survey of the building stock, construction practices, market prices for materials and equipment, existing legislation and support measures in countries under analysis, reference new buildings were defined (actual practice) for each of the following building types:

- Detached single family house (SFH).
- Multi-family house (MFH).
- Office buildings (OFFICE).

For each country under analysis, several simulations on the identified reference buildings were performed, using variants of improved thermal insulation and equipment for heating, cooling, ventilation and hot water. Roof-top photovoltaic systems were also considered as a compensation for improving the CO_2 balance and the renewable energy share of the reference buildings.

The aim of the simulation was to analyse the technical and economic impact of moving towards nZEB starting from the current situation in an effective and realistic manner and by minimising transition costs.

The results of simulations were evaluated for compliance with the nZEB principles as proposed in the 2011 BPIE study. In addition, the economic and financial implications of each nZEB variant were analysed in order to determine the most suitable and affordable solutions under the country's specific circumstances. Finally, the selected optimal solutions were extrapolated at national level to determine the direct and indirect benefits and impacts. Besides the CO_2 and energy saving potential, impacts on job creation and the industry/ technology development were also considered. Based on the simulation of the selected nZEB solutions, for each of these three countries are proposed nZEB definitions, policy recommendations and implementation roadmaps. The building simulations were undertaken with the TRNSYS software tool[1]. The economic analysis was performed by using the Ecofys analytical tool Built Environment Analysis Model (BEAM2) [2].

These studies were conceptualized, coordinated and finalised by BPIE. The overall data aggregation and selection, simulations and analysis were executed by Ecofys Germany as a lead consultant. The provision of data concerning national building stock, policies, market prices, as well as the definition and selection of reference buildings were made by the national consultants from BuildDesk-Poland, URBAN-INCERC-Romania and EnEffect-Bulgaria.

This paper is based on the above studies, but due to space constrains presents only the results of simulations for single-family homes and presents the main findings and recommendations for implementing nearly zero-energy buildings in Poland, Romania and Bulgaria.

1. TRNSYS is a transient systems simulation program, commercially available since 1975, which has been used extensively to simulate solar energy applications, conventional buildings, and even biological processes.

Overview of the existing building stock and construction rates

POLAND

The housing stock in Poland consists of approximately 13.7 million dwellings [2] in around 6 million buildings [5]. In urban areas, the majority of dwellings (76 %) are located in blocks of flats, in contrast to rural areas where the majority (90 %) are in single family homes. Individual single family buildings represent around 92 % of the Polish residential building stock. The blocks of flats, mainly concentrated in urban areas, represent around 8 % of the building stock but account for around 56 % of Polish dwellings. Some 75 % of the residential dwellings are owner-occupied. Most of the Polish single family houses are heated by gas or coal.

Multifamily houses and non-residential buildings are commonly heated with gas while in urban areas a significant share of buildings is also connected to a district heating network.

At the end of 2011, the total floor area of the Polish building stock was about 1,292 million m², whereas the residential floor area was about 980 million m² and non-residential floor area about 312 million m². Approx. 50 % of residential buildings are built before 1970 and around 87 % before 1989 [6]. The buildings built before 1990 have poor energy performance at around 250 kWh/m²/yr or above.

The most prevalent building type in the residential sector is the urban multi-family house (37 %), followed by the detached rural single family house (36 %). Detached single family and multi-family buildings together represent a 94 % share of total residential buildings. The most prevalent building types in the non-residential sector are office buildings (26 %) and educational facilities (26 %).

In Poland, according to our survey the new construction rates are generally higher in the non-residential sector than in the residential sector. In the residential sector the new construction rate is between 0.1 % and 2.4 %. In the non-residential sector, the new construction rate is between 0.0 % and 6.5 %.

ROMANIA

The housing stock in Romania consists of approximately 8.2 million dwellings in some 5.1 million buildings. In the urban area, the majority of dwellings (72 %) are found in blocks of flats, in contrast to rural areas, where the majority (94.5 %) are individual dwellings. Individual single family buildings represent around 98 % of the Romanian residential buildings stock. There are around 81,000 blocks of flats, mainly concentrated in urban areas, representing around 2 % of the building stock but accounting for 37 % of Romanian dwellings (around 3.18 million apartments). According to the preliminary results of the 2011 Census, the total number of buildings in Romania is about 5.3 million, whereas 5.1 million are residential buildings and 0.2 million are non-residential buildings.

Approximately 53 % of residential buildings are built before 1970 and more than 90 % before 1989 (in terms of m²), having an energy performance level between 150–400 kWh/m²/yr. Heating energy represents around 55 % of the overall energy use in apartments and up to 80 % in individual houses. The most common heating system in urban areas is a central gas boiler. A decreasing amount of about 18 % of the dwellings –

mostly apartments in multifamily buildings – is connected to a district heating network.

The buildings built before 1990 have poor energy performance at around 180–400 kWh/m²/yr.

According to floor area, the most prevalent building type in the residential sector is the rural detached single family house with 43 %, followed by the urban multi-family building with 34 %. In the non-residential building sector, the most prevalent building type in the existing non-residential sector is the retail building with 31 %, followed by educational buildings with 29 %, health buildings with 16 % and offices with 13 %.

New construction rates are generally higher in the non-residential sector than in the residential one. In the residential sector the average new construction rate is about 0.64 % [7]. The estimated construction rates for the non-residential sector were very high over the last decade and for certain sub-types even well above 10 %/year. This construction rate seems credible if we consider the strong impetus in the service sector in Romania and the lack of existing office buildings. Market research indicates that floor space of commercial offices almost doubled from 2005 to 2011; however the new high construction rate has been slowing down since 2009 and reached 2.5 % in 2011. Overall, it seems that the construction rates have been stabilized at a level similar to those of other Central and Eastern European countries, i.e. a new construction rate between 1.5–2.5 % for the overall non-residential sector and a rate of on average 5 % for office buildings only.

BULGARIA

In Bulgaria there are around 1,773 million detached single family houses (SFH), around 66 % of them being located in rural area. About 96 % of the 70,000 multi-family buildings (MFH, block of flats) are located in urban areas. Detached single family houses and multi-family blocks of flats represent almost 90 % of the residential building stock in Bulgaria and around 97 % of the net floor area in residential sector.

The total housing stock in Bulgaria comprises about 3.7 million dwellings, with the average dwelling size at around 60 m².

The total floor area of the building sector in Bulgaria in 2010 was about 262 Mio m², whereas 212 million m² of floor area was in the residential and 50 million m² was in the non-residential building sector.

The most prevalent building type in the residential sector is the urban multifamily building with 41 % and the rural single family house with 32 %. In the non-residential sector, the most prevalent building is the office building with 37 %, followed by educational buildings with 22 % and retail buildings with 19 %.

Around 68 % of dwellings were built after World War II and during the communist regime, when energy prices were very low and priority was given to minimizing the initial investments thus leading to a low quality architecture and insulation [8, 9].

The specific energy consumption per heated area is higher in Bulgaria than in Western European countries, mostly due to the very low quality insulation, which leads to a de facto energy poverty status and many people are not able to pay for heating their homes to the normal comfort level. A particular aspect in Bulgaria is the extensive use of firewood as the most common heating solution in single family homes from rural areas.

The new construction rates are calculated based on the available statistics for the years 2009 and 2010. New construction rates are generally higher in the non-residential than in the residential sector. In the residential sector the average construction rate is about 0.9 % while the average construction rate in the non-residential sector is 2.8 %.

Definition of reference buildings for the new single family houses

The survey undertaken on the local building stock and actual construction practice showed that the specific national situation in Poland, Romania and Bulgaria differs in many respects from the other EU Member States from Western Europe. Therefore, for analysing the impact of different nZEB options, the reference buildings selected had to match the range of building types found in these countries, taking into account typical shapes, sizes, characteristics and usage of new buildings. The main characteristics of identified reference single-family houses are presented in Table 1[2, 3, 4]. In a similar way, the reference new MFH and office buildings were defined.

Definition of nZEB solutions and simulation approaches

In order to determine the impact of improving the actual construction practice towards nZEB levels, for each country under analysis there have been several improvement variants of the reference buildings defined, both in terms of improved buildings envelope insulation and more efficient heating equipment. Assuming a smooth transition towards nZEB, the geometry of the reference buildings as they resulted from the actual practice have not been changed, even though they may be far from an optimum. The considered variants are presented in Tables 2[5], 3[6], [7] and 4[8].

For each of the four base variants, the following four heating supply options will be considered:

A. Air source heat pump.[9]

B. Ground collector brine heat pump.[10]

C. Wood pellet boiler (Bio boiler).

D. Gas condensing boiler.

The results of the simulations of the predefined nZEB solutions are analysed in comparison with the nZEB principles as they

2. Cooling system: SEER=Seasonal Energy Efficiency Ratio. The SEER rating of a unit is the cooling output during a typical cooling-season divided by the total electric energy input in watt-hours during the same period. The higher the unit's SEER rating the more energy efficient it is.

3. Internal gains: This value is to be understood as the maximum value. For persons, lighting, appliances and other internal gains schedules exist taking into consideration for example how many persons are at the moment in the respective zone.

4. Installed lighting power: This value is to be understood as a maximum value. For the hourly demand individual schedules for every zone have been considered.

5. Heat bridges have been included in the calculation of the U-values.

6. Heat bridges have been included in the calculation of the U-values.

7. Passive house standard: major shell improvements, no heat bridges, airtight construction, highly efficient mechanical ventilation (> 90 %), useful heating and cooling demand < 15 kWh/m²a.

8. Heat bridges have been included in the calculation of the U-values.

9. Solutions will be considered to have a low temperature floor heating system to get a better system efficiency.

10. Cf. previous footnote.

Table 1. Main characteristics of identified single-family houses in Poland, Romania and Bulgaria.

Parameter	Poland	Romania	Bulgaria
Number of conditioned floors	2	2	2
Net floor area	183.5 m²	99.7 m²	127 m²
Room height	2.65 m	2.5 m	2.65 m
U-walls	0.23 W/(m².K)	0.56 W/(m²K)	0.34 W/(m²K)
U-roof	0.20 W/(m².K)	0.35 W/(m²K)	0.27 W/(m²K)
U-floor	0.59 W/(m².K)	0.52 W/(m²K)	0.55 W/(m²K)
U-windows, frame fraction	1.40 W/(m².K); 25%	1.30 W/(m²K); 30%	1.70 W/(m²K); 21%
Window fraction (window/wall-ratio)	20%	12% (no windows on North facade)	13% (only 5% on North and West facades)
Shading	None	None	None
Air tightness	Moderate	Moderate	Moderate
Thermal bridges	Yes	Yes	Yes
Heating system	Gas boiler (set point: 20 °C); Heating efficiency: 0.9	Gas boiler (set point: 20 °C), Heating efficiency: 0.9	Wood boiler (set point: 20 °C) Heating efficiency: 0.82
DHW system	Same as for heating DHW efficiency: 0.85	Same as for heating, DHW efficiency: 0.9	Combination of wood boiler and electric heater DHW efficiency: 0.93 (40% Wood = 0.82 60% electric heater = 1.00)
Ventilation system	Natural/window ventilation (0.3 1/h)	Natural/window ventilation (0.5 1/h)	Natural/window ventilation (0.35 1/h)
Cooling system	None	Split system (set point: 26 °C), SEER: 2.75	Split system (set point: 26 °C), SEER: 3.2
Internal gains	16 W/m²	5 W/m²	13.5 W/m²
Installed lighting power	5 W/m²	18 W/m²	11.7 W/m²

Table 2. Definition of the nZEB variants for single-family homes in Poland.

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.23 W/m².K U-Roof: 0.20 W/m².K U-Floor: 0.59 W/m².K	1.4 W/m².K	0%	No	Reference
V1	U-Wall: 0.23 W/m².K U-Roof: 0.20 W/m².K U-Floor: 0.59 W/m².K	1.4 W/m².K	80%	No	+ mech. ventilation with heat recovery
V2	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.15 W/m².K	0.8 W/m².K	0%	No	+ improved building shell
V3	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.15 W/m².K	0.8 W/m².K	90%	No	Improved building shell + improved mech. ventilation with heat recovery
V4	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.15 W/m².K	0.80 W/m².K	90%	Yes	Improved building shell + improved mech. ventilation with heat recovery + solar collectors

Table 3. Definition of the nZEB variants for single-family homes in Romania.

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.56 W/m².K U-Roof: 0.35 W/m².K U-Floor: 0.52 W/m².K	1.3 W/m².K	0%	No	Reference
V1	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.36 W/m².K	1.0 W/m².K	0%	No	Improved building shell
V2	U-Wall: 0.15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.36 W/m².K	1.0 W/m².K	0%	Yes	Improved building shell + solar collectors
V3	U-Wall: 0;15 W/m².K U-Roof: 0.12 W/m².K U-Floor: 0.36 W/m².K	1.0 W/m².K	80%	No	Improved building shell + mech. ventilation with heat recovery
V4	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.36 W/m².K	0.80 W/m².K	90%	No	Passive house standard
V5	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.36 W/m².K	0.80 W/m².K	90%	Yes	Passive house standard + solar collectors

Table 4. Definition of the nZEB variants for single-family homes in Bulgaria.

Variants	U-value Opaque Shell	U-Value Window	Heat Recovery Rate	Solar Collector for DHW	Brief Description
V0	U-Wall: 0.34 W/m².K U-Roof: 0.27 W/m².K U-Floor: 0.55 W/m².K	1.7 W/m².K	0%	No	Reference
V1	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.20 W/m².K	1.0 W/m².K	0%	No	Improved building shell
V2	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.20 W/m².K	1.0 W/m².K	0%	Yes	Improved building shell + solar collectors
V3	U-Wall: 0.12 W/m².K U-Roof: 0.10 W/m².K U-Floor: 0.20 W/m².K	1.0 W/m².K	80%	No	Improved building shell + mech. ventilation with heat recovery
V4	U-Wall: 0.10 W/m².K U-Roof: 0.09 W/m².K U-Floor: 0.20 W/m².K	0.80 W/m².K	92%	No	Nearly passive house standard

had been defined in the BPIE study. Therefore, the following parameters are considered and calculated:

- Specific final energy demand detailed by building services (i.e. heating, domestic hot water, cooling, ventilation and auxiliary energy).
- Specific primary energy demand.
- Share of renewable energies.
- Specific CO_2 emissions.

In addition to the above-mentioned assumptions, for all solutions a further set of solutions with a rooftop PV system for compensating the remaining CO_2 emissions was assumed. The available roof areas as well as the required areas for solar thermal systems have also been considered; in some cases full compensation cannot be achieved. The sizes of the building's roof as well as the consideration of solar-thermal collectors introduce a limitation for the PV compensation in terms of maximum installed capacity of 4.8 kWp for SFH.

Important note: compensating the building's CO_2 emissions by introducing an additional onsite PV system significantly improves the primary energy demand of the building. However, the PV compensation doesn't necessarily supply the energy demand of the building within the EPBD scope (i.e. energy for heating, cooling, ventilation, domestic hot water and, in case of commercial buildings, for lighting), but the overall energy demand of the building (including the electricity for household appliances). In this case, the PV compensation helps reduce the primary energy demand and associated CO_2 emissions towards or below zero in the overall trade-off with the energy grids. Hence, the PV compensation may have a significant contribution to a nearly zero whole energy demand. For simplifying the evaluation methodology in this study only a PV compensation is considered. The PV compensation may be replaced in practice by any other renewable energy system. Moreover, the amount of the compensation can be reduced by e.g. improved building insulation, by improved building geometries or higher system efficiencies. Nevertheless, the PV compensation has a significant direct impact in the case of office buildings where lighting electricity consumption is within the EPBD scope and represents a significant share of the overall energy demand of the buildings.

The cost evaluation includes all investment, maintenance and operational costs of the building within EPBD energy scope. The costs are annualized over 30 years which is widely accepted to be the usual period of time until a new building should be renovated. The financial analysis took into account the actual interest rates on Polish (5 %), Romanian (8 %) and Bulgarian (7.5 %) markets. The costs for improving the building's external insulation and for heating equipment resulted from market surveys done for the elaboration of these studies. The nZEB solutions have been simulated in only one climate zone for each country, i.e. for Warsaw, Bucharest and Sofia.

Simulation results for the nZEB solutions

The results of the simulation for each solution and country in terms of primary energy consumption, renewable share, associated CO_2 emissions and total annualised additional costs (investment, energy cost savings and other running costs such as maintenance) are shown in Tables 5–7. Total final and primary energy demand for residential buildings includes the energy consumption within the EPBD scope: heating, cooling, ventilation, domestic hot water. The colour code used for highlighting the results of the different nZEB options is in line with the nZEB principles as they were defined in the 2011 BPIE study [10]. All solutions that meet all minimum requirements for primary energy consumption, CO_2 emissions and renewable energy share (i.e. all related boxes in below tables are in green colour) are in line with the nZEB principles. Moreover, the solutions that also meet the minimum requirement for final energy consumption are more sustainable than others because it is an absolute reduction of the energy need of the building (i.e. by implementing a better insulation).

Analysing the results of simulations, it appears that in Bulgaria and also in Poland it is possible to reach nZEB solutions even at negative annualised costs, i.e. benefits from energy savings are greater than investment, maintenance and operational costs. In Romania, the nZEB solutions are not cost-effective, but there are several solutions with additional annualised costs below 5 Euro/m^2 or slightly above this threshold. Most of the simulated nZEB variants in all three countries meet a CO_2 emissions level below 4 kg $CO_2/m^2/yr$ and a renewable energy share above 50 % only when using the PV compensation.

However, it is important to highlight the fact that the financial and energy analysis are based on very conservative assumptions, using the actual interest rates and technology prices and according to the actual practices in construction. For instance, it is a significant optimization potential of the buildings' geometries towards those recommended by passive houses design which will lead to additional costs reductions. Moreover, by implementing ambitious nZEB requirements in the Bulgarian building codes, this will generate a wider market deployment of the energy efficient and renewable technology which will consequently reduce their prices and will overall generate lower costs for nZEB.

In addition, the financial evaluation of the nZEB solutions considered the actual interest rate in the countries which are higher than on other Western European markets. However, according to the estimated economic evolution, the interest rates are likely to decrease consistently by 2020 when the nZEB requirement has to become legally binding. Additional support policies may also consider a potential subsidy of the interest rate in order to ease the transition to nZEB and to make them competitive with buildings at today's standards. Overall, a reduction of the interest rate may impact positively in the financial analysis and may even make nZEB investments profitable over a given period of time, as is the case in other EU countries already having better conditions.

Proposed nZEB definitions for Poland, Romania and Bulgaria

Based on the above analysis, on the simulation results shown in Tables 5–7 and taking mainly into consideration the additional costs and results for basic variants without PV compensation, the following levels are proposed for consideration as nZEB definitions for single-family houses in Poland, Roma-

Table 5. Simulation results for the SFH in Poland.

	final specific demand [kWh/m2/yr]	Without CO_2 compensation				With CO_2 compensation (by additional PV)			
		primary energy demand [kWh/m2/yr]	CO_2 emissions [$kgCO_2$/m2/yr]	renewable share [%]	total additional annualized costs [Euro/m2/yr]	primary energy demand [kWh/m2/yr]	CO_2 emissions [$kgCO_2$/m2/yr]	renewable share [%]	total additional annualized costs [Euro/m2/yr]
V0 – Reference	111	123.0	22.5	0%	0	n.a	n.a.	n.a.	0.0
V1 – Air heatpump	30.1	60.2	7.6	35%	-1.2	3.9	0.5	129%	2.9
V1 – Brine heatpump	24.2	48.4	6.1	35%	-0.7	0.0	0.0	135%	2.8
V1 – Bioboiler	101.8	26.9	0.9	98%	1.4	19.6	0.0	101%	1.9
V1 – Gasboiler	101.4	114.9	20.7	1%	1.3	58.6	13.6	29%	5.3
V2 – Air heatpump	19.7	39.3	4.9	35%	-3.2	0.0	0.0	135%	-0.4
V2 – Brine heatpump	15.7	31.3	3.9	35%	-2.7	0.0	0.0	135%	-0.5
V2 – Bioboiler	68.7	15.0	0.2	99%	-1.1	8.9	0.0	104%	-0.6
V2 – Gasboiler	69	76.5	14.0	0%	-1.8	20.2	6.9	41%	2.3
V3 – Air heatpump	16	31.9	4.0	35%	-2	0.0	0.0	135%	0.3
V3 – Brine heatpump	13.9	27.7	3.5	35%	-1.6	0.0	0.0	135%	0.4
V3 – Bioboiler	50.4	14.9	0.7	97%	0.4	8.8	0.0	103%	0.9
V3 – Gasboiler	51.2	58.6	10.5	2%	-0.4	2.3	3.4	57%	3.6
V4 – Air heatpump	13.2	26.3	3.3	35%	-1	0.0	0.0	135%	0.9
V4 – Brine heatpump	10.4	20.7	2.6	35%	-0.7	0.0	0.0	135%	0.8
V4 – Bioboiler	37	13.2	0.8	94%	1	6.8	0.0	103%	1.5
V4 – Gasboiler	37	43.5	7.6	3%	-0.2	-5.6	1.4	70%	3.4
	<40	<40	<4	>50	<5	<40	<4	>50	<5
Legend	40<x<60	40< x<70	4<x<7	30>x<50	5<x<10	40< x<70	4<x<7	30<x<50	5<x<10
	>60	>70	>7	<30	>10	>70	>7	<30	>10

nia and Bulgaria (Table 8). In order to be sustainable and in line with the EU policies and long-term goals, the proposed nZEB definition should limit at the same time both primary energy consumption[11] and associated CO_2 emissions[12]. At the same time a minimum share of renewable energy[13] for supplying the remaining energy need of the building needs to be introduced.

While the proposed nZEB definitions by 2020 are estimated to be feasible at the same primary energy consumption level (30–50 kWh/m^2/yr) and renewable energy share (40 %), the minimum requirement for the associated CO_2 emissions are slightly different, taking into account the burden (additional costs) to reach a very low level.

For Romania it is foreseen a less strict interim target because there the building codes don't currently ask for a minimum energy performance requirement (there are only prescriptive component requirements) but also because the associated cost for increasing the energy performance of the new buildings appear to be higher than for the other two countries.

Direct and indirect benefits for moving towards nZEB in Poland, Romania and Bulgaria

Overall, the payback from investing in better buildings occurs over time. It contributes substantially to energy security, environmental protection, the social inclusion of people by creating or preserving jobs and offering a better quality of life, as well as supporting the sustainable development of the construction sector and supply chain industry.

While the upfront investment is relatively high and the return on investment is usually longer than for other economic activities, there are multiple benefits for building users and owners, the construction industry, public budget and society as a whole.

The benefits of the implementation of nZEBs are much wider than simply leading to energy and CO_2 savings and they can be summarized as follows:

- The quality of life in a nearly Zero-Energy Building is better than in a building constructed according to the current practice. Cost-saving possibilities arising from the appropriate design of the building and high quality construction

11. The Energy performance of Buildings Directive (2010/31/EU) asks specifically the EU Member States to implement nearly zero-energy buildings by 2020 which have to be defined by minimum performance requirements in primary energy.

12. The EU Roadmap for moving to a competitive low-carbon economy by 2050 identified the need of reducing by around 90 % the CO2 emissions in residential and tertiary sectors. As identified in BPIE study on Principles for nearly zero-energy buildings, in order to reach this goal, another minimum requirement should be introduced.

13. The Article 13 of Renewable Energy Directive (2009/28/EC) asks specifically the EU Member States to introduce renewable energy requirements in building codes by 2014. At the same time, the nZEB definition as mentioned in the EPBD, stipulates that a significant share of the remaining energy need of the building have to be supplied by renewable energy sources, including on-site and nearby.

Table 6. Simulation results for the SFH in Romania.

	final specific demand [kWh/m2/yr]	without CO_2 compensation: primary energy demand [kWh/m2/yr]	without CO_2 compensation: CO_2 emissions [$kgCO_2$/m2/yr]	without CO_2 compensation: renewable share [%]	without CO_2 compensation: total additional annualized costs [Euro/m2/yr]	with CO_2 compensation (by additional PV): primary energy demand [kWh/m2/yr]	with CO_2 compensation (by additional PV): CO_2 emissions [$kgCO_2$/m2/yr]	with CO_2 compensation (by additional PV): renewable share [%]	with CO_2 compensation (by additional PV): total additional annualized costs [Euro/m2/yr]
V0 – Reference	161.6	180.8	32.8	0	0	n.a.	n.a.	n.a.	0
V1 – Air heatpump	24.6	49.3	6.2	40%	2.5	0	0	140%	5.7
V1 – Brine heatpump	20.3	40.7	5.1	40%	10.7	0	0	140%	13.2
V1 – Bioboiler	76	22.3	1	100%	7.7	7.9	0	110%	8.6
V1 – Gasboiler	76	87.2	15.6	0	-1.5	-24.2	1.5	80%	5.4
V2 – Air heatpump	18.9	37.8	4.8	40%	6.4	0	0	140%	8.7
V2 – Brine heatpump	14.3	28.7	3.6	40%	14.4	0	0	140%	16.2
V2 – Bioboiler	56.5	17.5	0.9	100%	11.3	3.1	0	110%	12.1
V2 – Gasboiler	56.5	65.3	11.6	0	3.4	-26.8	0	80%	9.2
V3 – Air heatpump	18.8	37.6	4.7	40%	1.2	0	0	140%	3.6
V3 – Brine heatpump	16.9	33.7	4.2	40%	7	0	0	140%	9.2
V3 – Bioboiler	53.4	19.4	1.2	90%	8.6	5	0	110%	9.5
V3 – Gasboiler	53.4	63.1	11	0	0.1	-24.4	0	90%	5.5
V4 – Air heatpump	15.6	31.2	3.9	40%	3.4	0	0	140%	5.3
V4 – Brine heatpump	13.6	27.1	3.4	40%	8.1	0	0	140%	9.9
V4 – Bioboiler	41.2	16.2	1.1	90%	12.8	1.8	0	110%	13.8
V4 – Gasboiler	41.2	49.3	8.5	0	5.1	-18.6	0	90%	9.3
V5 – Air heatpump	10.3	20.6	2.6	40%	5.7	0	0	140%	7
V5 – Brine heatpump	8.7	17.4	2.2	40%	10.6	0	0	140%	11.7
V5 – Bioboiler	21.7	14.1	1.4	80%	15.1	-0.3	0	120%	16
V5 – Gasboiler	21.7	28.8	4.7	10%	10.5	-8.2	0	90%	12.8
	<40	<40	<4	>50	<5	<40	<4	>50	<5
Legend	40< x <60	40< x<70	4<x<7	30>x<50	5<x<10	40< x<70	4<x<7	30<x<50	5<x<10
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Table 7. Simulation results for the SFH in Bulgaria.

	final specific demand [kWh/m2/yr]	without CO_2 compensation: primary energy demand [kWh/m2/yr]	without CO_2 compensation: CO_2 emissions [$kgCO_2$/m2/yr]	without CO_2 compensation: renewable share [%]	without CO_2 compensation: total additional annualised costs [Euro/m2/yr]	with CO_2 compensation (by additional PV): primary energy demand [kWh/m2/yr]	with CO_2 compensation (by additional PV): CO_2 emissions [$kgCO_2$/m2/yr]	with CO_2 compensation (by additional PV): renewable share [%]	with CO_2 compensation (by additional PV): total additional annualised costs [Euro/m2/yr]
V0 – Reference	169.9	86.4	45.1	90%	0	n.a	n.a.	n.a.	0
V1 – Air Heatpump	25.5	51.1	6.4	35%	-11.23	0	0	135%	-7.73
V1 – Brine Heatpump	21.2	42.5	5.4	35%	-6.37	0	0	135%	-3.46
V1 – Bioboiler	91	21.9	0.5	99%	-4.28	11.6	0	104%	-3.57
V1 – Gasboiler	91	102	18.5	1%	-5.58	36.4	10.2	37%	-1.07
V2 – Air Heatpump	19.4	39	4.9	35%	-9.78	0	0	135%	-7.11
V2 – Brine Heatpump	15	29.9	3.8	35%	-4.95	0	0	135%	-2.9
V2 – Bioboiler	71	16.6	0.3	99%	-3.93	6.3	0	106%	-3.22
V2 – Gasboiler	71	79.4	14.4	1%	-5.23	26.1	7.7	38%	-1.57
V3 – Air Heatpump	20.8	41.8	5.3	35%	-8.78	0	0	135%	-5.92
V3 – Brine Heatpump	18.1	36.4	4.6	35%	-5.69	0	0	135%	-3.2
V3 – Bioboiler	72.1	18.8	0.6	98%	-2.96	8.5	0	105%	-2.26
V3 – Gasboiler	72.1	81.6	14.7	1%	-4.27	15.9	6.4	47%	0.23
V4 – Air Heatpump	15.6	31	3.9	35%	-7.12	0	0	135%	-4.99
V4 – Brine Heatpump	13.5	27.1	3.4	35%	-4.85	0	0	135%	-2.99
V4 – Bioboiler	49.4	13.2	0.5	98%	-2.75	2.9	0	108%	-2.04
V4 – Gasboiler	49.4	55.9	10.1	1%	-3.51	-9.7	1.8	68%	1
	<40	<40	<4	>50	<5	<40	<4	>50	<5
Legend	40< x <60	40< x<70	4<x<7	30>x<50	5<x<10	40< x<70	4<x<7	30<x<50	5<x<10
	>60	>70	>7	<30	>10	>70	>7	<30	>10

Table 8. Proposed nZEB definitions for SFH in Poland, Romania and Bulgaria.

Building type	Minimum requirements	Year	
		2015/2016	2020
Single family buildings in Poland	Primary energy [$kWh/m^2/yr$]	70	30–50
	Renewable share [%]	>20	>40
	CO_2 emissions [$kgCO_2/m^2/yr$]	<10	<3–6
Single family buildings in Romania	Primary energy [$kWh/m^2/yr$]	100	30–50
	Renewable share [%]	>20	>40
	CO_2 emissions [$kgCO_2/m^2/yr$]	<10	<3–7
Single family buildings in Bulgaria	Primary energy [$kWh/m^2/yr$]	60–70	30–50
	Renewable share [%]	>20	>40
	CO_2 emissions [$kgCO_2/m^2/yr$]	<8	<3–5

almost entirely cover the additional costs of the energy-efficient building envelope. The quality of life is greater through better (thermal) comfort. The nearly Zero-Energy Building provides good indoor air quality. Fresh filtered air is continuously delivered by the ventilation system. It is more independent of outdoor conditions (climate, air pollution etc.). The thick and well insulated structures provide effective sound insulation and noise protection.

- Ambient benefits arise through reduced energy demand that reduces wider environmental impacts of energy extraction, production and supply.
- There are environmental benefits from improved local air quality.
- Social benefits arise through the alleviation of fuel poverty.
- Health benefits are possible through improved indoor air quality and reduced risks of cold homes, particularly for those on low-incomes or for elderly householders.
- Macro-economic benefits arise through the promotion of innovative technologies and creating market opportunities for new or more efficient technologies and through the provision of certain incentives for pilot projects and market transformation.
- Private economic benefits: higher investment costs may be outweighed by the energy savings over the lifetime of the building (the building offers less sensitivity to energy prices and to political disturbances). When a building is sold, the high standard can be rewarded through a re-sale price up to 30 % higher compared with standard buildings.
- Job creation can arise through the manufacturing and installation of energy efficiency measures and of renewable energy technologies.
- There will be decreased energy dependence on fossil fuels and therefore on the future energy prices [11].

While this wasn't the main aim of the study, an approximate estimation of the macro-economic impact was done, by extrapolating results from the reference buildings to the national level, e.g. (average energy and CO_2 savings per m^2) × (m^2 built new per year) × 30 years (2020–2050). The results of this evaluation are presented in Table 9[14] in terms of additional investments, additional new jobs, CO_2 and energy savings generated by 2050.

However, this is a conservative approach without considering additional important factors that may positively influence the macro-economic benefits. As an example, the job creation impact is based on the job intensity of construction industry and reflects only the additional work places that may be created at the execution level and doesn't include the jobs in the supply chain industry induced by up-scaling the market and the indirect jobs in the administration of the processes (e.g. additional auditors and control bodies for new tech). Moreover, by moving towards very efficient buildings and increasing the need for new technology will impact mainly on new job profiles such as renewable systems and heat pumps installers. Therefore, it will be an increased need for these new activities all over the country and driven not only by additional invested volumes as we considered in this study but also by the local needs for such new job profiles[15]. Consequently, it is very likely to have a much higher job creation potential than estimated in this study.

Policy recommendations and a roadmap-2020 for implementing nZEBs in Poland, Romania and Bulgaria

Based on the analysis of the country situation as well as on the results of the previous study for defining the nZEB principles and on related studies, some key recommendations merge that should be considered when designing an nZEB implementation roadmap:

14. Additional new jobs: This is the estimated job effect in construction sector only and without considering the additional impact in the supply chain industry and other related sectors. It was considered that any 1 Mio euro invested will generate around 17 new jobs, as identified in several previous studies such as BPIE (2011) Europe's buildings under the microscope.

15. As an example, additional investments in a very well established construction sector already having all necessary job profiles and spread all over the considered country or region, then the job impact is determined with a fair approximation by using the job intensity of the sector. However, if the additional invested capital supposed to expand new qualifications as is the case for nZEB, it is necessary to create all over the given country or region a critical mass of specialists for these new qualifications able to provide the requested services. In this case, the job creation potential is much higher than in the first case (even few times higher).

Table 9. The macro-economic impact of the nZEB implementation in Poland, Romania and Bulgaria (2020–2050).

Indicator	Poland	Romania	Bulgaria
CO_2 emissions savings in 2050 [Mio t CO_2]	31	6.8	4.7–5.3
Cumulative energy savings in 2050 [TWh]	92	40	15.3–17
Additional annual investments [Mio EURO]	242–364	82–130	38–69
Additional new jobs [full time employees]	4,106–6,185	1,390–2,200	649–1,180

1. Policy-makers should concentrate long-term programmes so as to provide stable frameworks and facilitate the long-term planning of all stakeholders.
2. The buildings strategies should be in line with the complementary energy and climate strategies at national and EU level to ensure that other important policy objectives are not harmed.
3. Impact assessment (ex-ante, interim and ex-post) of the planned policies together with a simple but effective monitoring and control mechanism are important in order to have a clear image of the necessary measures to be implemented, risks, challenges and benefits.
4. Different instruments should be part of a wider holistic policy package which should comprise regulatory, facilitation and communication aspects. The German investment bank KfW is a good example of a strong communication policy that managed to raise awareness among the building owners to such an extent that the financial products and mechanisms for buildings are well known terms and are used by the commercial banks and construction companies to advertise their offers. Therefore implementing targeted awareness campaigns is recommended because it is seen as key to a scheme's success.
5. Clear communication is indispensable since it provides information to consumers and market players about incentives and energy efficiency measures available to them. In addition, wide public consultation with relevant stakeholders is necessary at all implementation stages of buildings policy.
6. Within individual Member States, different instruments need to be coordinated with each other to ensure success. One example is the Carbon Emissions Reduction Target (CERT) in the UK which is closely coordinated with other instruments [12]. The overlapping of financial support instruments should be avoided so as to offer clear, simple and coherent market instruments.
7. Higher energy performance of buildings should be rewarded by better financial support, i.e. higher grants or lower interest for dedicated loans. This is again another best practice from other countries, including the above mentioned KfW example.

The results of the simulations showed that the additional financial efforts involved in moving towards nearly Zero-Energy Buildings are manageable with appropriate policy measures. By improving the thermal insulation of new buildings and by increasing the share of renewable energy use in a building's energy consumption, the implementation of nearly Zero-Energy Buildings in Poland, Romania and Bulgaria generate macroeconomic and social benefits.

There are multiple benefits for both society and the business environment. Nevertheless, to ensure a cost-effective and sustainable market transformation, to develop appropriate policies and to increase institutional capacities, concerted action is needed. It is vitally important to start preparing, today, an implementation roadmap based on a major public consultation of all relevant stakeholders and linked to a continuous information campaign. Elaborating a policy roadmap and announcing the future measures in a timely way will provide the business sector and the market with the necessary predictability to adapt their practices to the upcoming requirements.

To support these national efforts, BPIE proposes 2020 roadmap for nZEB implementation in Poland, Romania and Bulgaria [13] which takes into account the required improvements at the level of policy, building codes, capacity building, energy certification, workforce skills, public information and research & demonstration projects.

To have a coherent and sustainable transition, all proposed measures are to be implemented together. They are interlinked and ensure an overall consistency in the proposed implementation package, while trying to preserve a balance between increased requirements and support policies. Half measures make any market transformation process longer and less effective, at the same time causing additional burdens on society and economy.

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