RePublic_ZEB
ZEROING IN ON ENERGY

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REFURBISHMENT OF THE PUBLIC BUILDING STOCK TOWARDS NZEB

ACRONYM OF THE PROJECT: REPUBLIC_ZEB

D3.2 REPORT ON THE COMMON CRITERIA AND PRINCIPLES FOR PUBLIC BUILDING NZEB DEFINITION IN SOUTH AND EAST EUROPEAN COUNTRIES

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RePublic_ZEB Project

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Project consortium

BME	WP3 Leader
BRE	WP6 Leader
BSERC	WP2 Leader
CRES	Partner
CTI	WP1-WP7 Leader Coordination
EIHP	Partner
URBAN-INCERC	Partner
IREC	Partner
LNEG	WP5 Leader
MACEF	Partner
POLITO	WP 4 Leader
ZRMK	Partner

Project overview

The RePublic_ZEB project is focused on the energy and CO_2 emissions associated with existing public buildings and their refurbishment towards nZEB.

The **core objective** of the project is to:

- Define costs-benefit optimized “packages of measures” based on efficient and quality-guaranteed technologies for the refurbishment of the public building stock towards nZEB that are standardized and adopted by builders and building owners.

From this stems three **basic objectives:**

(i) State-of-the-art assessment of the public building stock through a country-specific evaluation of the energy consumption and CO_2 emissions;

(ii) Define reference buildings; and;

(iii) Develop a common framework and a harmonized methodology for the definition of a nZEB concept for public buildings.

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1. EXECUTIVE SUMMARY

This report represents the deliverable D3.2 of WP3 of the RePublic_ZEB project, and presents the comprehensive work performed within Task 3.2.

The starting of the report is the review of the main definitions and principles as regards *nearly zero energy building* (nZEB). The general definition of nZEB was introduced in the Directive 2010/31/EU of the European Parliament and of the Council (EPBD recast) on 19 May 2010. According to the Article 2 of the EPBD recast, the nZEB means a building that has a very high energy performance, and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. The performance level of *nearly* zero energy is a subject of national decision taking into consideration the national conditions. The boundaries of the system must be determined first, i.e. to determine what belongs in the energy need. It is recommended that each country should set limits on the numerical indicator of the primary energy consumption, the minimum share of RES, and in addition a numerical indicator for CO_2 emission should be determined.

Based on the relevant standards and studies and considering the existing legislative status and requirements of the target countries, this D3.2 report presents the common framework and a harmonized methodology for the definition of nZEB public buildings.

The *energy flow* and the *system boundaries* of nearly zero energy public buildings are presented in details in this report. The primary energy consumption of heating, cooling, ventilation, DHW and lighting are included in the energy performance, while the energy use of the appliances is excluded. The *building energy use* is the energy use of the building technical systems, which includes all the conversion and system losses. The renewable energy produced on site shall be deducted from the amount of energy to be delivered to the building site, and is taken into account in the calculation of the delivered and exported energy balance at the building site. The calculation of Renewable Energy Ratio (RER) is also presented in the report, which should be used by the target countries of RePublic_ZEB project in order to calculate the share of renewable energy sources in nZEB.

Three indicators have been proposed to be used for the specification of nZEB public buildings: the non-renewable primary energy, the renewable energy ratio and the CO_2 emission.

As regards the non-renewable primary energy, the upper limit of the requirement is the least ambitious, which has been set according to the principle of cost optimality. Setting the cost optimal values were a request of the EPBD recast, and most of the target countries already defined these values. The lower limit of the primary energy consumption can be set by considering the best available technology. The packages of energy efficiency measures for different kind of public buildings will be detailed in national sections in D3.3, therefore the calculation of the lower limit of the primary energy taking into account the proposed *packages of measures* can be done after the building energy simulations finishes in WP4. At this point of the project the lower limits of the non-renewable primary energy figures for public buildings were estimated, which will be modified subsequently, taking into account the simulation results of WP4.

Concerning the share of RES in nZEB public buildings the numerical values should be defined. Taking into consideration the GDP, the average global horizontal radiation of the countries, and the summer and winter climatic conditions that are presented in D3.1, the numerical requirements of the renewable energy ratios are proposed for each target country concerning the refurbishment of public buildings towards nZEB level.

Introducing an indicator on the CO_2 emission of buildings would be a good way to ensure coherence and consistence between the long-term energy and environmental goals of the EU. At this stage of the project the nZEB primary energy requirements are estimated and those values can be fulfilled with numerous kinds of energy sources. Therefore the CO_2 emission for nZEB buildings can be defined after the building energy simulations is done in WP4 with the proposed packages of measures that will be assembled in D3.4.

To sum up, the definition of system boundaries and the energy flow of nZEB public buildings have been defined. The proposed calculation methodology, the consideration of net primary energy is consistent with the guideline accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012, that had to be followed by each Member States for setting the cost optimal requirements. This nZEB concept should be introduced in the national legislations as regards the building energy calculation. The proposal for the RER requirement has been given for each target country of the project. The lower limit of the primary energy consumption has been estimated, that – together with the CO_2 emission requirement – has to be reviewed after the building energy simulation is finished in WP4.

2. THE MAIN DEFINITIONS AND PRINCIPLES

The general definition of *nearly zero energy building* (nZEB) was introduced in the Directive 2010/31/EU of the European Parliament and of the Council (EPBD recast) on 19 May 2010. According to the Article 2 of the EPBD recast, the nearly zero energy building means a building that has a very high energy performance, and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from on-site or nearby renewable sources. The calculated or measured amount of energy needs to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting.

The Article 9 (3a) of the EPBD recast requires Member States to describe the detailed application of the definition of nearly zero energy buildings in practice, reflecting the national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values and may take into account relevant European standards. Based on D3.1 report it can be stated that all of the target countries of RePublic_ZEB project, except Macedonia, transposed the general definition of nearly zero energy building into the national legislation, however many of them has not yet elaborated neither the application of the definition nor the numerical requirement in terms of annual primary energy use.

2.1 The definition of nearly zero energy building

The EPBD recast launched the term of nearly zero energy building, but does not give exact definitions for the details, like the numerical requirement of the primary energy consumption, the mandatory share of RES, or what exactly means nearby, etc. EPBD recast does not give minimum or maximum harmonized requirements as well as details of energy performance calculation framework, it will be up to the Member States to define what “a very high energy performance” and “to a very significant extent by energy from renewable sources” exactly constitute for them. The detailed definition of nZEB and all the relevant phrases should be formulated by the Member States.

The building energy calculation of nZEB shall be based on delivered and exported energy according to the EPBD recast, the prEN 15603:2015 and the guideline accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012. Detailed definitions related to this context are available in the above mentioned standard and also in the *REHVA Report No 4. nZEB technical definition and system boundaries for nearly zero energy buildings*.

Nearly zero energy building (Source: REHVA: nZEB technical definition and system boundaries for nearly zero energy buildings)

Technically and reasonably achievable national energy use of > 0 $kWh/(m^2 a)$ but no more than a national limit value of primary energy, achieved with a combination of best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal.

NOTE 1 ‘reasonably achievable’ means by comparison with national energy use benchmarks appropriate to the activities served by the building, or any other metric that is deemed appropriate by each EU Member State.

NOTE 2 The Commission has established a comparative methodology framework for calculation of cost-optimal levels (cost optimal).

NOTE 3 Renewable energy technologies needed in nearly zero energy buildings may or may not be cost-effective, depending on available national financial incentives.

This definition is absolutely consistent with the Task 3.2 of RePublic_ZEB project, since in the description of this Task it is written that an upper and a lower limit should be defined for primary energy requirement. The upper limit is the least ambitious which can be set according to the principle of cost optimality (Article 5 of the EPBD recast), whilst the lower limit is set by the best available technology, which may not be cost optimal in the current situation. The Member States might determine their individual position within the corridor based on specific relevant conditions.

This is in context with the EPBD recast, as the performance level of *nearly* zero energy is a subject of national decision taking into consideration:

- Technically reasonably achievable level of primary energy use
- Mandatory share of RES to cover the primary energy use
- Available financial incentives for renewable energy or energy efficiency measures
- Cost implications and ambition level of the definition.

Non-renewable primary energy factor (Source: prEN 15603:2015)

for a given energy carrier, the non-renewable primary energy, including the delivered energy and the considered energy overheads of delivery to the points of use, divided by the delivered energy.

Renewable primary energy factor (Source: prEN 15603:2015)

for a given distant or nearby energy carrier, the renewable primary energy, including the delivered energy and the considered energy overheads of delivery to the points of use, divided by the delivered energy.

Total primary energy factor (Source: prEN 15603:2015)

for a given energy carrier: sum of renewable and non-renewable primary energy factors.

On Figure 1 the total primary energy factor, the non-renewable primary energy factor and the renewable primary energy factor can be seen by visualization of the energy source in nature, the energy supply chain, and the system boundary, which shall be taken into account for building energy calculations of nZEBs.

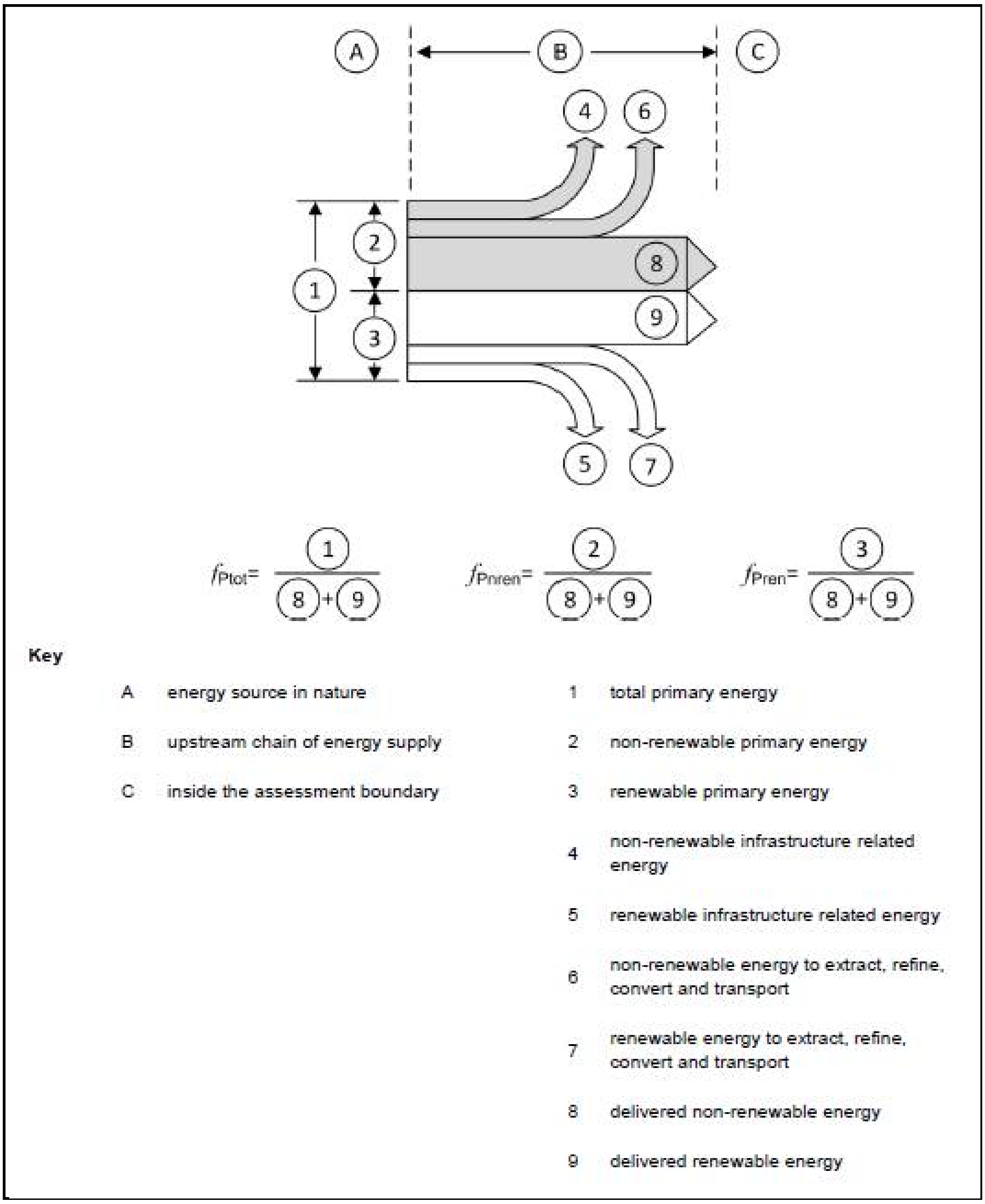

Figure 1. Primary energy factors
(Source: prEN 15603:2015)

2.2 Criteria how to rate nZEBs

The EN 15603:2008 (Energy performance of buildings — Overarching standard EPB) standard specified a general framework for the assessment of overall energy use of a building, and the calculation of energy ratings in terms of primary energy. The revision of this standard was required due to the EPBD recast. As a result of the revision new terms and definitions related to nZEB were introduced in the standard in 2015, furthermore a new rating methodology was proposed for nearly zero energy buildings.

Concerning the nZEB rating, the revised standard follows the approach that using only the primary energy consumption to rate the nZEB buildings may lead to disproportionate building design. The high usage of renewable energy with low primary energy factors would compensate building structures with poor insulation, which can lead to waste the produced energy. Therefore the nZEB requirements may be defined on several levels, not only with primary energy indicator.

The standard proposes to combine the different requirements in a coherent assessment of nZEB. The proposed assessment methodology goes step by step 'from the needs to the overall energy performance expressed in primary energy use'. Only if the requirement of each step is reached, then the building can be qualified at the end as 'nZEB'. At this point of the project the non-renewable primary energy, the renewable energy ratio and the CO_2 emission were selected as nZEB indicators (see in Chapter 5), but later within the lifetime of the RePublic_ZEB project the following requirements given by prEN 15603:2015 standard may also be included in the final requirements related to nZEB public buildings:

1) First requirement: Building energy need

According to prEN 15603:2015 the first requirement should examine the quality of the building envelope, characterized by the *building energy need*. The following parts should be taken into account:

- Thermal characteristic of the building envelope;
- Transmission and ventilation properties;
- Partition of building into different zones;
- Climatic data;
- Heat gains from internal heat sources, solar properties;
- Comfort requirements.

All the components above should be designed in a way, to guarantee the proper indoor climatic conditions, and to avoid the negative effects such as poor indoor air quality. The energy needs should be calculated with EN ISO 13790.

2) Second requirement: Total primary energy use

The second requirement should examine the performance of the technical building systems (heating, cooling, DHW, ventilation, lighting), characterized by the energy use. The technical building systems consume different energy carrier. To sum up these different energy carriers the energy consumptions should be expressed in *total global primary energy*.

As specified in EN 15217, the *Energy Performance* (EP) is expressed as the building *global primary energy demand* divided by the *conditioned area*. The *global* primary energy refers to all the EPBD energy services (heating, cooling, DHW, ventilation, lighting) and is calculated according to EN 15603.

EP can either include only non-renewable energy (EP_{nren}), or include both non-renewable energy and renewable energy (EP_{tot}). According to EN 15603:

$$EP_{tot} = EP_{nren} + EP_{ren}$$

$$RER = EP_{ren} / EP_{tot}$$

Thus, the primary energy factors can be defined as:

- renewable primary energy factor: taking into account only renewable energy overheads of delivery to the point of use, excluding non-renewable energy overheads and primary energy components;
- non-renewable primary energy factor: taking into account only non-renewable energy overheads of delivery to the point of use, excluding renewable energy overheads and primary energy components;

- total primary energy factor: the sum of the non-renewable primary energy factor and the renewable primary energy factor.

The total primary energy factor takes into account the losses outside the assessment boundary (e.g. electricity generation and distribution). The total primary energy use should be calculated according to prEN 15603.

3) Third requirement: Non-renewable primary energy use without compensation and exported energy

The third requirement should examine the usage of renewable energies, characterized by the non-renewable primary energy consumption. The third requirement does not take into account:

- Compensation between different energy carriers (e.g. between gas and on-site PV production);
- The effect of exported energy.

This requirement takes into account only the energy that is used to provide on-site services.

4) Fourth requirement: Final nZEB rating – Numerical indicator of non-renewable primary energy use with compensation

Through the final nZEB rating the compensation between energy carriers and the effect of exported energy is taken into account.

2.3 Principles of nearly zero energy buildings

The flexibility of the nZEB definition in EPBD towards its adaptation to the local and regional level, as well as the practical application of nZEB definition in Europe have shown that there are a number of challenges that needs to be addressed in its successful implementation. The study *"Principles For nearly Zero-energy buildings - Paving the way for effective implementation of policy requirements"* of the Buildings Performance Institute Europe (BPIE) sets several challenges that needs to be overcome and presents three main principles. These challenges and principles is interesting for describing the nZEB concept of public buildings, therefore in the following the relevant outcomes are presented.

The first challenge is related to the objectives of the EU in terms of carbon emissions, energy efficiency, use of renewable energy sources and other indicators. EU targets for carbon emissions for 2050, set new conditions for nZEB buildings about nearly zero carbon emissions, despite the requirement for energy consumption. This will directly affect **the level of ambition** in the affected countries.

The challenge to merge the concepts of nearly zero carbon emissions and nZEB with technical solutions that are implemented has its effects on the definition of nZEB. Basically, in the majority of cases, the implications are small, because the reduction in primary energy consumption causes a proportional reduction of CO_2 emissions. There is difference only in the case when nuclear energy is used. Therefore, it is very important the **conversation factors** for conversion of final in primary energy to be accurate and regularly updated.

The ability to expand the definition towards future **energy positive buildings** is also a challenge. The definition should not cause a situation where future buildings could not be converted into positive energy buildings.

The applicability of the definition in different **climatic conditions, types of buildings, traditions** is also a challenge. In terms of climate, there are two proposed options. The first option proposes to calculate the energy requirement for an average European building in average European climate conditions according to EU objectives for 2050. Then these averages could be corrected through the use of national and local versus European degree-days for heating + cooling. The second option is to calculate a fixed value close to zero, which will be the same for all of Europe. This option can be used only if the first option is too complex for practical application.

Next, the question is whether the **household electricity (plug load)** should be taken into account. According to EPBD, the definition should take into account only the energy of certain services: heating, cooling, DHW, ventilation and lighting. It is not necessary to include additional energy consumption when considering the nZEB conditions.

Consideration of a **group of buildings** as one unit is also challenging in forming definition for nZEB. The current EPBD considers only individual buildings. Considered according to energy production, for example, district heating, more buildings with mutual heating has advantages such as improved energy efficiency, lower investment etc.

The definition of nZEB need to **balance measures for energy efficient and use of renewable energy sources**. The challenge of this topic is how to do it in terms of meeting the regulations and cost-optimality. Therefore, it is important that the definition has limit on the energy demand and to set conditions for the share that needs to be covered by renewable energy sources.

The relationship between cost-optimality and the definition of nZEB has significant impact. While common methodology for calculating cost-optimal levels appears, each country may adopt its own methodology. The aim is to gradually diversify these levels towards the goals of 2021. At this point, each country can set its goals with two limits: upper, which takes into account the cost optimality and lower limit, obtained by applying the latest technologies. These levels in the future are expected to be equalized, given the assumption that energy prices will rise, while the technology prices will fall.

For a definition to be sustainable, it must be clear, flexible in terms of possible application and future technology options, to be consistent with other similar definitions (passive buildings) and ambitious. According to that, for the definition to be sustainable, it must be based on its own principles. The report *"Principles For nearly Zero-energy buildings - Paving the way for effective implementation of policy requirements"* distinguish three principles:

Principle 1: Energy demand

> *There should be a clearly defined boundary in the energy flow related to the operation of the building that defines the energy quality of the energy demand with clear guidance on how to assess corresponding values.*

According to this principle, the boundaries of the system must be determined first, i.e. to determine what belongs in the energy need. According to EPBD, it includes requirements for heating, cooling, DHW, ventilation and lighting. Account to EPBD, lighting is taken into account only in non-residential buildings.

It is recommended that each country should set limits on the numerical indicator and that it would have some flexibility. As it is mentioned earlier, each country should determine the lower and upper limit.

Principle 2: Renewable energy share

> *There should be a clearly defined boundary in the energy flow related to the operation of the building where the share of renewable energy is calculated or measured with clear guidance on how to assess this share.*

According to this principle, the minimum share of renewable energy in the energy demand should be determined. According to EPBD, a significant portion of energy needs should be met by on-site or nearby renewable energy sources. But numerical indicator for that significant portion should be determined.

Principle 3: Primary energy and CO_2 emissions

> *There should be a clearly defined boundary in the energy flow related to the operation of the building where the overarching primary energy demand and CO_2 emissions are calculated with clear guidance on how to assess these values.[1]*

Extensive use of renewable energy does not necessarily mean a significant reduction in carbon emissions. An example of this can be heat pumps. Therefore, in addition, numerical indicator for primary energy needs and carbon emissions should be determined.

2.4 The requirements related to the definition of nZEB

According to the EPBD recast, nearly zero energy buildings are defined (Article 2, paragraph 2) as buildings with high energy characteristics and with nearly zero or very low energy need (as defined in Annex 1 of the Directive), which most of that need should be provided by energy generated from renewable sources on site or nearby.

The general international definition of nearly zero energy buildings included in the EPBD recast determines the main requirements:

1. Very high energy performance: nearly zero, or very low amount of energy.
2. The energy use should be covered to a very significant extent by energy from RES (on-site or nearby)

The application of the definition at national level means that these requirements should be included in the national, regional and local requirements and according to them, to provide numerical indicators. The definition gives significant freedom in the interpretation of the requirements for applications, as well as the approach for the implementation of the definition, thus the existence of a number of different definitions for nZEB.

Authors of the report called *Towards nearly zero-energy buildings: Definition of common principles under the EPBD* made a database (sheet) with 75 certification schemes, definitions and descriptions of nZEB in 17 countries. Only part of these definitions is accepted nationwide, while the rest are other voluntary implemented definitions by NGOs, associations and companies. The conclusion from that analysis is that in Europe there are a number of variants of the concept of nZEB. Some of the concepts are mostly concentrating on the performance of the building and technical building systems (passive houses, low energy houses). However many definitions do not set requirements for energy ratings and energy performance indicators, but set a levelled annual energy balance with different categories. Based on previous research on existing nZEB definitions, standards and legislation, the report *Towards nearly zero-energy buildings: Definition of common principles under the EPBD* presented the basic and specific categories of the requirements that one nZEB definition should contain. The requirements related to nZEB should be as follows:

1. Unit of balance: site energy, total primary energy, non renewable primary energy, equivalent carbon emissions, environmental credits and politically/strategically decided factors with respect to the strategic aims (climate change, resources, energy costs, etc.).

2. Calculation system: space heating, DHW, cooling and air conditioning, auxiliary energies, lighting, central services, user specific consumption (e.g. appliances, plug loads, information systems, etc.) embodied energy (e.g. for erecting, recurring or complete life cycle), and electric mobility.

3. System boundaries: definition of generation sectors in order to clarify, which renewable energy options are considered.

4. Weighting system: determining conversion factors depending on the unit.

5. Normalization: depending on the reference area.

6. Balance period: annual, monthly, etc.

7. Minimum requirements: comfort level, indoor temperatures, air quality, lighting standards, minimum efficiency indicators, definition of low amount of energy and significant extent of energy that should be covered by renewables.

The project Task 40 / Annex 52 examined the applicability of the ZEB definition in practice, and it provides five main principles that a definition for ZEB must be based upon. These principles are related to netZEB buildings, but some of them can be important also for nearly zero energy buildings:

1. Boundary conditions
    a. physical boundaries
    b. functionality
    c. effectiveness
    d. climate
    e. comfort

2. Weighting system
    a. metrics
    b. accounting method
    c. asymmetric weighting

3. Net zero balance
    a. Items of the balance
    b. balancing period
    c. energy efficiency
    d. supply options

4. Temporal energy match
    a. load match
    b. grids interaction
    c. carrier switching

5. Monitoring procedure and post occupancy protocol

If we compare the report *Towards nearly zero-energy buildings: Definition of common principles under the EPBD,* and the project *Task40 / Annex 52* outcomes, it can be noted that the categories of requirements that a definition should contain are very similar. These basic requirements can be used for defining the nZEB concept of RePublic_ZEB.

3. OVERVIEW OF THE EXISTING REQUIREMENTS OF PRIMARY ENERGY IN nZEBs IN THE TARGET COUNTRIES

The Article 9 (3a) of the EPBD recast requires Member States to describe the detailed application in practice of the definition of nearly zero energy buildings, reflecting the national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. All of the target countries, except Macedonia, transposed the definition of nearly zero energy building into the national legislation, however many of them has not yet introduced the numerical requirement in terms of annual primary energy use.

The situation is better for setting the primary energy requirements according to the principle of cost optimality. Article 4 of the recast EPBD requires Member States to take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels. According to Article 5, Member States shall calculate cost-optimal levels of minimum energy performance requirements using the comparative methodology framework. In most of the target countries, except Macedonia and Greece, the cost optimal calculations have been performed.

In the RePublic_ZEB project the approach for setting the upper limit of the energy demand of nZEBs is taking into account the principle of cost optimality, whilst the lower limit will be set by considering the best available technologies. Therefore it makes sense to present the existing nZEB requirements in the target countries. On one hand it is useful to review the existing values, on the other hand it may serve basis for setting requirements for those countries which have not formulated the primary energy requirement for nZEB public buildings (Section 5).

As it is presented in D3.1, Croatia and Hungary introduced the numerical primary energy requirement of nZEB into the national legislation, Slovenia and Romania also elaborated it for nZEB, but the values are not yet confirmed officially. In Bulgaria the current requirements of class “A” means nZEB, so currently the primary energy requirement for different types of nZEBs has been set according to class “A”. In Italy the first calculations were performed for total primary energy consumption of nZEBs for office buildings and for residential buildings respectively, for each climatic zones within the country, however these calculations considered constant indoor temperatures through the heating and the cooling season, 20°C and 26°C respectively, which results relatively high primary energy needs. The RER considered was 50% for the Italian figures, therefore the non-renewable primary is half of the total primary energy.

The existing national requirements of primary energy consumption in the target countries can be seen for nZEB office buildings on Figure 2, nZEB health care facilities on Figure 3, nZEB residential buildings on Figure 4, and nZEB educational buildings on Figure 5, in numerical order. The presented figures express non-renewable primary energy.

The primary energy consumption of public buildings includes the annual primary energy consumption of heating, cooling, DHW, ventilation and lighting (except residential buildings, where lighting is not considered). The heating and the cooling energy demand depends on the geographical location and the climatic conditions, whilst the energy need of DHW production, lighting and the ventilation are practically independent from the location within the target countries. Several target countries, which already set the nZEB requirement on primary energy, have similar climatic conditions as it was shown in D3.1, but the available requirements are quite different, which may mean the level of ambition of the nZEB requirement varies among the countries.

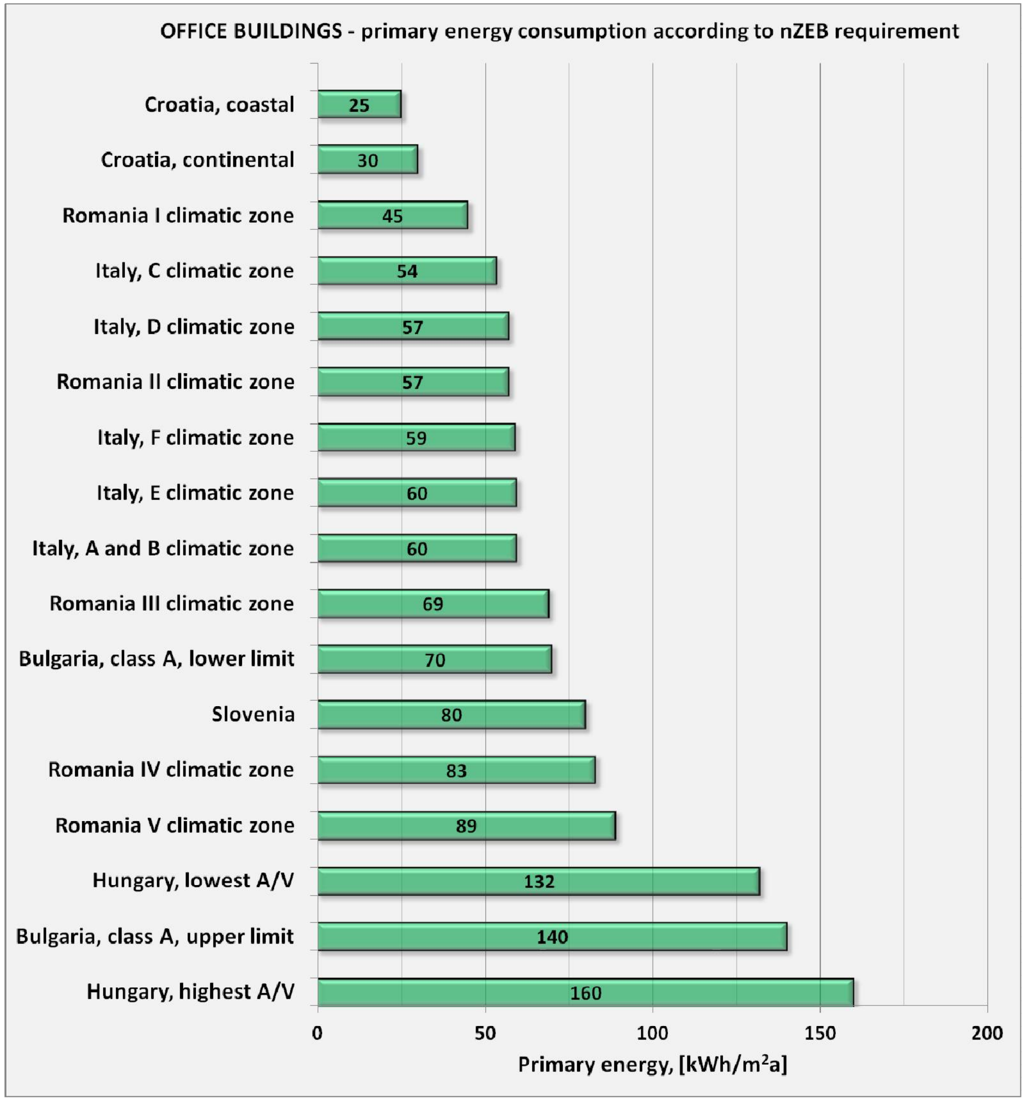

Figure 2. Existing requirement of primary energy consumption in nZEB office buildings

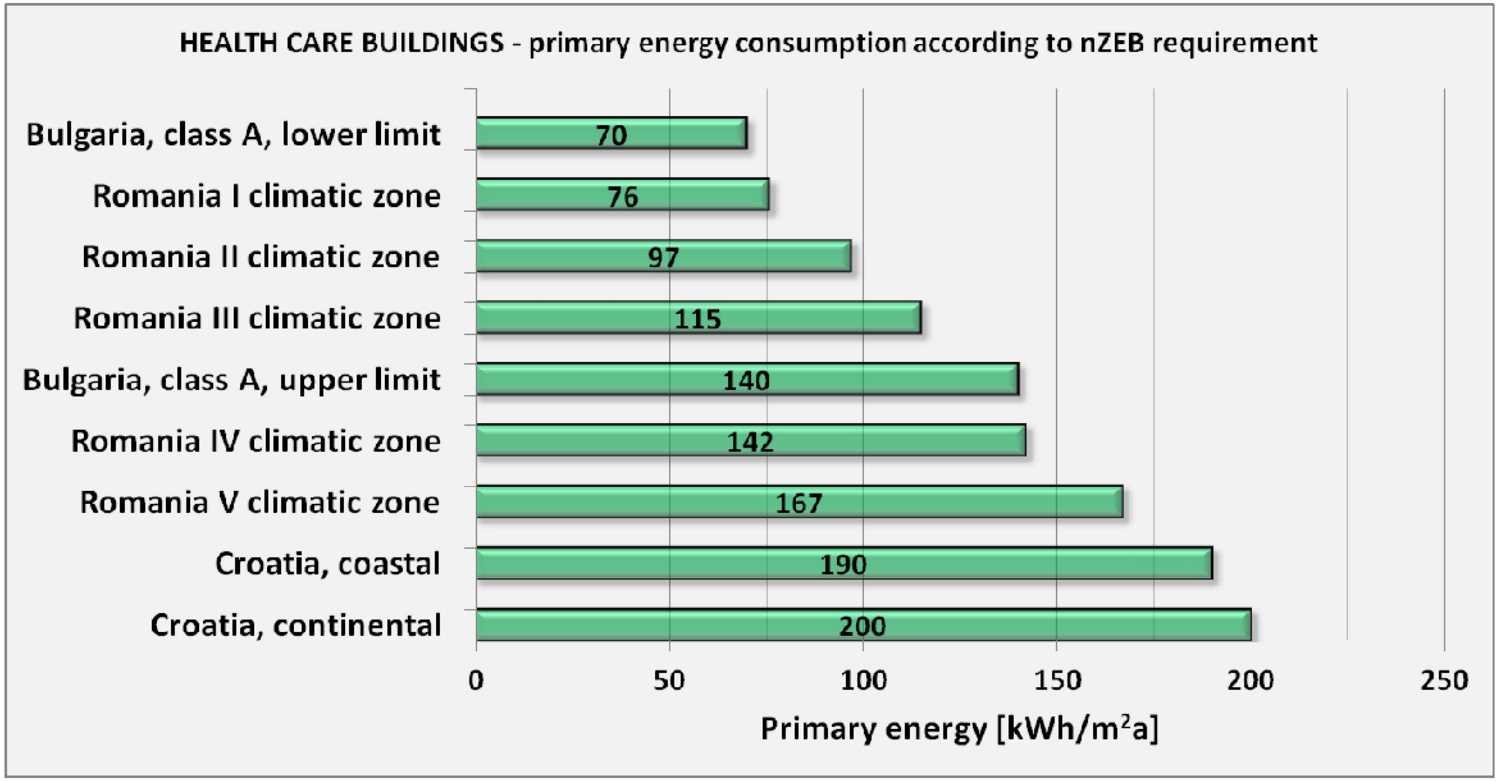

Figure 3. Existing requirement of primary energy consumption in nZEB health care buildings

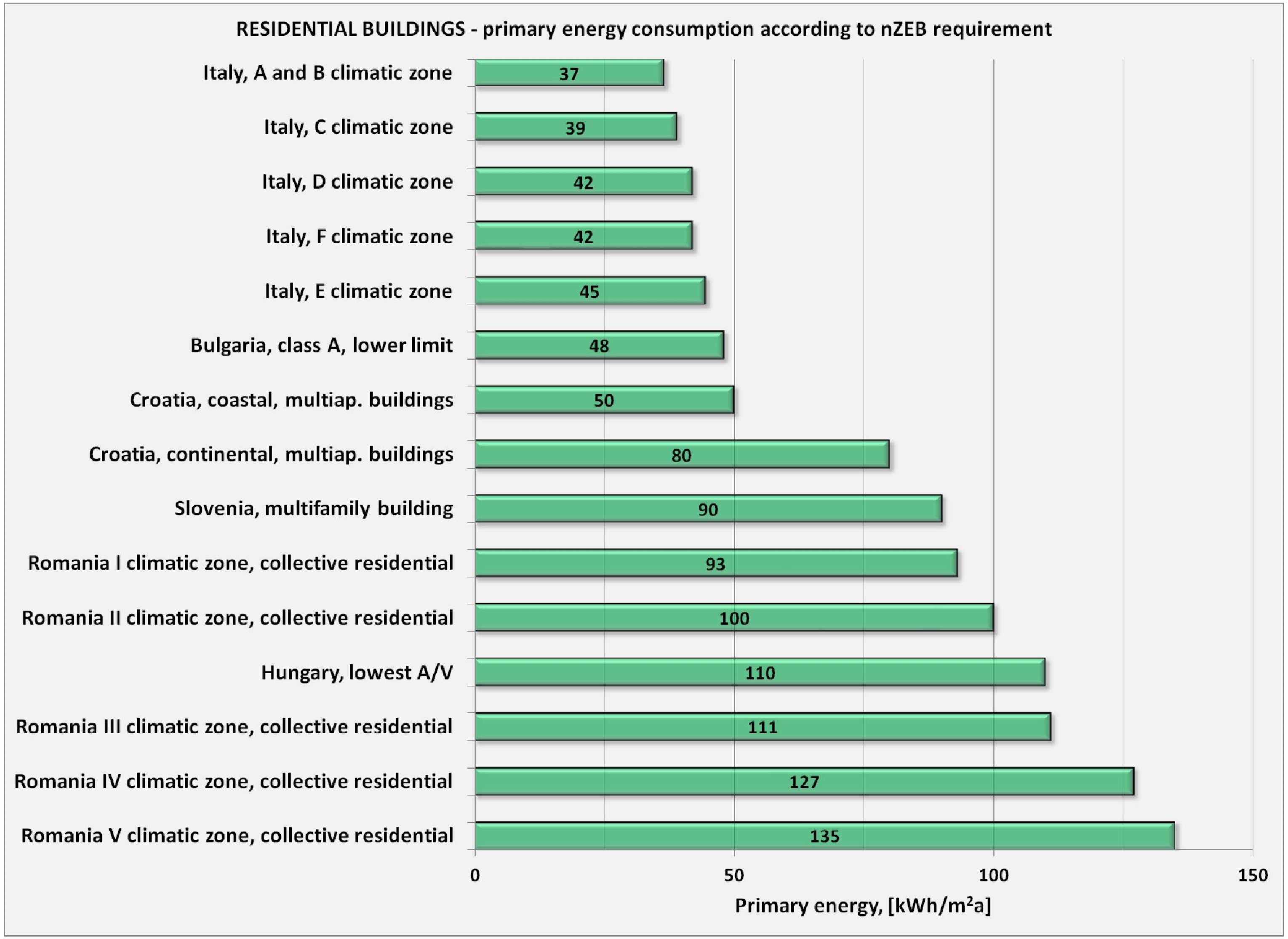

Figure 4. Existing requirement of primary energy consumption in nZEB residential buildings

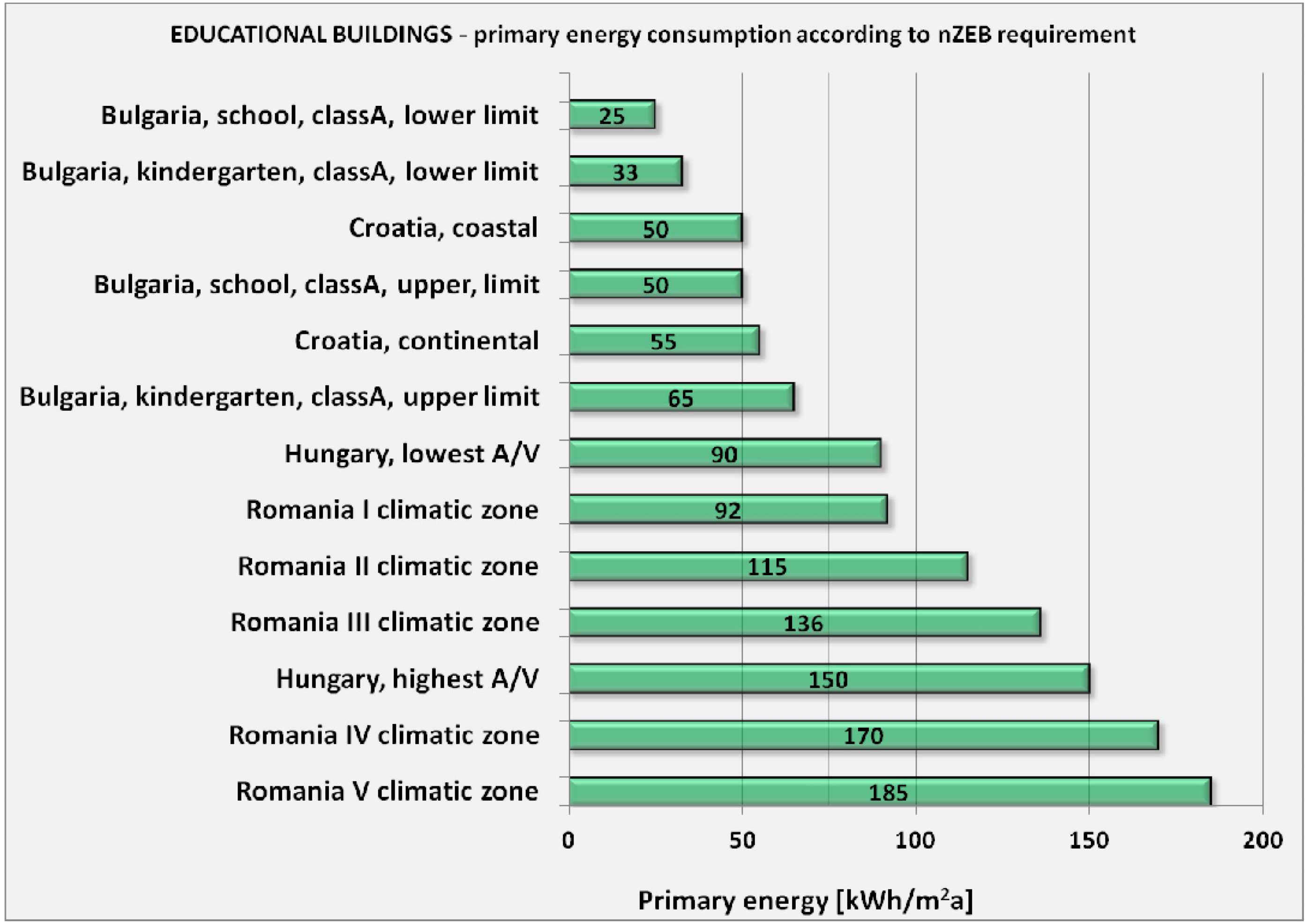

Figure 5. Existing requirement of primary energy consumption in nZEB educational buildings

4. HARMONIZED METHODOLOGY FOR THE DEFINITION OF nZEB

The EPBD recast set a general definition for nZEB, but the practical application of the definition and setting a numerical indicator for the primary energy consumption based on local conditions are the responsibility of Member States. The general definition of the nZEB in the EPBD recast includes two requirements that should be followed every nZEB building. The first one is the very high energy performance, and the second one is the low amount of energy should be covered to a very significant extent by energy from on-site or nearby renewable sources.

These two requirements define the general principles of nearly zero energy buildings, but the details should be elaborated on one hand to avoid different interpretation, and on the other hand to ensure the practical application of the definition. This Chapter of the D3.2 report takes into account the relevant standards and studies that were presented mainly in Chapter 2, and it considers also the current legislative status and the requirements of the target countries in South and East Europe in order to give a proposal for the common framework and a harmonized methodology for the definition of nZEB concept for public buildings. The proposed suitable parameters to describe a nZEB, the units of these requirements, the system boundaries, the energy conversion factors, the delivered and exported energy uses to be considered will be presented.

4.1 Principles of nZEB public buildings

The categories of requirements that a definition should cover were reviewed in Chapter 2. These requirements are directly derived from the principles for nZEB; they are tailoring the definition according to the principles and make the definition practically applicable. The requirements for nZEBs are elaborated the recommendations based on the EPBD and RED.

Unit of balance

This includes reference figure for balancing the energy demands, such as: site energy, non-renewable primary energy, total primary energy, exergy, equivalent carbon emissions, energy costs, environmental credits and politically/strategically decided factors with respect to the strategic aims (climate change, resources, energy costs, etc.).

According to Article 9 (3a) of the EPBD recast **the primary energy is considered for unit of balance.**

Type of energy use to be considered in the calculation

The systems that will be included in the balancing the primary energy with renewable energy and the defining of the energy needs should be determined. These can be (at present or in the future): space heating, domestic hot water, cooling and air conditioning, auxiliary energies, lighting, central services, user specific consumption (e.g. appliances, plug loads, information systems, etc.) embodied energy (e.g. for erecting, recurring or complete life cycle), and electric mobility.

According to Article 2 (4) of the EPBD recast, the energy performance of a building means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building. For public buildings the energy used for **heating, cooling, ventilation, domestic hot water and lighting will be considered.** For those public buildings, which function is residential building (e.g. social house), the lighting will not be considered in the energy performance according to the EPBD recast.

System boundaries

Definition of generation sectors to clarify which renewable energy options are considered – defining what on-site and limitation of nearby renewable energy sources.

This can include definition of the physical boundaries as well – if one building or more buildings as one block is allowed.

EPBD/RED: Article 2.2 of the EPBD **-** "The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" [2]

According to this article of the EPBD, **on-site and nearby renewable energy sources can be taken into consideration for implementation of nZEBs**.

The clear description of the system boundaries and the energy flow of nZEBs are detailed in Chapter 4.2.

Conversion factor

Determining conversion factors depending on the unit related to the energy demand and generation. In the RePublic_ZEB project **the national primary energy factors will be considered**.

4.2 Definition of nearly zero energy buildings' energy flow and system boundaries

In the next two sub-chapters the energy flow and the system boundary is presented related to the nearly zero energy buildings.

4.2.1 Energy flow of nearly zero energy buildings

The energy flow has to be clarified in order to ensure a common calculation methodology of primary energy, as well as renewable energy ratio (RER) for nearly zero energy buildings in the target countries. The proposal for the calculation of the energy flow and for the system boundary is mainly based on Rehva Report No. 4 and prEN 15603:2015 standard. The proposed calculation methodology is in line with the guideline accompanying Commission Delegated Regulation (EU) No 244/2012.

The main points that shall be considered for the energy flow of nearly zero energy buildings:

- The *building needs* are heating, cooling, ventilation, DHW, lighting and appliances. The *building energy need* consists of heating energy, cooling energy, and electricity for lighting and appliances, respectively. The *building energy need* exists due to the heat transmission between the building and its environment, the solar gains and loads, and the internal heat gains and loads.The *building energy need* does not include the losses of building technical system. All components of the building energy need are included in the energy performance of nZEB public buildings except the energy use of the appliances. Furthermore lighting is not included in the energy performance of residential buildings.
- The *building energy use* is the energy use of the building technical systems, which includes all the conversion and system losses.
- *On-site renewable energy* is the heating energy, cooling energy or electricity that is produced from non-fossil renewable sources, like solar, geothermal, aerothermal, hydrothermal, biomass, biogas, wind, hydropower, etc. The solar gains and loads, which

may have a significant effect on the building energy need, are not taken into account as renewable sources.

- *Exported energy* is the energy supplied by technical building systems through the assessment boundary.
- It is very important that the renewable energy produced on site shall be deducted from the amount of energy to be delivered to the building site, and is taken into account in the calculation of the delivered and exported energy balance at the building site. So, the energy produced on-site from RES has to be deducted from the energy use of the building technical system, which results lower amount of delivered energy. If the produced renewable energy (usually the electricity produced by PV, but it can be heating or cooling energy as well) on site is higher than the building need, than it shall be considered as exported energy, which reduces the primary energy consumption.

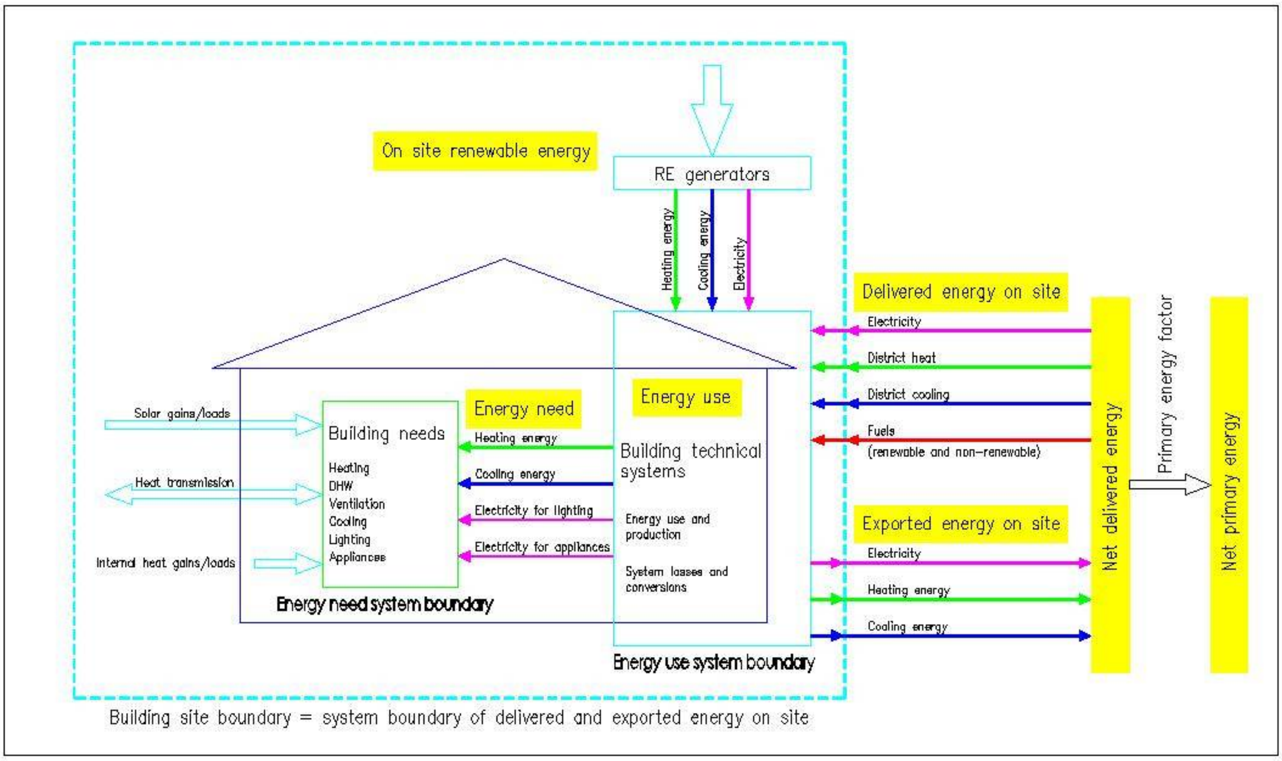

Figure 6. System boundary of delivered and exported energy on site

(Original source: Rehva Report No. 4. REHVA nZEB technical definition and system boundaries for nearly zero energy buildings)

The consideration of **non-renewable net primary energy,** so as the deduction of the exported energy from the delivered energy, is consistent with the guideline accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012. This nZEB concept should be introduced in the national legislations regarding the building energy calculation.

4.2.2 nZEB System Boundary

The delivered energies can be classified according to the perimeters, such as on-site, nearby, and distant, respectively. The ***on-site energy source*** in the definition of nearly zero energy building means the building, the premises and the parcel of land on which the building is located. On-site renewable energy inter alia could be as follows:

- Solar thermal energy that generated by thermal solar collectors installed on the roof, on the building facade, or on the premises.
- Thermal energy (for heating and/or cooling, and/or DHW) that generated by geothermal/air to water/water to water heat pump installed in the building, or on the premises.

- Thermal energy (for heating and/or DHW) that generated by biomass boiler installed in the building, or on the premises.
- Electricity that generated by PV panels installed on the roof, on the building facade, or on the premises.

The building site boundary is the system boundary of delivered and exported energy on site. The relation of *building energy need*, *building energy use*, *delivered* and *exported energy on site*, and *renewable energy on site* can be seen in Figure 6.

Another important issue is the specification of *nearby* in terms of nZEB. Based on the experience of D3.1 report, the meaning of nearby is different in the Member States, therefore it makes sense to consider the *nearby* and the *distant* definitions that are included in prEN15603:2015 in this context to make a common understanding on them. ***Nearby energy source**,* means energy source, which can be used only at local or district level, connected to the same branch of the distribution network (for electricity: distribution network means medium voltage or lower), or having a dedicated connection, requiring specific equipment for the assessed building (or building unit) to be connected to it (for example district heating, or district cooling). The nearby assessment boundary can be seen on Figure 7 representing the energy flow at *on-site* and *nearby.*

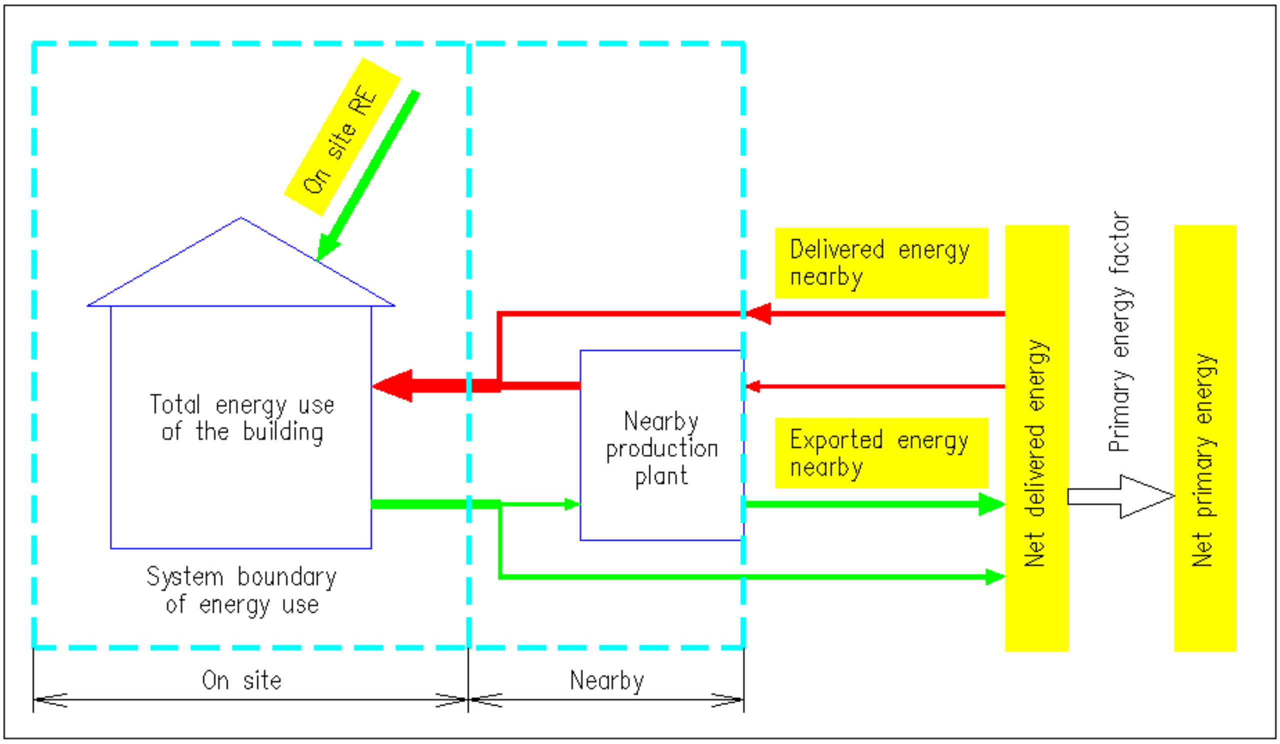

Figure 7. Nearby assessment boundary to be used in the case of nearby energy production linked contractually to the building
(Original source: Rehva Report No. 4. REHVA nZEB technical definition and system boundaries for nearly zero energy buildings)

Distant energy sources means not on-site nor nearby energy sources.

The concept of on-site, nearby and distant perimeters and the assessment boundary is represented on Figure 8.

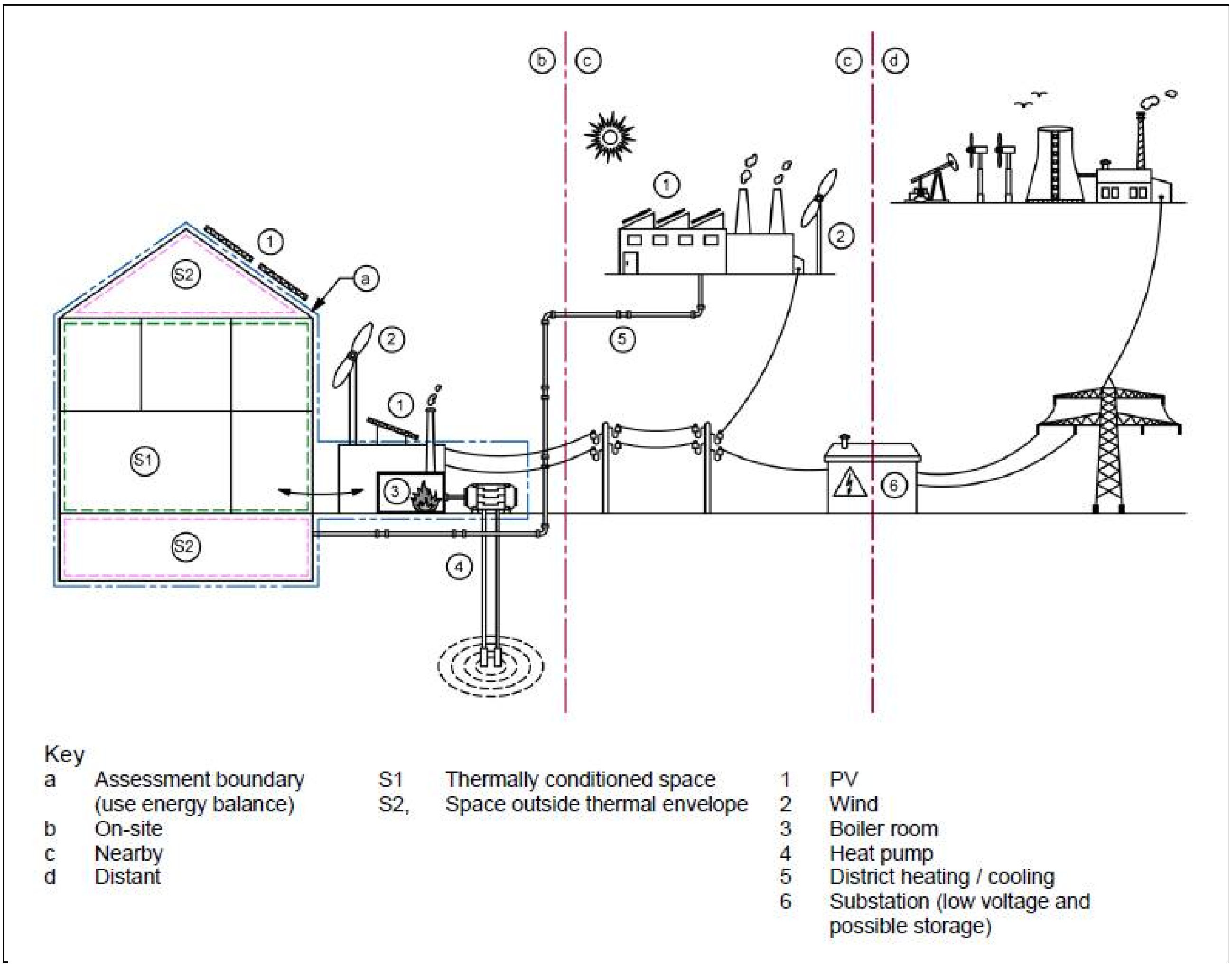

Figure 8. Schema representing the concept of perimeters and assessment boundary
(Source: pr EN 15603)

4.3 Renewable Energy Ratio

For the calculation of the RER, the renewable and the non-renewable primary energy factors and the amount of delivered and exported energy are needed to know. As it is presented on Figure 1 in Chapter 2, the non-renewable primary energy factor expresses the amount of delivered non-renewable energy to the total primary energy, whilst the renewable energy factor represents the amount of delivered renewable energy to the total primary energy. The equation of renewable energy ratio for nearly zero energy buildings is as follows:

$$RER_P = \frac{\sum E_{Pren,RER}}{\sum E_{Ptot}} \quad (1)$$

where

RER_P is the Renewable Energy Ratio, [-]
$E_{Pren,RER}$ is the renewable primary energy, [kWh/m^{2}a]
E_{Ptot} is the total primary energy, [kWh/m^{2}a]

The renewable primary energy has to be calculated as follows:

$$\sum E_{Pren,RER} = \sum_i E_{ren,i} + \sum_i \left(\left(f_{del,tot,i} - f_{del,nren,i}\right) E_{del,i}\right) \tag{2}$$

where

$E_{ren,i}$	is the renewable energy produced on site or nearby for energy carrier i, [kWh/m^{2}a];
$f_{del,tot,i}$	is the total primary energy factor (-) for the delivered energy carrier i;
$f_{del,nren,i}$	is the non-renewable primary energy factor (-) for the delivered energy carrier i;
$E_{del,i}$	is the delivered energy on site or nearby for energy carrier i, [kWh/m^{2}a];

The total primary energy has to be calculated as follows:

$$\sum E_{Ptot} = \sum_i E_{ren,i} + \sum_i \left(E_{del,i} f_{del,tot,i}\right) - \sum_i \left(E_{\exp,i} f_{\exp,tot,i}\right) \tag{3}$$

where

E_{Ptot}	is the total primary energy, [kWh/m^{2}a]
$E_{ren,i}$	is the renewable energy produced on site or nearby for energy carrier i, [kWh/m^{2}a];
$E_{del,i}$	is the delivered energy on site or nearby for energy carrier i, [kWh/m^{2}a];
$f_{del,tot,i}$	is the total primary energy factor (-) for the delivered energy carrier i;
$E_{exp,i}$	is the exported energy on site or nearby for energy carrier i, [kWh/m^{2}a].
$f_{exp,tot,i}$	is the total primary energy factor (-) of the energy compensated by the exported energy for energy carrier i;

These equations proposed to be used by the target countries of the RePublic_ZEB project for calculating the renewable energy ratio in their nZEB public buildings.

5. PROPOSED NUMERICAL INDICATORS FOR nZEB PUBLIC BUILDINGS IN THE TARGET COUNTRIES

After clarifying the energy flow and the RER calculation for nearly zero energy buildings, the numerical indicators should be determined for the characteristic public building categories of the targeted South and East European countries of the RePublic_ZEB project. The EPBD recast clearly promotes primary energy as the indicator for the energy performance of buildings. However, buildings should follow also the EU's long-term goals by 2050, certainly, CO_2 reduction is closely related to the reduction of energy consumption and energy decarbonisation.

5.1 Non-renewable primary energy indicator

The non-renewable primary energy requirement as numerical indicator should be defined for different public building categories. Based on D2.1 the main public building categories which represent significant part of the public building stock in the target countries are as follows:

1. Office building
2. Residential building
3. Educational building
4. Health care facilities

The non-renewable primary energy has to be calculated taking into account the delivered and exported energy and the non-renewable primary energy factors as detailed in Section 4.2, therefore the **non-renewable primary energy indicator** is given by the equation as follows:

$$EP_{nren} = \sum_i \left(E_{del,i} f_{del,nren,i} \right) - \sum_i \left(E_{\exp,i} f_{\exp,nren,i} \right) \quad (4)$$

where

E_{Pnren}	is the non-renewable primary energy, [kWh/m^{2}a]
$E_{del,i}$	is the delivered energy on site or nearby for energy carrier i, [kWh/m^{2}a];
$f_{del,nren,i}$	is the non-renewable primary energy factor (-) for the delivered energy carrier i;
$E_{exp,i}$	is the exported energy on site or nearby for energy carrier i, [kWh/m^{2}a].
$f_{exp,nren,i}$	is the non-renewable primary energy factor (-) of the energy compensated by the exported energy for energy carrier i;

Taking into account the non-renewable primary energy with the deduction of the exported energy for nZEB public buildings is in line with the guideline accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012, and is also consistent with the proposal of the standard prEN15603:2015 (Final nZEB rating: Numerical indicator of non-renewable primary energy use with compensation, Annex H.5 in the standard).

The upper limit of the primary energy indicator is the least ambitious, which can be set according to the principle of cost optimality, whilst the lower limit can be set considering the best available technology, which may not be cost optimal in the current status.

According to the request of EPBD recast each target country of the project, except Macedonia, performed the cost optimal calculations. As a result of these calculations the primary energy value has been formulated for different public building types. These values express the upper limit of the nZEB primary energy consumption, since generally it can be stated that the requirement of primary energy for nZEB is definitely lower than the cost optimal value, and it results higher global costs.

The available cost optimality values of primary energy consumption can be seen for office buildings on Figure 9, residential buildings on Figure 10, educational buildings on Figure 11, and health care facilities on Figure 12. Concerning the health care facilities only Croatia, Bulgaria, Romania and the United Kingdom have elaborated the cost optimal values. Defining the cost optimal values is the request of EPBD recast, however some countries of the target countries have not fulfilled this request. Presumably the cost optimal values of primary energy consumption will be defined before the RePublic_ZEB project finishes, therefore the cost optimal values – as upper limit of the primary energy consumption of nZEB – will be presented for each target country in the final report of the project.

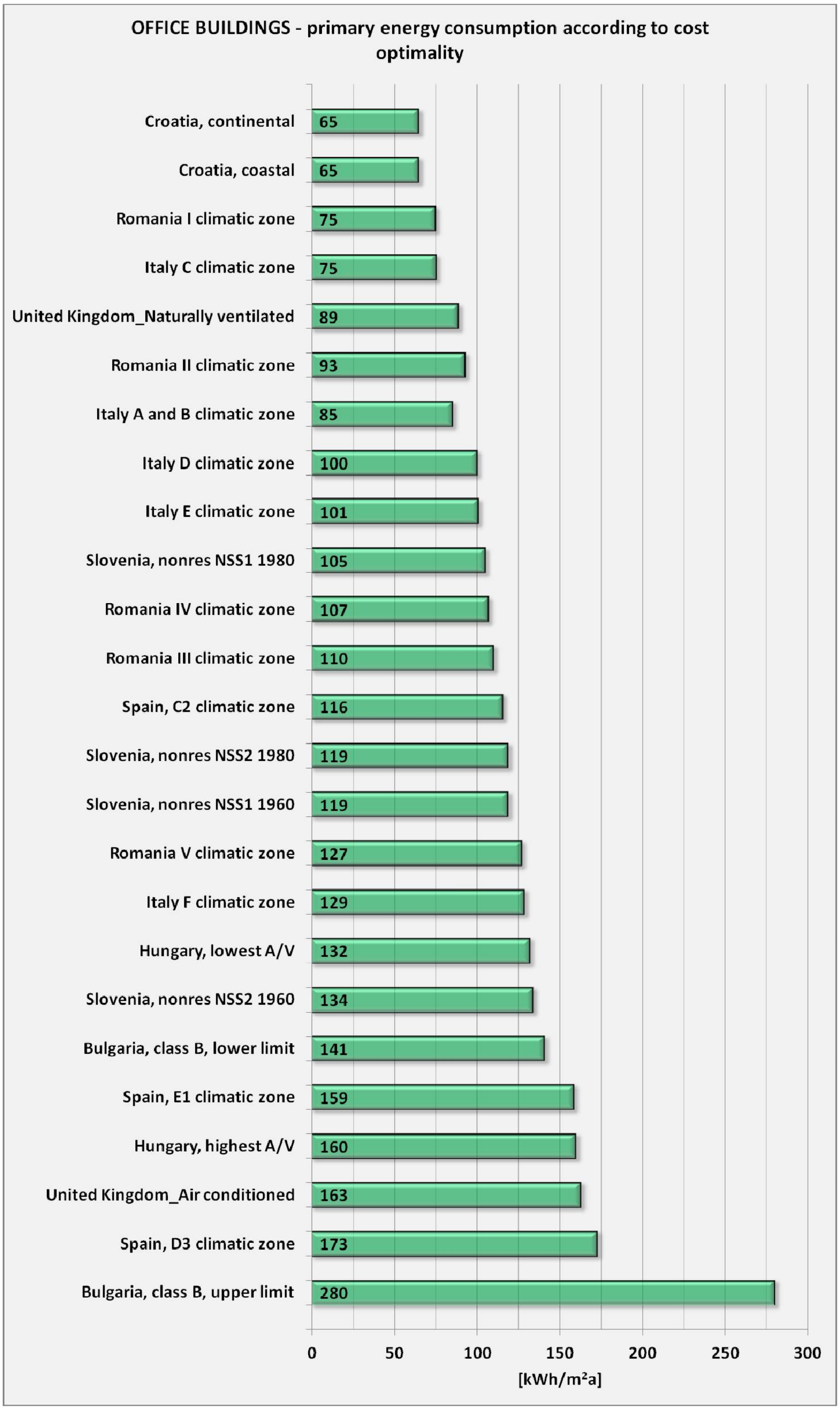

Figure 9. Primary energy consumption according to cost optimality, office buildings

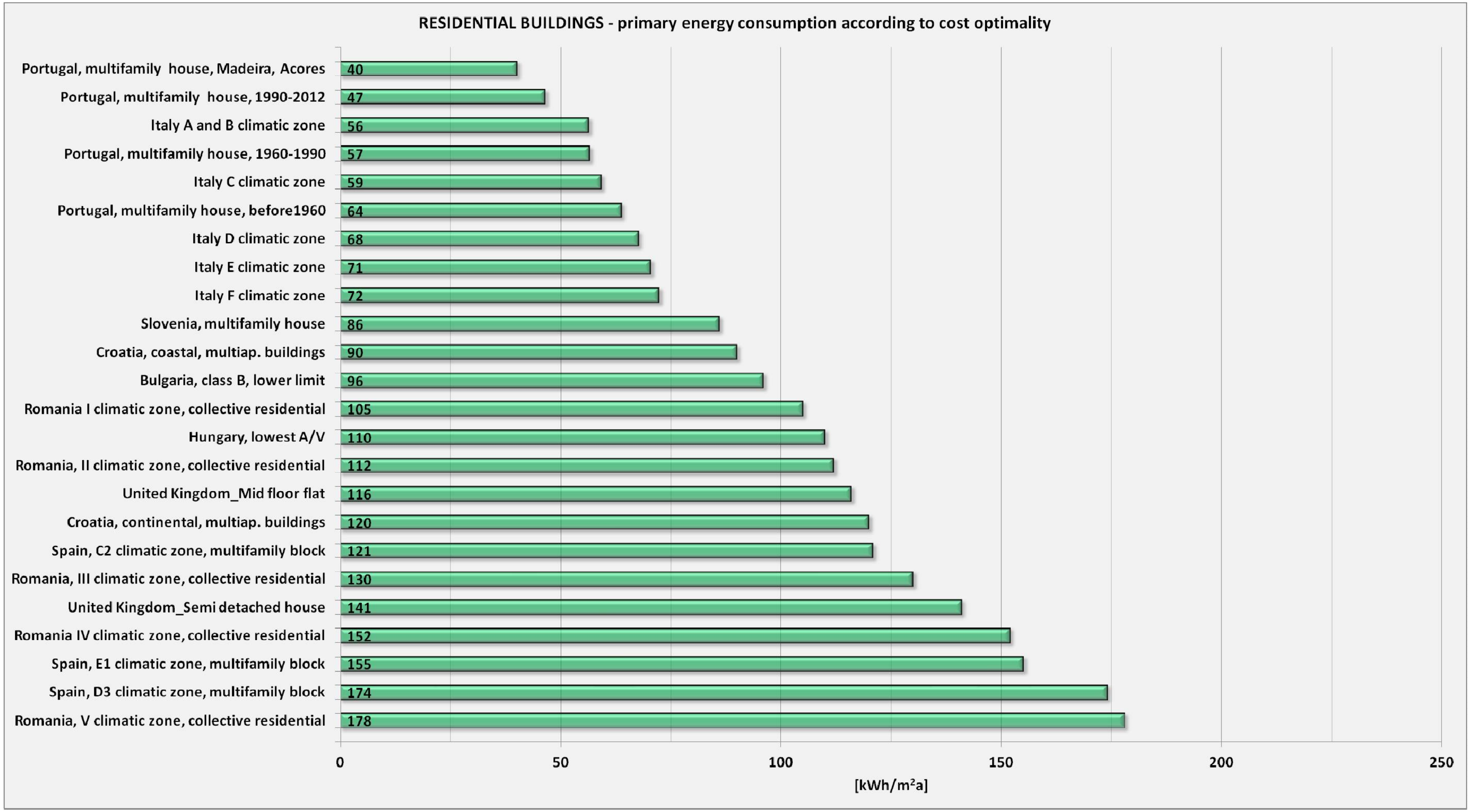

Figure 10. Primary energy consumption according to cost optimality, residential buildings

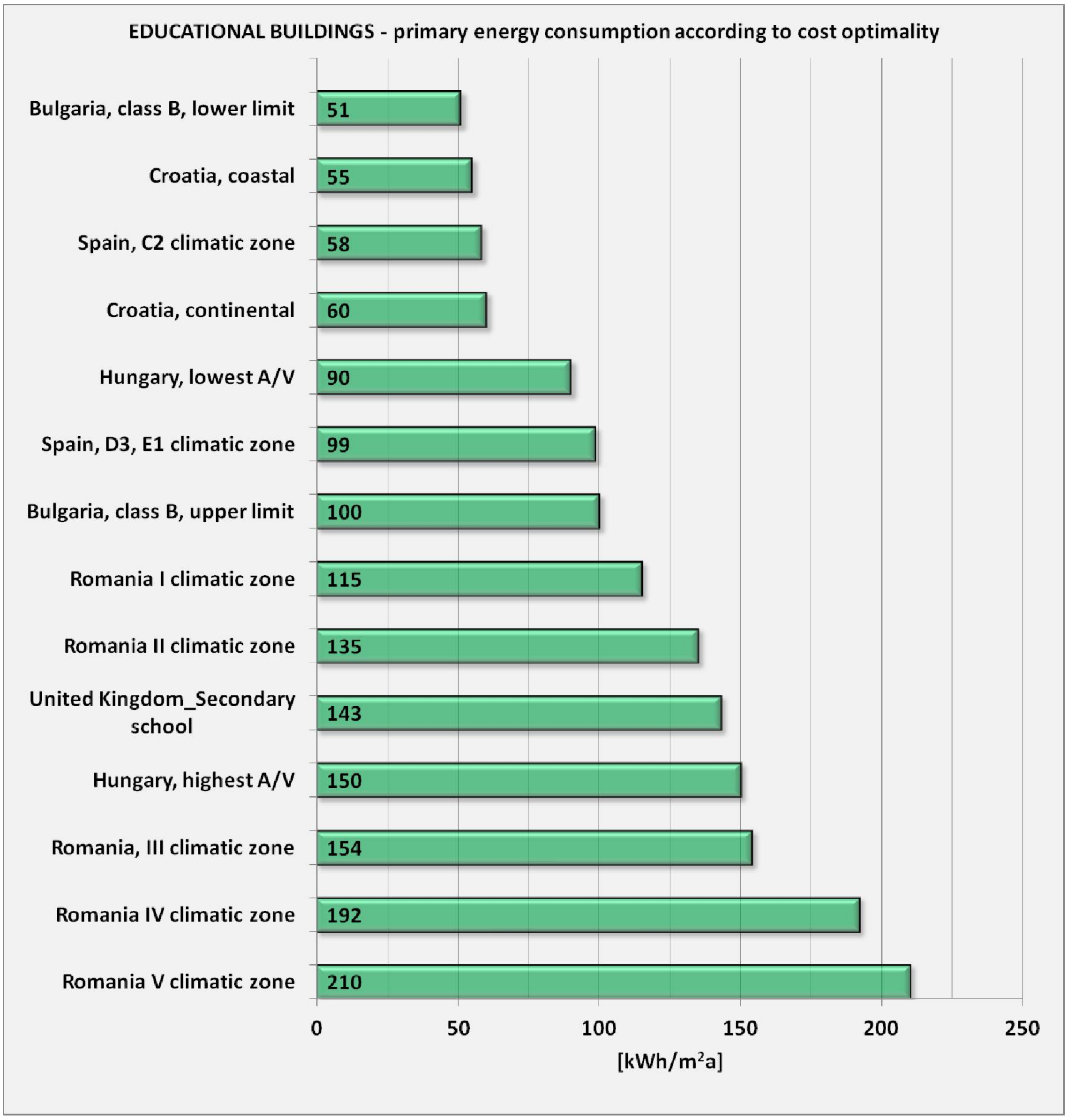

Figure 11. Primary energy consumption according to cost optimality, educational buildings

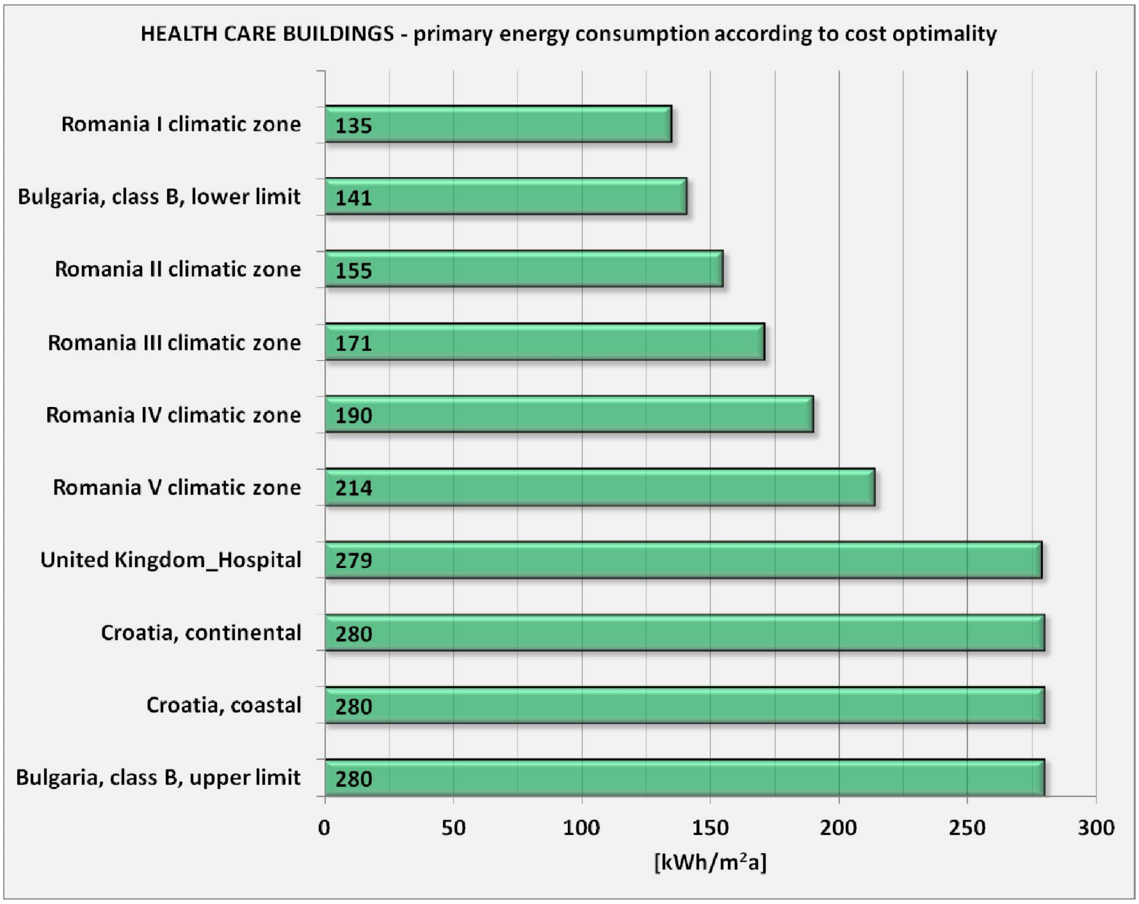

Figure 12. Primary energy consumption according to cost optimality, health care facilities

The lower limit of the primary energy consumption can be set by considering the best available technology. Our proposal is to calculate the lower limit of annual primary energy consumption taking into account the proposed *packages of measures* for the refurbishment of public buildings, including the energy efficiency measures on the building envelope (thermal insulation of external walls, roof, changing the windows, solar shading, etc.), the measures on the high efficient HVAC systems and solutions (low temperature heating, high efficiency heat recovery system, etc.), and the usage of energy generation systems that use renewable energy sources (thermal solar collector, PV, geothermal heat pump, etc.). However, these *packages of measures* will be assembled in a following report of the project (D3.4), and the dynamic building energy simulations will be undertaken at a later stage within the RePublic_ZEB project (WP4).

The solutions to be considered for a nZEB, should meet the following general criteria:

- the EP is lower than the cost-optimal levels (nZEB is more energy efficient than cost-optimal building);
- the differential Global Cost (ΔGC) is negative (nZEB is cost effective)[1];
- the national minimum energy performance requirements for nZEBs are fulfilled.

At this point of the project the lower limit of the primary energy can only be an estimation derived from:

[1] It could be discussed whether a very high energy efficiency non cost-effective solution could be acceptable.

1. Taking into consideration the available nZEB requirements in South and East Europe.
2. Available simulation results of other nZEB related projects.
3. Available data of nZEB buildings as best practices.

It is very important to note when the building energy simulation activity will be executed in WP4 on the selected representative reference buildings (based on D2.2) with the proposed packages of measures (based on D3.4), the estimated lower limit of the primary energy might be modified according to the building energy simulation results.

It has to be also noted that in many cases the requirements, the available simulation results and also the best practice of nZEB buildings are related to new buildings. However, there are several constraints of the refurbishment of existing public buildings – for example the densely built urban environment may reduce the possibility of the utilization of the renewable energy sources, implementing the heat recovery might be difficult due to the lack of mechanical ventilation system in many existing public buildings (see details in Annexes of D2.2), the heat insulation of the basement floor is almost impossible, etc. – therefore it seems that the requirements should not be the same for the refurbishment of existing public buildings as for new buildings.

<u>1) Setting the lower limit of the primary energy of heating considering the available nZEB requirements</u>

Some of the target countries have already introduced requirements of annual primary energy consumption in nZEBs, as it was presented in Chapter 3, which gives the possibility to review these values and to define the requirements for those countries, which have not yet defined the requirement of the primary energy consumption as regards nZEBs.

It is more than evident that the climatic conditions have a great influence on the building energy demand (especially on the heating and the cooling) and therefore on the primary energy consumption. However, it should be noted that the primary energy consumption of public buildings includes several energy services above the heating and the cooling, such as the ventilation, the lighting, as well as the energy consumption of producing DHW. This makes the comparison of the existing primary energy values very difficult. From the overall primary energy need, the heating energy is roughly proportional to the heating degree day, however the other parts of the primary energy consumption influenced by many parameters (internal heat loads, fresh air need, national standards for DHW and lighting, etc.). Therefore it makes sense to review and compare only the heating energy content of the existing requirement of primary energy consumption, taking into account the heating degree days of the representative cities of the climatic zones in the target countries.

Firstly, the heating degree days were calculated considering 18°C base temperature, with a tool that can be found on www.degreedays.net, which uses temperature data from www.wunderground.com. The heating degree days for the representative cities can be seen on Figure 13 and Figure 14.

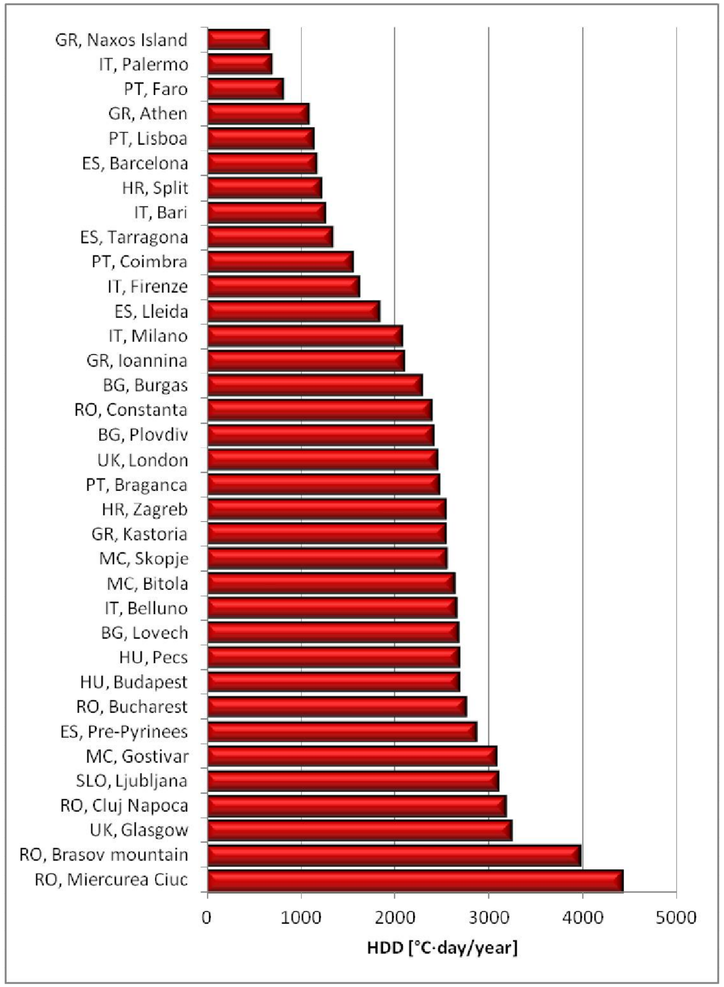

Figure 13: Numerical order of the heating degree days

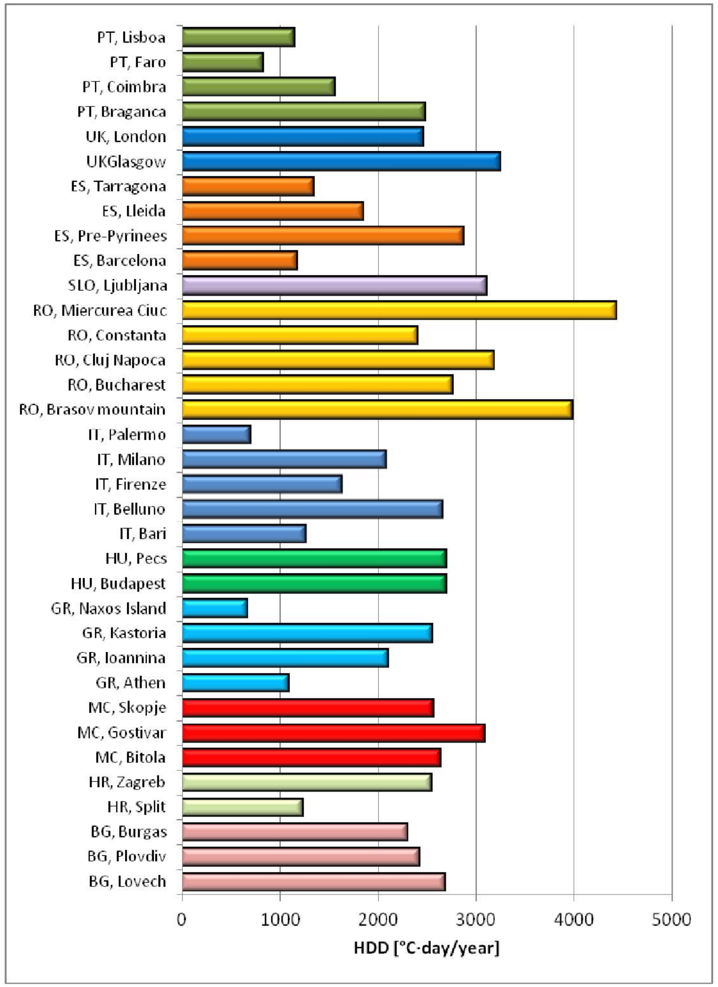

Figure 14: Heating degree days, country by country

The Consortium partners separated the primary energy need of heating from the overall primary energy (including all building services, such as the heating, cooling, DHW, lighting and ventilation) taking into account the main reference building categories. This gave the possibility to compare the existing nZEB primary energy consumption of heating in the target countries and select the values which may serve as reference for those countries, which have not introduced the primary energy requirement on nZEB. The primary energy of heating in nZEB office buildings and the corresponding HDD values are presented on Figure 14 in numerical order. On this figure, the twentieth of heating degree days are presented instead of the overall values, due to the heating degree days are much higher than the primary energy requirement, and the visualisation of these values in a common figure is better on this way.

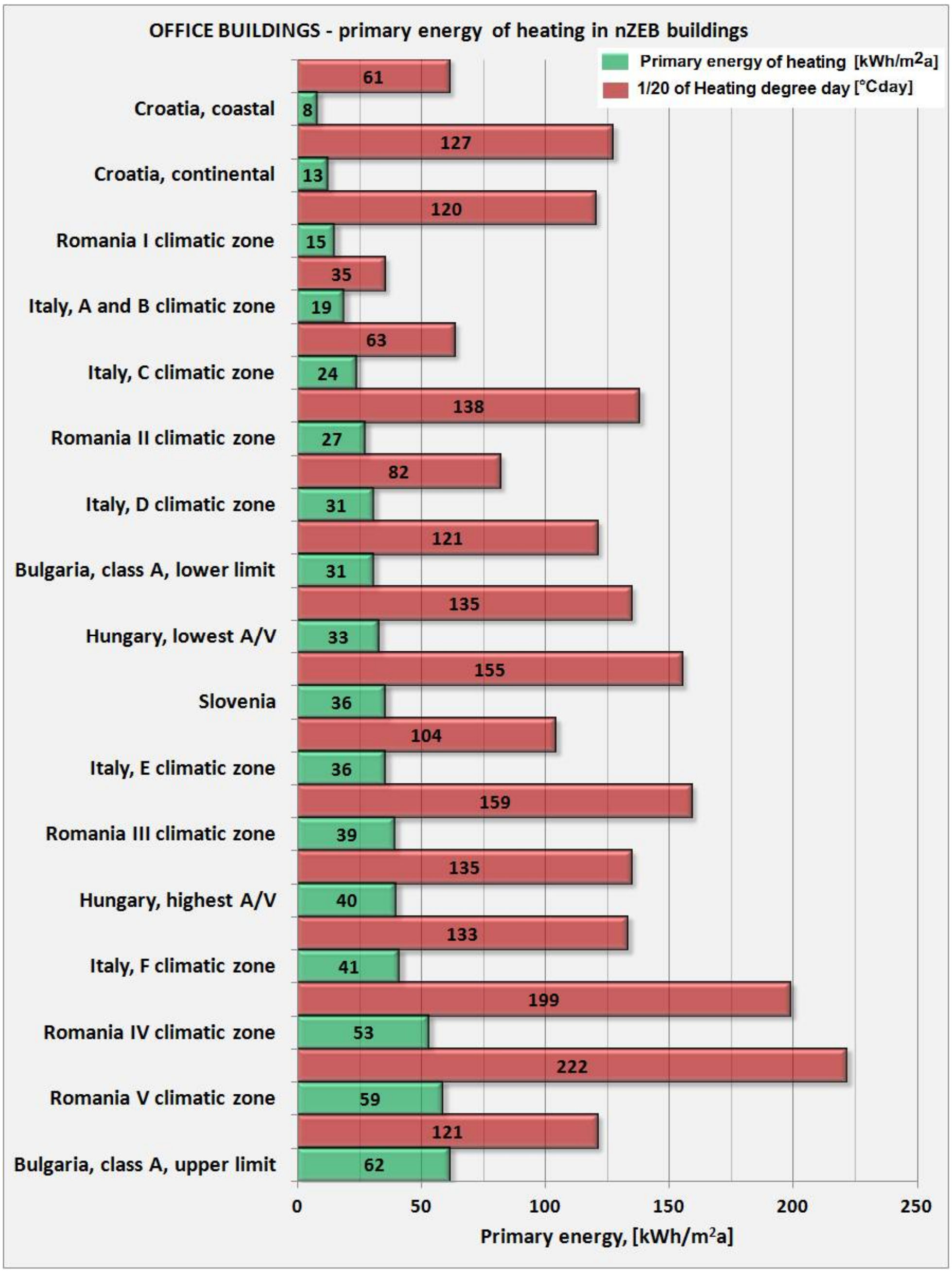

Figure 15. Primary energy of heating in nZEB office buildings and the HDDs

Based on Figure 15 it can be concluded that the numerical order of the primary energy of heating and the heating degree days shows a great difference, which may mean that the existing level of ambition is quite different in these countries and climatic zones. Therefore the comparison of the available nZEB primary energy values of heating makes sense with introducing a new ratio, which expresses the relation of the primary energy of heating to the heating degree day of a climatic zone:

$$PDD = \frac{Ep_{heating}}{(\frac{HDD}{20})} \quad (5)$$

where

PDD is the heating primary energy ratio based on heating degree days, [kWh/m^{2}a(°Cday)]

$Ep_{heating}$ is the annual primary energy consumption of space heating and ventilation [kWh/m^{2}a];

HDD is the annual heating degree day, [C°day]

For example, the heating primary energy ratio (PDD) for the Croatian coastal climatic zone is as follows:

$$PDD = \frac{8}{61} = 0.13$$

The higher value of the PDD may mean the level of ambition of the primary energy requirement is lower, whilst the lower value of the PDD may mean the requirement of the primary energy is stricter.

On one hand the PDD-analysis could be the basis for setting the requirement of primary energy consumption of heating for those target countries, who have not formulated the requirement, and on the other hand the existing requirements can be compared with an appropriate method, which gives a good possibility for proposing stricter requirements for some of the target countries if it seems necessary and achievable.

The PDD ratio was calculated considering all the existing heating primary energy values for office, residential, educational and health-care nZEB buildings in the participant South and East European countries of the RePublic_ZEB project in order to compare the values. Since the point of this comparison is to select those values which could be the reference for the rest of the countries, therefore in each case the three lowest PDD values were selected as reference (Figure 16, Figure 17, Figure 18 and Figure 19, respectively). It has to be mentioned that concerning the nZEB office buildings the Croatian heating primary energy is the lowest value, however it was not considered for setting the reference value of PDD, since in Croatia the primary energy conversion factor for electricity is only 1.6, while in the other participant countries of the project the primary energy conversion factor for electricity is significantly higher. Therefore the Croatian values cannot be applied as reference value to be used in the office buildings.

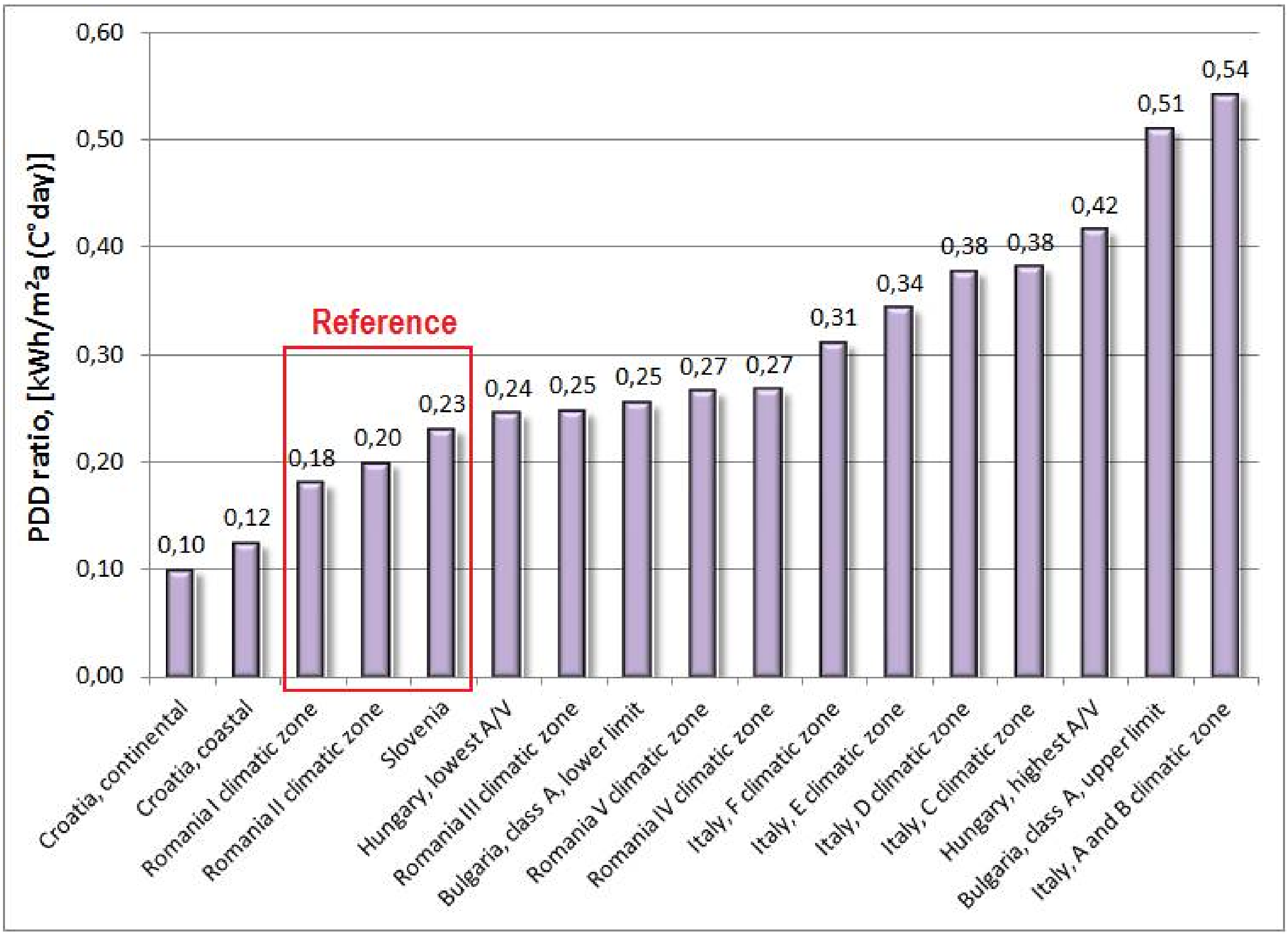

Figure 16. PDD ratio for nZEB office buildings

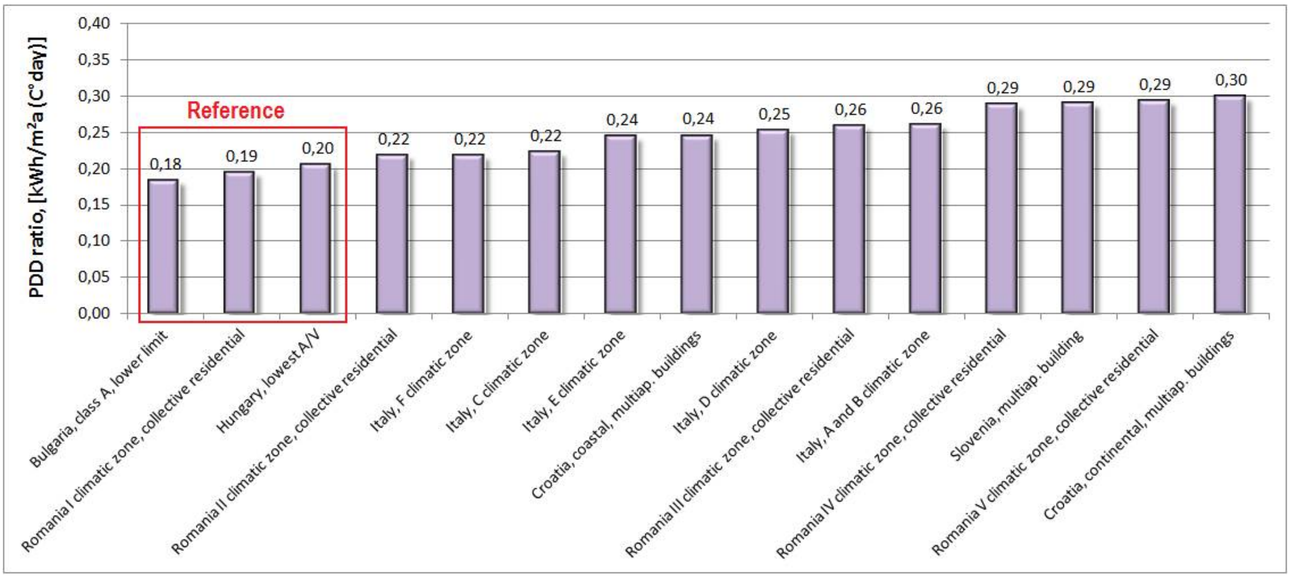

Figure 17. PDD ratio for nZEB residential buildings

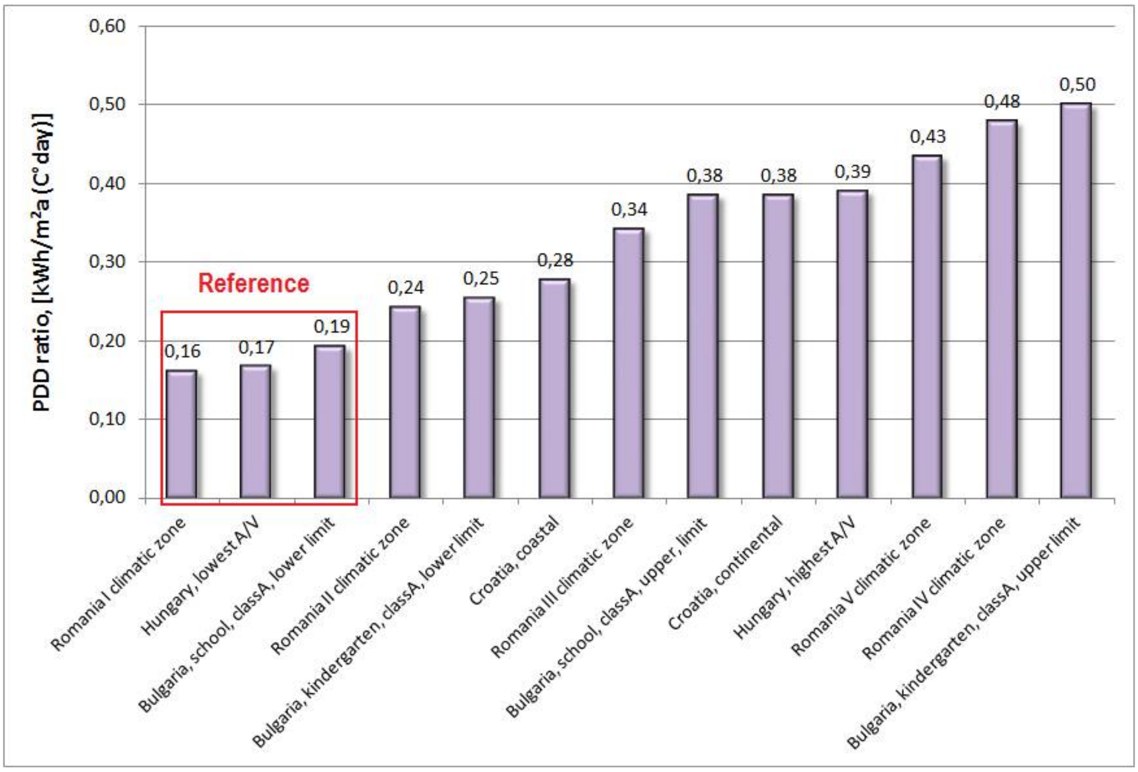

Figure 18. PDD ratio for nZEB educational buildings

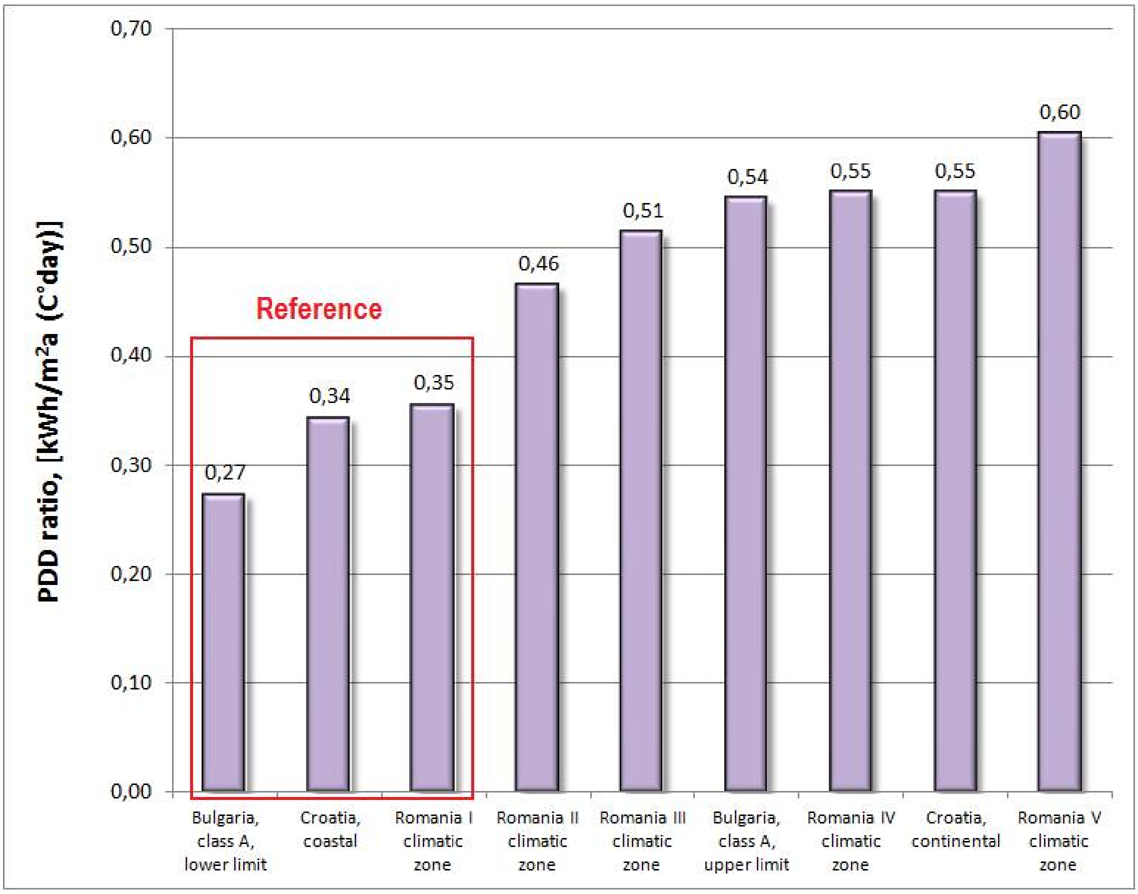

Figure 19. PDD ratio for nZEB health care buildings

The averages of the selected PDD values are then calculated in order to define the reference value of the PDD for the main public building types. This reference PDD value serves the basis for proposing heating primary energy values for nZEB public buildings in the participant countries.

On Figure 16, Figure 17, Figure 18 and Figure 19 the selected PDD values can be seen in red rectangles. The average of these values expresses the reference PDD values which are as follows:

- Office buildings: $PDD_{ref,office}$ = 0.20
- Residential buildings: $PDD_{ref,res}$=0.19
- Educational buildings: $PDD_{ref,edu}$ =0.17
- Health-care buildings: $PDD_{ref,he}$ =0.32

These reference PDDs can be used for setting the primary energy requirement for heating (space heating and ventilation) for those South and East European countries, which has not formulated the nZEB primary energy requirement. The reference primary energy ratio has also been used to propose stricter requirement for those countries which requirement seem to be not ambitious enough. Taking into account the reference PDD values the proposed lower limit of the primary energy requirement of heating is presented in Table 1.

Table 1. Estimation of the non-renewable primary energy of heating as regards different nZEB public building categories

Country, representative city of the climatic zone	Public building category			
	Office buildings [kWh/m²a]	Residential buildings [kWh/m²a]	Educational buildings [kWh/m²a]	Health care buildings [kWh/m²a]
GR, Naxos Island	7	6	6	11
PT, Faro	8	8	7	13
IT, Palermo	7	7	6	11
PT, Lisboa	11	11	10	18
ES, Barcelona	12	11	10	19
ES, Tarragona	13	13	11	21
IT, Bari	13	12	11	20
HR, Split	12	12	10	20
PT, Coimbra	16	15	13	25
GR, Athens	11	10	9	17
IT, Firenze	16	16	14	26
ES, Lleida	18	18	16	30
IT, Milan	21	20	18	33
GR, Ioannina	21	20	18	34
UK, London	25	23	21	39
BG, Burgas	23	22	20	37

RO, Constanta	24	23	20	38
PT, Braganca	25	24	21	40
HR, Zagreb	25	24	22	41
BG, Plovdiv	24	23	21	39
GR, Kastoria	26	24	22	41
IT, Belluno	27	25	23	43
HU, Pecs	27	26	23	43
MC, Bitola	26	25	22	42
MC, Skopje	26	24	22	41
HU, Budapest	27	26	23	43
BG, Lovech	27	26	23	43
RO, Bucharest	28	26	23	44
ES, Pre-Pyrinees	29	27	24	46
MC, Gostivar	31	29	26	49
SLO, Ljubljana	31	30	26	50
UK, Glasgow	32	31	28	52
RO, Cluj Napoca	32	30	27	51
RO, Brasov	40	38	34	64
RO, Miercurea Ciuc	44	42	38	71

Following the above mentioned approach, the **non-renewable primary energy of heating in nZEB public buildings in South and East European countries** are as follows, depending on the geographical location and the climatic condition:

1. **nZEB office building: 7-44 kWh/m^{2}a**
2. **nZEB residential building: 6-42 kWh/m^{2}a**
3. **nZEB educational building: 6-38 kWh/m^{2}a**
4. **nZEB health care building: 11-71 kWh/m^{2}a**

The elaborated method (PDD analysis) is able for comparing and proposing requirements on the primary energy of heating. However the other components of the overall primary energy consumption (such as primary energy of cooling, DHW, lighting) influenced by many parameters (internal heat loads, fresh air need, national standards for DHW and lighting, etc.), therefore the proposal for those primary energy values cannot be made by the PDD analysis.

2) Setting the lower limit of the primary energy consumption considering simulation results from other projects

The result of the simulations that performed in the report *Towards nearly zero energy buildings* are as follows:

Zone 1 Catania (Athens, Palermo,...): new nZEB office building's non-renewable primary energy use: **17-30 kWh/m²a.**

Zone 3 Budapest (Ljubljana, Milano,...): new nZEB office building's non-renewable primary energy use: **38-55 kWh/m²a.**

It has to be mentioned that these non-renewable primary energy figures refer to new office buildings, but the refurbishment of existing public buildings may have some technical constraints, thus the values for major refurbishment of public buildings might be lower. The building energy simulation in the RePublic_ZEB project will be done in WP4.

3) Setting the lower limit of the primary energy consumption considering available nZEB buildings' data

The technical solutions of a nZEB office building located in Helsinki was analyzed as best practice that should be followed. The detailed dynamic building energy calculations that were performed for this building provided help for our work. This nZEB building was constructed in 2011. The building envelope has a high thermal characteristic as the U-value of the outer walls is 0.17 W/m²K, U-value of the base floor is 0.16 W/m²K, the windows U-value is 0.8 W/m²K with a g value of 0.3. The south facades are double facades with integrated PV cells providing effective solar protection at the same time. All the building, except the atrium space, is air-conditioned with mechanical ventilation system and free cooling system with passive and active chilled beams. All the cooling energy is provided from boreholes (free cooling), the chilled water is directly circulated in air handling units and chilled beams. The building is connected to a district heating system, the heating is based on radiators. The air handling units are installed with high efficiency heat recovery (78-80%), the ventilation is demand controlled in most of the rooms. The lighting system consists of T5 fluorescent lamps with 7 W/m² installed power. Daylight, occupancy and time control is used in larger rooms, and occupancy and time control in cellular offices. On site renewable energy is the electricity that produced by PV system (7.1 kWh/m²a), and the cooling energy produced by the free cooling system with the boreholes (10.6 kWh/m²a), respectively. The simulated energy performance of the building can be seen in Table 2.

Table 2. nZEB building energy simulation results
(Source: The Rehva European HVAC Journal, February, 2012)

	Net energy need [kWh/m²a]	Delivered energy [kWh/m²a]	Primary energy factor [-]	Non-renewable primary energy [kWh/m²a]
Space and ventilation heating	26,6	32,2	0,7	22,6
DHW	4,7	6,1	0,7	4,3
Cooling	10,6	0,3	1,7	0,5
Fans and pumps	9,4	9,4	1,7	16,0
Lighting	12,5	12,5	1,7	21,3
PV		-7,1	1,7	-12,0
Total	*64*	*53*		*53*

The weather condition of Helsinki differs from the target countries, i.e. the heating degree day is higher, whilst both the cooling degree day and the global horizontal radiation are lower. The primary energy factors of the target countries are higher than it was presented in Table 2 for Helsinki, due to the conversion factor of electricity is about 2.5, and the factor of district heating is about 0.8-1.2 in the target countries. Therefore the net energy demand and the primary energy factors had to be adjusted in order to ensure the adaptability of these values to the target countries.

The space heating is roughly proportional with the HDD therefore the net heating demand was calculated for the representative cities of each climatic zone in the target countries, based on the ratio of HDD of Helsinki to the HDD of representative cities of target countries. The calculated space and ventilation net heating energy need is between 4 kWh/m^{2}a (Italy, B climatic zone, Palermo) and 27 kWh/m^{2}a (Romania, V climate zone, Miercurea Ciuc).

In many buildings there is not mechanical ventilation system, therefore 80% of heat recovery cannot be implemented even if a new ventilation system is installed in the building, which may have some difficulties, therefore it is not possible in every case. However, the aim is to set the achievable lowest value of primary energy, therefore the values given in Table 3 were considered as lower limit of space and ventilation heating energy need.

Table 3. Estimated space and ventilation heating energy need in nZEB office buildings

Space and ventilation heating energy need, kWhm^{2}a			
BG, Lovech	16	IT, Palermo	4
BG, Plovdiv	14	RO, Brasov	24
BG, Burgas	14	RO, Bucharest	16
HR, Split	7	RO, Cluj Napoca	19
HR, Zagreb	15	RO, Constanta	14
MC, Bitola	16	RO, Miercurea Ciuc	27
MC, Gostivar	18	SLO, Ljubljana	19
MC, Skopje	15	ES, Barcelona	7
GR, Athen	7	ES, Burgos	18
GR, Ioannina	13	ES, Lleida	11
GR, Kastoria	15	ES, Tarragona	8
GR, Naxos Island	4	UK, Glasgow	19
HU, Budapest	16	UK, London	15
HU, Pecs	16	PT, Braganca	15
IT, Bari	8	PT, Coimbra	9
IT, Belluno	16	PT, Faro	5
IT, Firenze	10	PT, Lisboa	7
IT, Milano	12	-	-

The cooling energy demand is estimated based on the simulation results of the report *Towards nearly zero energy buildings*: for Palermo 25 kWh/m^{2}a is considered, as the highest cooling energy need; the lowest cooling demand is the Romanian V. climate zone, where the CDD is only a bit higher than the CDD of Helsinki, therefore the lowest cooling need is estimated to 12 kWh/m^{2}a.

Finally the Finnish primary energy factors were replaced with 1.0 factor for the thermal energy and 2.5 for electricity, as these are more usual in the target countries.

As a result of this approach the **non-renewable primary energy of nZEB office buildings** within the target countries of the RePublic_ZEB project can be estimated between **42-83 kWh/m^{2}a**, depending on the climatic conditions.

5.2 Renewable Energy Ratio indicator

The D3.1 report presented that there is a significant variety in the numerical figures of mandatory share of RES. In some countries the basis is primary energy, while elsewhere it is final energy (delivered energy to the building), or only some part of final energy. The existing requirements for mandatory share of RES vary between 10% and 55% in the target countries:

- Romania 10% (primary energy),
- Hungary 25% (primary energy),
- Croatia 30% (delivered energy),
- Italy 50% (it has not yet been specified if the RER requirement refers to primary or to delivered energy),
- Slovenia 50% (delivered energy),
- Bulgaria 55% (delivered energy).

These are the currently applied numerical requirements for the share of renewable energy sources in nearly zero energy buildings. The rest of the target countries, such as Macedonia, Greece, Portugal and Spain have not yet specified numerical requirement for mandatory share of RES concerning nZEBs.

It has to be highlighted that the proposal for the **RER requirement** as regards to major refurbishment of public buildings in the target countries of the project has to be flexible for several reason:

- The climatic conditions, including the global solar radiation as well as the outdoor temperature characteristic is different (groups of countries have been defined in D3.1 based on the climatic conditions).
- In many cases the usage of renewable energy sources in existing public buildings has constraints:
  - A densely built urban environment may reduce the possibility of utilization of renewable energy sources: e.g. there is not a land to be used for making the boreholes for a geothermal heat pumps system, the roof may be shaded by other buildings, etc.
  - Implementing the heat recovery might be difficult due to the lack of mechanical ventilation system in many existing public buildings (see details in Annexes of D2.2).
  - Usually in public buildings (except hospitals) there is not significant energy need of producing DHW that might be covered by solar thermal collectors.
- The GDP of a country measures the size of a country's economy and it has an effect on the financial instruments that can be provided by the state/local authorities for major refurbishment of existing public buildings. Based on D3.1 report, the GDP of the target countries is between 3,861 and 27,181 EUR/capita, therefore for those countries which have lower GDP, the numerical requirement of RER might be set for a lower level.

Taking into account the GDP, the average global horizontal radiation of the country, and the summer and winter climatic conditions that are presented in D3.1, the proposed numerical requirements are presented in Table 4.

Table 4. Recommended minimum renewable energy ratio to be used for the refurbishment of public buildings towards nZEB level

Country	Recommended minimum RER requirement for the refurbishment of public buildings
Italy	50%
Spain	40%
Portugal	40%
Greece	35%
Slovenia	30%
Croatia	30%
Hungary	25%
Bulgaria	25%
Macedonia	20%
Romania	15%

5.3 CO_2 emission indicator

Introducing the **CO_2 emission indicator** of buildings (linked to the primary energy indicator) is a good way to ensure the coherence and consistence between the long-term energy and environmental goals of the EU. Therefore both the primary energy and the CO_2 emission should be considered as indicators for nearly zero energy buildings.

The CO_2 emission depends on the CO_2 content of the energy that is used in the building. The CO_2 emission can be calculated using the national CO_2 conversion factors [gCO_2/kWh]. The conversion factor of the electricity very depends on the fuel-mix and the efficiency of the power plants. For those countries, which have numerous power plants with coal and/or oil fuels, the CO_2 conversion factor is much higher. For example in Bulgaria, the CO_2 factor of electricity is 819 gCO_2/kWh whilst in Croatia this value is only 235 gCO_2/kWh. As a consequence the requirement for CO_2 emission should not be the same for each target country.

At this stage of the project the nZEB primary energy requirements are estimated and those values can be fulfilled with numerous kinds of energy sources. Therefore the CO_2 emission for nZEB buildings can be defined after the building energy simulations is done in WP4 with the proposed packages of measures that will be assembled in D3.4.

Indicative numbers for CO_2 emissions are as follows, which might be reviewed considering the results of the building energy simulations in WP4, and taking into account the national CO_2 conversion factors:

Source of information	Type of building(s)	Proposed CO_2 emission
BPIE: Principles for nearly zero energy buildings	Reference buildings in the simulations: New single family residential building (129 m^2) New multi storey non-residential building (office), with a size that also could represent a typical multi-family building (1600 m^2)	3 $kgCO_2/m^2a$
Zero Carbon Homes proposal concerning carbon compliance targets for new dwellings	New dwellings	Detached: 10 $kgCO_2/m^2a$ Semi-detached, end terrace and mid terrace: 11 $kgCO_2/m^2a$ Apartments (up to 4 storeys): 14 $kgCO_2/m^2a$
Proposed targets for maximum admissible values of CO_2 emission in Romania (the values have not been official yet)	New office, educational building, health care facility, collective residential, individual residential	*Climatic zone I* Office: 12 $kgCO_2/m^2a$ Education: 24 $kgCO_2/m^2a$ Health care: 21 $kgCO_2/m^2a$ Coll./single res.: 25/24 $kgCO_2/m^2a$
Proposed targets for maximum admissible values of CO_2 emission in Romania (the values have not been official yet)	New office, educational building, health care facility, collective residential, individual residential	*Climatic zone II* Office: 15 $kgCO_2/m^2a$ Education: 30 $kgCO_2/m^2a$ Health care: 26 $kgCO_2/m^2a$ Coll./single res.: 27/30 $kgCO_2/m^2a$
Proposed targets for maximum admissible values of CO_2 emission in Romania (the values have not been official yet)	New office, educational building, health care facility, collective residential, individual residential	*Climatic zone III* Office: 19 $kgCO_2/m^2a$ Education: 37 $kgCO_2/m^2a$ Health care: 32 $kgCO_2/m^2a$ Coll./single res.: 30/40 $kgCO_2/m^2a$
Proposed targets for maximum admissible values of CO_2 emission in Romania (the	New office, educational building, health care facility, collective	*Climatic zone IV* Office: 24 $kgCO_2/m^2a$

values have not been official yet)	residential, individual residential	Education: 49 $kgCO_2/m^2a$ Health care: 41 $kgCO_2/m^2a$ Coll./single res.: 35/42 $kgCO_2/m^2a$
Proposed targets for maximum admissible values of CO_2 emission in Romania (the values have not been official yet)	New office, educational building, health care facility, collective residential, individual residential	*Climatic zone V* Office: 24 $kgCO_2/m^2a$ Education: 53 $kgCO_2/m^2a$ Health care: 48 $kgCO_2/m^2a$ Coll./single res.: 37/54 $kgCO_2/m^2a$

6. CONCLUSION

This report presents the review of the main definitions as regards nearly zero energy buildings, presenting a harmonized methodology for the definition of nZEB, including the principles, the energy flow and the system boundary of nZEB public buildings.

The general definition of nZEB was introduced in the Directive 2010/31/EU of the European Parliament and of the Council (EPBD recast) on 19 May 2010. According to the Article 2 of the EPBD recast, the nZEB means a building that has a very high energy performance, and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. The calculated or measured amount of energy have to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting. The Article 9 (3a) of the EPBD recast requires Member States to describe the detailed application of the definition of nearly zero energy buildings in practice, including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Based on D3.1 report it can be stated that all of the target countries of RePublic_ZEB project, except Macedonia, transposed the general definition of nearly zero energy building into the national legislation, however many of them have not yet elaborated neither the application of the definition nor the numerical requirement in terms of annual primary energy use.

The general definition of the nZEB in the EPBD recast includes two requirements that should be followed by every nZEB building. The first is the very high energy performance, and the second is the low amount of energy that should be covered to a very significant extent by renewable energy sources. These two requirements define the general principles of nearly zero energy buildings, but the details had to be elaborated in order to avoid different interpretation, and on the other hand to ensure the practical application of the definition.

Based on the relevant standards and studies and considering the existing legislative status and requirements of the target countries, this D3.2 report presents the common framework and a harmonized methodology for the definition of nZEB public buildings.

The *energy flow* of nearly zero energy public buildings is detailed in this report. The corresponding *unit of balance* is non-renewable primary energy. The *national primary energy factors* will be considered in the building energy calculations. All components of the building energy need – such as heating, cooling, ventilation, DHW and lighting – are included in the energy performance, except the energy use of the appliances. Furthermore the lighting is not included in the energy performance of residential buildings. The *building energy use* is the energy use of the building technical systems, which includes all the conversion and system losses. The renewable energy produced on site shall be deducted from the amount of energy to be delivered to the building site, and is taken into account in the calculation of the delivered and exported energy balance at the building site. The proposed calculation methodology, the consideration of non-renewable net primary energy is consistent with the guideline accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 that had to be followed by each Member States for setting the cost optimal requirements. This nZEB concept should be introduced in the national legislations as regards the building energy calculation. The calculation of Renewable Energy Ratio (RER) is also presented in the report, which should be used by the target countries of RePublic_ZEB project in order to calculate the share of renewable energy sources in nZEB.

The solutions to be considered for a nZEB, should meet the following general criteria:

- the EP is lower than the cost-optimal levels (nZEB is more energy efficient than cost-optimal building);

- the differential Global Cost (ΔGC) is negative (nZEB is cost effective)[2];
- the national minimum energy performance requirements for nZEBs are fulfilled.

Thus, three indicators have been proposed to be used for the specification of nZEB public buildings:

- Non-renewable primary energy
- Renewable Energy Ratio
- CO_2 emission

Non-renewable primary energy

Taking into account the non-renewable primary energy with the deduction of the exported energy for nZEB public buildings is in line with the guideline accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012, and is also consistent with the proposal of the standard prEN15603:2015 (Final nZEB rating: Numerical indicator of non-renewable primary energy use with compensation, Annex H.5 in the standard).

According to the description of Task 3.2 of the project, the upper limit of the primary energy requirement is the least ambitious, which can be set according to the principle of cost optimality, whilst the lower limit can be set considering the best available technology, which may not be cost optimal currently. The available (existing in the target countries' legislation) cost optimal primary energy consumption of the main public building categories was presented for those countries that already performed the cost optimal calculations according to the EPBD recast. These values were taken into account as upper limit of the primary energy of nZEB. Some countries of the target countries have not yet fulfilled the EU request on defining the cost optimality. In these countries presumably the cost optimal values of primary energy consumption will be defined before the RePublic_ZEB project finishes, therefore the cost optimal values – upper limit of the primary energy consumption of nZEB – will be presented for each target country in the final report of the project.

The lower limit of the primary energy consumption can be set by considering the best available technology as it is mentioned above. Our proposal is to calculate this level of primary energy taking into account the proposed *packages of measures* (D3.4) for the refurbishment of public buildings, including the energy efficiency measures on the building envelope (thermal insulation of external walls, roof, changing the windows, solar shading, etc.), measures on the high efficient HVAC systems and solutions (low temperature heating, high efficiency heat recovery system, etc.), and the usage of energy generation systems that use renewable energy sources (thermal solar collector, PV, geothermal heat pump, etc.). However, these *packages of measures* will be assembled in a following report of the project (D3.4), and the dynamic building energy simulations will be undertaken at a later stage within the RePublic_ZEB project (WP4). Therefore at this point of the project the lower limit of the primary energy can only be an estimation derived from:

1. Taking into consideration the available nZEB requirements in South and East Europe.
2. Available simulation results of other nZEB related projects.
3. Available data of nZEB buildings as best practices.

The estimated lower limit of the primary energy will be modified after the building energy simulation finishes in WP4.

<u>Taking into consideration the available nZEB requirements in South and East Europe</u>

Some of the target countries have already introduced nZEB primary energy requirements. The primary energy consumption includes several energy services, such as the heating and the

[2] It could be discussed whether a very high energy efficiency non cost-effective solution could be acceptable.

cooling, the ventilation, the lighting, as well as the energy consumption of producing DHW, which makes the comparison of the available primary energy values very difficult. From the overall primary energy need, the heating energy is roughly proportional to the heating degree day, however the other parts of the primary energy consumption influenced by many parameters (internal heat loads, fresh air need, national standards for DHW and lighting, etc.). Therefore only the heating energy content of the primary energy consumption could be reviewed. The comparison of the existing nZEB primary energy values of heating was done by introducing the primary energy ratio (PDD), which expresses the relation of the primary energy of heating to the heating degree day of the climatic zone. Based on the analysis the most ambitious and achievable primary energy ratios were selected as reference values for setting the primary energy requirement for heating (space heating and ventilation) for those South and East European countries, which have not formulated the nZEB primary energy requirement, and to propose stricter requirement for those countries which requirement seem to be not ambitious enough. As a result of the analysis the primary energy of heating in nZEB public buildings in South and East European countries are estimated depending on the geographical location and the climatic condition.

Setting the lower limit of the primary energy consumption considering simulation results from other projects and publications

The corresponding results of the building energy simulations performed in the report *Towards nearly zero energy buildings* have been presented for some South and East European cities. The building energy simulation in the RePublic_ZEB project will be done later in Work Package 4.

Setting the lower limit of the primary energy consumption considering available nZEB buildings' data

A nZEB office building located in Helsinki was analyzed as best practice. The weather condition and the primary energy factors of Helsinki differ from the target countries, therefore the net energy demand and the primary energy factors were adjusted in order to ensure the adaptability of these values to the target countries. As a result of the analysis the non-renewable primary energy of nZEB office buildings within the target countries of the RePublic_ZEB project is estimated between 42-83 kWh/m^{2}a, depending on the climatic conditions.

Renewable Energy Ratio

The D3.1 report has presented that there is a significant variety in the numerical figures concerning the mandatory share of RES. It has to be highlighted that the proposal for the RER requirement as regards to major refurbishment of public buildings in the target countries of the project has to be flexible for several reasons. Taking into consideration the GDP, the average global horizontal radiation of the countries, and the summer and winter climatic conditions that are presented in D3.1, the numerical requirements of the renewable energy ratio are proposed for each target country concerning the refurbishment of public buildings towards nZEB level.

CO_2 emission

Introducing an indicator on the CO_2 emission of buildings would be a good way to ensure coherence and consistence between the long-term energy and environmental goals of the EU. Therefore both the primary energy and the CO_2 emission should be considered as indicators for nearly zero energy buildings.

The CO_2 emission depends on the CO_2 content of the energy that is used in the building. The CO_2 emission can be calculated using the national CO_2 conversion factors [gCO_2/kWh]. The conversion factor of the electricity very depends on the fuel-mix and the efficiency of the power plants. As a consequence the requirement for CO_2 emission should not be the same for each target country.

At this stage of the project, the nZEB primary energy requirements are estimated and those values can be fulfilled with numerous kinds of energy sources. Therefore the CO_2 emission for nZEB buildings can be defined after the building energy simulations is done in WP4 with the proposed packages of measures that will be assembled in D3.4.

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8. ACRONYMS

BPIE	Building Performance Institute Europe
CDD	Cooling Degree Day
DHW	Domestic hot water
EC	European Commission
EED	Energy Efficiency Directive
EP	Energy Performance
EPBD	Energy Performance of Buildings Directive
EU	European Union
GDP	Gross Domestic Product
HDD	Heating Degree Day
HVAC	Heating, Ventilation, Air Conditioning
MS	Member State
nZEB	nearly Zero Energy Building
RED	Renewable Energy Directive
RER	Renewable Energy Ratio
RES	Renewable Energy Source