# Towards nearly zero-energy buildings

Definition of common principles under the EPBD

*Final report – Executive Summary*

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## Definition of common principles under the EPBD

Final report - Executive Summary

**By:**

**Ecofys:** **Andreas Hermelink, Sven Schimschar, Thomas Boermans**
**Politecnico di Milano / eERG:** **Lorenzo Pagliano, Paolo Zangheri, Roberto Armani**
**University of Wuppertal:** **Karsten Voss, Eike Musall**

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# 1 Introduction

The building sector is one of the key sectors to achieve the 20/20/20 targets of the EU. Beyond these targets, Europe also aims at bringing about drastic reductions of greenhouse gas emissions in the residential and service sectors of 88% to 91% compared to 1990 by 2050. With the recast of the Energy Performance of Buildings Directive (EPBD), the framework has been set to proceed along this track. Two mechanisms will be decisive for the development of the building sector:

- The principle of *nearly zero-energy buildings*. According to article 2.2. "'*nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. 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;"* Annex I, article 1 stipulates *that "The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs."* Article 9.1. regulates that *"Member States shall ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings (1a) and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings."*
- The principle of *cost optimality*, which gives guidance for the energy performance requirements of new buildings, existing buildings undergoing major renovation, and retrofitted or replaced elements that form part of the building envelope.

In both cases, Member States have to report to the European Commission regarding the related activities, progress and results and the European Commission has to set out rules regarding the methodology - explicitly for the methodology to calculate cost optimal levels, but in a guiding sense also for the principle of nearly zero energy buildings. Above, the European Commission needs to facilitate, steer and evaluate the reporting and implementation activities of the Member States.

Therefore, the project aims to support the European Commission in its activities to:

- Give guidance to the MS on how to interpret the requirements for nearly zero energy buildings as stated in article 2.2 of the EPBD;
- Develop a common reporting format on nearly zero-energy buildings to be used by Member States and to evaluate the adequacy of measures and activities reported by Member States in their national plans on nearly zero energy buildings;
- Link cost optimality and the nearly zero energy buildings principle in a consistent way and investigate their convergence until 2021.

To achieve these objectives, the project is divided into four main tasks and various sub-tasks. Figure 1 illustrates this approach.

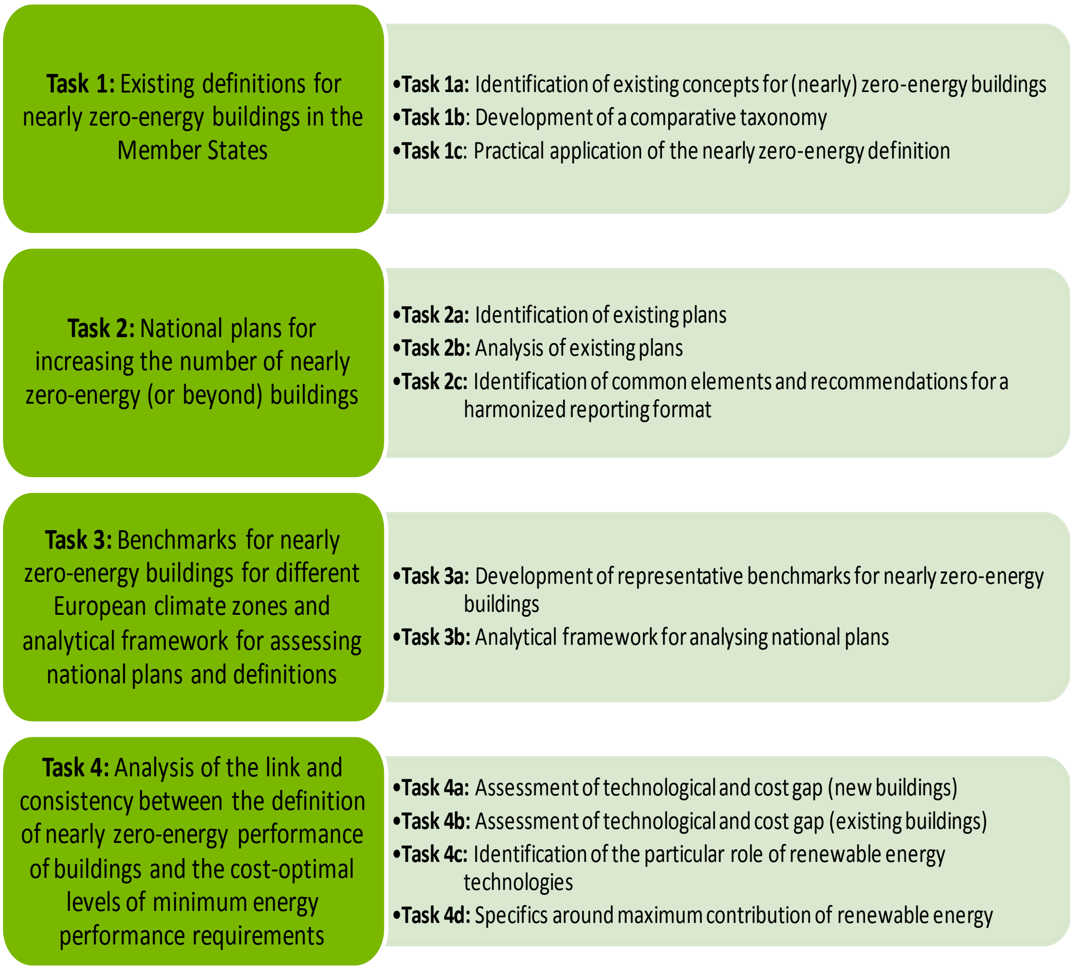


**Figure 1. Task Setup**

Chapters 2-5 summarise the most important outcomes of each task and chapter 6 presents the main conclusions and an outlook.

# 2 Identification of existing concepts for (nearly) zero-energy buildings

### Literature review

First we reviewed literature on existing definitions, labels and calculations methodologies addressing (nearly) zero energy buildings. A comprehensive literature list, originally developed between 2009 and mid-2010 in an on-going IEA project named “Towards Net Zero Energy Solar Buildings” (SHCP Task 40/ECBCS Annex 52) was updated with recent reports, references and extended queries till the end of 2012. This included *publications* about planned and existing definitions or methodologies from private actors, institutions or companies, certification measures as well as official building code procedures in progress within EU Member States and abroad. 17 countries and two international associations were included in *queries* to 15 country experts.. About 100 references were identified and listed.

**Systematic analysis of existing "definitions"**

A spreadsheet based questionnaire was filled by 15 international experts to identify and compare existing ZEB definitions, certifications, descriptions, calculation methodologies and labels. 75 approaches covering 17 countries were detected but, at the end of 2012, only a single one is included in national legislation (Denmark).

For Europe we found a large variety of concepts and examples for nearly zero-energy buildings. There are *non-governmental* examples putting emphasis on different aspects (like the "zeroHaus", "Plusenergiehaus©", "Minergie©-A" or "Passivhaus") as well as *government-initiated programs* which usually focus on the buildings' efficiency (e.g. German KfW-building standard or Minergie© from Switzerland).

In general, these approaches aim at a more or less equalised annual energy balance. Calculation procedures used are different in basic assessment categories and not necessarily in line with EN standards underpinning the EPBD: The analysis of the compiled definitions revealed different metrics (site energy, source energy, $CO_2$ emissions), different balance boundaries and types as well as different ways of normalisation.

**Example buildings**

Within the IEA project "Towards Net Zero Energy Solar Buildings" Wuppertal University developed a comprehensive database with more than 330 real buildings aiming at a (nearly) equalised energy balance from the past two decades. Buildings of all typologies and climates are covered. Here, 13 buildings were selected from the database representing the most well-known definitions or labels and some best practice buildings. It is noticeable that mid-European building practice gives highest priority to *efficiency* measures. In most cases the heating demand is drastically reduced by following - more or less - the Passive House concept; in some cases electricity use by lighting and appliances is included. On-site power generation from renewables, usually from PV, balances demands of heat pumps, other HVAC systems and use-specific consumers. In multi-fuel buildings the on-site power generation additionally balances the fuel or district heat use on a primary energy or $CO_2$ emission basis. In some commercial buildings or large domestic renovation projects the balance boundary is expanded to off-site renewable energy generation as on-site options are found to be insufficient.

**Comparative taxonomy and reporting template for nearly zero-energy definitions**

The definitions and schemes we found come up with many differences in their energy or emission balance calculations; these are broadly in line with the EU's and EPBD's aim to conserve flexibility in the development and implementation of national definitions and calculation procedures. A main reason is the variety in building cultures and climates throughout the EU. However, it is essential to move towards a harmonised framework of definitions which should be consistent with relevant EU legislation. Therefore a list of 14 major assessment categories for definitions and procedures was created; subsequently we refined it based on discussions about selected definitions and building examples, and further developed it into a comparative taxonomy.

We translated the taxonomy into a reporting spreadsheet, allowing the European Commission to characterise proposed national definitions and check whether they are in line with the EPBD requirements. For this purpose, the assessment categories were compared with EPBD/ Renewable Energy Directive (RED) requirements. An initial version of the reporting spreadsheet was checked in a pre-test using "frontrunner definitions". We analysed "MINERGIE©-A" standard from Switzerland, published in 2011, "EffizienzhausPlus" of the German Federal Ministry of Transport, Building and Urban Development and a newly developed standard of the Norwegian Zero Emission Building Centre at Trondheim University. Subsequent modifications added flexibility to the spreadsheet. The final reporting template was implemented as an "active" spreadsheet. It includes all assessment categories and items which are mandatory under the EPBD or RED. Each category refers to the appropriate EPBD/RED section. Where possible, the most likely answers are pre-defined in pull-down menus. Own entries are possible. For each assessment category clarifications and explanatory figures are presented on demand. The terminology reflects the EU nomenclature. Categories not mandatory under the EPBD/RED are included to give the possibility to explain definitions' components beyond the EPBD and RED. The spreadsheet allows the European Commission to perform a comparative analysis.

**Test of definitions with building examples**

In this analysis four balance approaches were chosen to test their applicability and robustness with data from building examples. The balance approaches reflect different metrics (primary energy, carbon emissions), balance boundaries (with and without plug loads) and weighting systems (symmetric or asymmetric primary energy or carbon emission factors) while the building examples covered various climates, typologies, sizes and energy supply options. The test was created by using a beta version of the so-called "Net ZEB evaluator" with calculated energy data from seven well documented (nearly) net zero energy buildings. The tool was developed within the above mentioned IEA project and will be published in early 2013. All four balance types are pre-defined in the tool. The tool not only allows to check annual energy or emission balances but also to characterise the load match and the grid interaction profile of a building by simplified indicators; neither load match nor grid interaction indicators are required by the EPBD yet. We added them because of their growing importance.

All four balance procedures, reflecting different accounting methods, are conceivable in the framework of the EPBD but it was found to be difficult or even impossible to compare their results. Thus different national accounting or balance methods respectively will complicate an accurate comparison. This is why the Member States should possibly apply the templates mentioned above.

# 3 National plans for increasing the number of nearly zero-energy buildings

Member States have to report their plans for increasing the number of nearly zero-energy buildings to the European Commission. We had the task to develop a template for these plans that Member States may use for their reporting.

Two aspects are especially important for such a template:

- Put least possible additional reporting burden on Member States;
- Provide an adequate format to the European Commission to evaluate compatibility and/or distance to target between national plans and EPBD requirements.

Figure 2 illustrates our approach for developing such template.

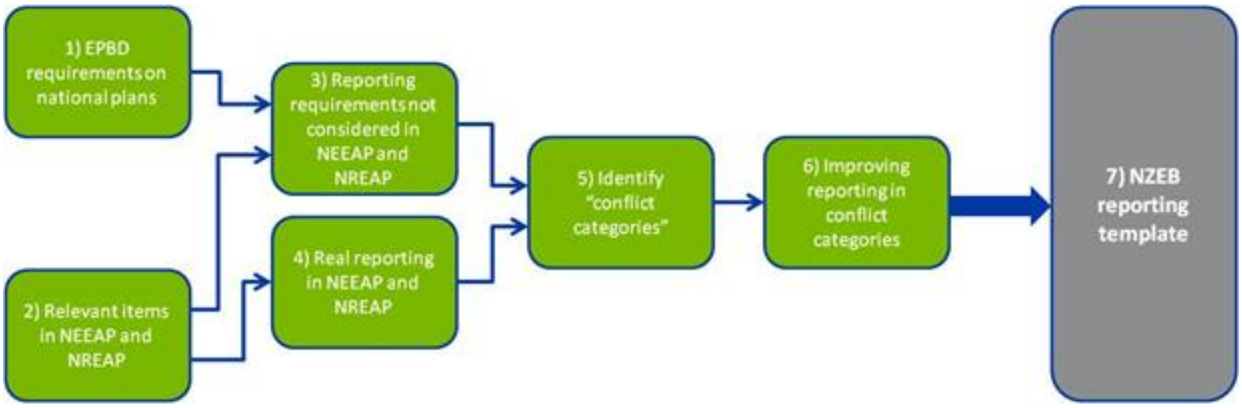


**Figure 2 Methodology for the development of a nearly zero-energy building reporting template**

First we analysed the EPBD requirements on topics to be included in these plans. We clustered these requirements into six categories (Figure 3).

The NEEAP and NREAP *templates* already ask the Member States for some relevant input regarding the implementation process for nearly zero-energy buildings, the new NEEAP template specifically addressed part of these reporting requirements. We found that 5 out of 6 categories shown in Figure 3 are addressed in the templates. None of them asked for the national application of the definition in practice for nearly zero-energy buildings (requirement 1). We concluded that requirement 1 needed special attention in our development of a reporting template.

Then we analysed how accurately the EPBD requirements are reflected in the NEEAP and NREAP templates and for 12 Member States we elaborated scores on the extent the respective questions were answered. Generally, the NEEAP reporting is less complete than the NREAP reporting. A major reason may be the lack of a template for the first round of NEEAPs – so every Member State developed its own report structure - while there was a NREAP template from the start. As to reporting on nearly zero-energy buildings just 5 out of 12 countries achieved a medium score, 7 scored lower. No country provided all necessary information.

**EPBD reporting requirements on national plans**

**Requirement 1**

National definition of nearly zero-energy building available (reflecting their national, regional or local conditions and including a numerical indicator of primary energy use)?
→ EPBD Article 9 Paragraph 3(a)

**Requirement 2**

By 2015 intermediate targets for improving the energy performance of new buildings incl. a view on how to ensure that by 31 December 2020, all new buildings are nearly zero-energy buildings
→ EPBD Article 9 Paragraph 3(b) in combination with EPBD Article 9 Paragraph 1(a)

**Requirement 3**

By 2015 intermediate targets for improving the energy performance of new buildings incl. a view on how to ensure that by 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings
→ EPBD Article 9 Paragraph 3(b) in combination with EPBD Article 9 Paragraph 1(b)

**Requirement 4**

Policies and financial or other measures to promote that by 31 December 2020, all new buildings are nearly zero-energy buildings, including details of national requirements and measures in order to increase the share of all kinds of energy from renewable sources (by 31. December 2014 requirement for minimum levels of energy from renewable sources) and to set minimum energy performance requirements with a view to achieving cost-optimal levels
→ EPBD Article 9 Paragraph 3(c) in combination with EPBD Article 9 Paragraph 1(a), EPBD Article 6, EPBD Article 4 and Directive 2009/28/EC Article 13(4)

**Requirement 5**

Policies and financial or other measures to promote that by 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings, including details of national requirements and measures in order to increase the share of all kinds of energy from renewable sources (by 31. December 2014 requirement for minimum levels of energy from renewable sources) and to set minimum energy performance requirements with a view to achieving cost-optimal levels
→ EPBD Article 9 Paragraph 3(c) in combination with EPBD Article 9 Paragraph 1(b), EPBD Article 6, EPBD Article 4 and Directive 2009/28/EC Article 13(4)

**Requirement 6**

Policies and financial or other measures , following the leading example of the public sector, to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings, including details of national requirements and measures in order to increase the share of all kinds of energy from renewable sources (by 31. December 2014 requirement for minimum levels of energy from renewable sources) and to set minimum energy performance requirements with a view to achieving cost-optimal levels
→ EPBD Article 9 Paragraph 3(c) in combination with EPBD Article 9 Paragraph 2, EPBD Article 7, EPBD Article 4 and Directive 2009/28/EC Article 13(4)

**Figure 3. EPBD reporting requirements**

More specifically categories 1-3 in particular are not well covered in the NEEAPs and NREAPs. In contrast, input to categories 4-6 is provided in most of the relevant NEEAP and NREAP sections, therefore reporting on these categories is expected to be less challenging for the Member States.

***Harmonised nearly zero-energy building reporting template***

Based on the previous findings we developed a harmonised reporting template. The main objective is to stimulate comparable input and results from Member States' national plans.

The template has eight main input sections. First Member States are asked to describe the starting point in their country in as much detail as possible (e.g. historic development of requirements), then the six reporting categories mentioned above have to be filled in. Finally an overall self-evaluation for possible improvements is requested.

Based on the previous analyses, we derived the following recommendations regarding the template:

- Major items to be addressed in the national reports: the national definition for nearly zero-energy buildings, the intermediate targets and the 'promotional framework' for nearly zero-energy buildings.
- A template should guide the Member States in their reporting and support the European Commission in evaluating the reports. Without a template, the national plans will probably have a widely dispersed format and thus add significant complexity to the evaluation of these reports.
- The European Commission should aim to convince Member States to use the template and to fill in all reporting categories. In the first NEEAPs, where no template was available, some questions were not answered at all, whereas in the template-based NREAP the reporting was very good. Member States will clearly benefit from using a template. It will avoid their own time consuming developments and allow them to compare their measures and plans with other Member States. Of course, as in the case with the NEEAPs and NREAPs the Member States are not obliged but strongly encouraged to use the NZEB reporting template.
- The complete nearly zero-energy building report should be embedded in the National Energy Efficiency Action Plans (NEEAP), as referred to in the EPBD recital 21.
- The four reports 'nearly zero-energy buildings', 'cost-optimality', 'NEEAP' and 'NREAP', should ideally be required at the same point in time. At the moment, the reporting schedules differ significantly.
- To facilitate reporting for Member States, these four reports - all containing building sector related information - might be merged: redundant information in the specific reports may be avoided and more transparency achieved. If this is not feasible, all sections asking for similar information in different reports should be harmonised: questions asking for the same input should be identical and putting references to another report's section that already includes the information should be encouraged.
- We conclude that a commonly used template would significantly facilitate the compilation and subsequent evaluation and comparison of national reports on increasing the number of nearly zero-energy buildings. A common format of these reports would contribute to an efficient distribution of examples and strategies on how to achieve nearly zero-energy building standard by 2021 in Europe.

# 4 Benchmarks for nearly zero-energy buildings and analytical framework for assessing national plans

Numeric benchmarks are most useful when the values to be compared with these benchmarks result from transparent and - ideally - identical calculation methodologies. Therefore Task 3a developed an explicit methodology for analysing building variants in terms of energy performance and global costs over 30 years, for detailing the inputs and assumptions of such an analysis and for clearly reporting the results. This methodology is intended to represent a useful example for Member States while drafting their national plans for increasing the number of nearly zero-energy buildings. The methodology's main objective is to support Member States in transparently expressing the meaning and ambition level of requirements for nearly zero-energy buildings for different climates and building types. It also may be used by the European Commission as a guiding tool for analysing those plans and requirements.

Subsequently, we also concluded that in addition to benchmarks for primary energy, energy needs etc. being discussed, benchmarks for transparent methodologies that finally result in such energy benchmarks should also be included.

Based on this insight we also derived bandwidths of possible nearly zero-energy building benchmarks for different European climate zones.

In particular, Member States should ensure that good quality data are available, including:

- Climate data matching the minimum quality specified in EN standards, ideally on a grid of a few kilometres space and both based on recent measurements and on forecasts of future weather evolution, as e.g available in U.K. by CIBSE;
- Cost data for building components, explicitly and clearly correlated to their physical and performance features; analysis of potential technological and cost evolution of main components. At present those data in many cases are difficult to access for policymakers, designers, etc.

In principle, benchmarks could be set without deriving them on any sophisticated calculation or related cost. Yet, verifying whether an energy and comfort benchmark is met or not requires transparent and accurate definitions and calculations (or measurement). Global costs over the lifetime of the building are an important parameter both for private investors and for decision makers. Therefore, we chose to follow the cost-optimal methodology (as laid down in Commission Regulation 244/2012 and accompanying guidelines) for developing these benchmarks, in line with the tender requirement.

The terminology used here, and recommended for use in the formulation of the Member States' plans for increasing the number of nearly zero-energy buildings, is the one defined in EN standards, i.e. EN 15603:2008 (E) "Energy performance of buildings - Overall energy use and definition of energy ratings" and the technical report CEN/TR 15615, "Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella Document".

In particular the reader should be fully aware of the definitions for *a) energy need, b) energy use, c) delivered energy* and *d) primary energy* in order to fully grasp the proposed methodology for calculation and presentation of results.

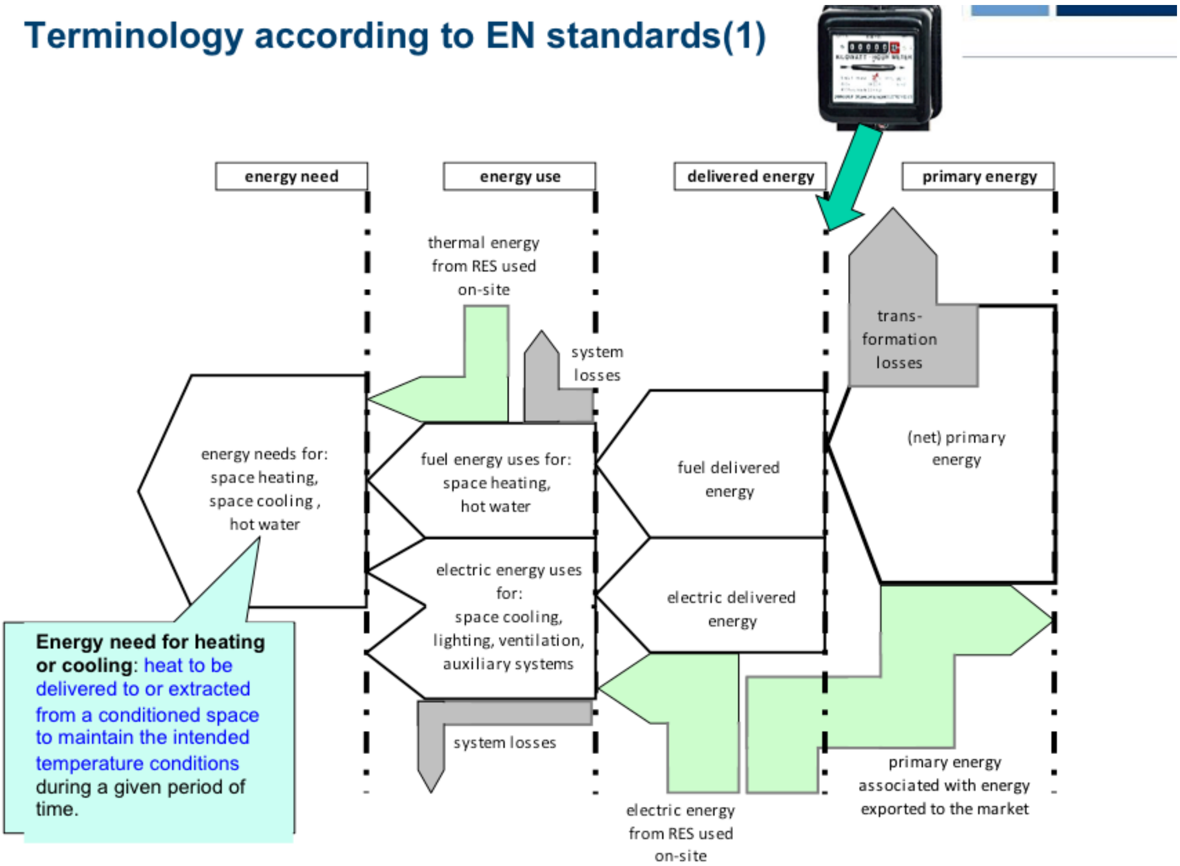


**Figure 4 Terminology according to EN standards**

From EPBD definitions given in Article 2, 9 and Annex I, it follows that:

a) Member States have to choose *an energy performance indicator* (which can be chosen e.g. at the level of energy need for heating, cooling and hot water plus energy use for lighting, and/or delivered energy, and/or embedded energy,, and/or load match with the grid,...) AND a numeric indicator of primary energy use;
b) The time interval over which to calculate the performance may be a year but shorter sub-intervals e.g. a month, a day, an hour might be the basis for calculations or included in the other indicators that might be used to evaluate energy performance as described in Annex I.

This seems to imply that Member States can determine their own "detailed application in practice of the definition" by choosing - for the primary energy balance - among different nearly zero-energy building definition *families* and additional indicators next to primary energy per year. As such, they may use a different calculation time interval from a year, which is especially useful for analysing the interaction of the building with the electricity grid and other energy grids.

Based on this interpretation of the EPBD our analysis includes:

- a critical and exhaustive review of the definition of nearly zero-energy buildings around the world and in particular in Europe;
- a classification of those definitions in 4 *families* depending on the extent of energy use included or excluded, choice of metric, weighting system, etc.;
- the application of the four main definitions to case studies of real buildings;
- a methodology for analysing building variants of building prototypes in terms of energy performance and global costs over 30 years;
- a numerical analysis based on the developed methodology using one of the definition *families* with a symmetric weighting factor, including a sensitivity analysis on the main economic factors, and a few examples of application with an asymmetric weighting factor;
- a description of the possible impact on the grid which has to act as a buffer for the buildings, absorbing energy when they produce in excess (e.g. solar energy in summer).

### The "case" of electricity and load match

The share of electricity-supplied buildings is assumed to rise and therefore the interaction of (nearly zero-energy) buildings with the grid will gain importance. Many energy experts agree that a simplified energy balance over a year "does not show the complete interaction with the grid; assumes that the grid is an infinite storage; [and] allows for «lazy» design: no concern about timing of electricity generation and use".[1]

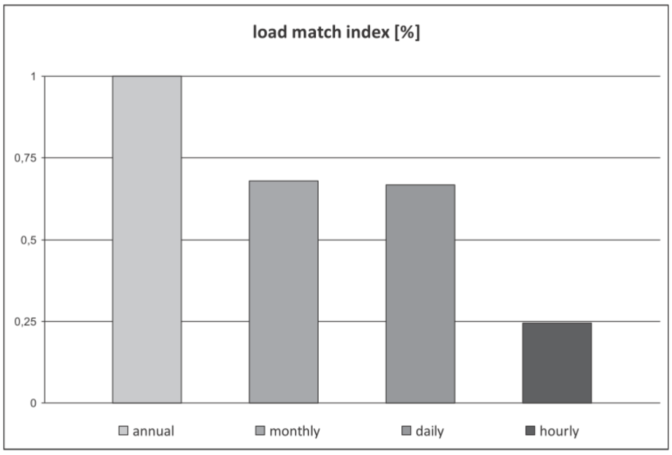


**Figure 5. Load match index as a function of the time step for balancing (Koch et al, 2011)**

The case of electricity is pointed out in the example of Figure 5. All columns show a one year balance but were calculated using different time steps. Using a one-year time step, on-site generated electricity equals the annual consumption. Shorter sub-intervals yield different results. Without local storage on an hourly basis only 25% of energy generated on-site might be used exactly at the time step of generation, while 75% is sent to the grid at a certain time step and taken from the grid at a different one. This implies the use of conventional energy sources with high primary energy content and emissions and/or the installation of large storage capacity. However the adoption of more detailed energy balances requires a series of assumptions and decisions about the calculation steps on which CEN itself is developing further analysis in view of the revision of EN standards, including EN 15603:2008.

A way to reduce the absolute value of the potential mismatch between demand and local generation (also non-electricity) is to reduce energy needs. Taking variants included in the nearly zero-energy

[1] Hogeling (2012), Presentation on CEN EU Mandate M480

building benchmark area, Member States might decide to privilege variants with very low energy needs also in view of reducing the mismatch.

**Lessons learnt and recommended indexes for the definition of nearly zero-energy buildings**

Extensive numerical analysis was performed based on the methodology presented in this report and using as an example one of the definition *families* (so-called "nZEB limited" , in which plug loads are excluded from the balance) with a symmetric weighting factor.

For a scenario with **2010** prices,

- even under relatively conservative assumptions about the performance and availability of energy efficiency technologies, buildings constructed with very low energy needs for heating, cooling and hot water have global costs (30 years) lower or comparable to buildings with high energy needs, all those results being relatively robust towards changes in various economic parameters, e.g. the assumed interest rates.

For a scenario with **2020** prices

- the economic attractiveness of low energy need buildings grows, meaning that in all cases the cost optimum moves towards zero. This effect shows under still conservative assumptions about the performance improvement of the building envelope and system technologies as well as about reduction of costs of technologies that have moderate level of embedded energy. A stronger effect would show with less conservative assumptions.

This result is reinforced should energy prices rise more significantly than assumed in the main part of the study[2]. Buildings with low energy needs are thus significantly less prone to risks connected to volatility of costs/prices of conventional and renewable energy during their lifetime.

It is likely to be a good economic investment to continue policy support for innovation to stimulate the building industry to continue improving performance and to completely close the gap between cost-optimal and zero energy. Buildings with low energy needs have additional benefits usually neglected, underrated or at least not explicitly mentioned: more uniform temperature distribution, less draughts, higher availability of daylighting (if energy for lighting has been accurately taken into account), etc. In a nutshell: generally higher thermal and visual comfort and better use of valuable floor space.

Many of the energy efficiency technologies which contribute to buildings with low energy needs are applicable both in rural and urban dense areas, while renewable energy sources (solar, soil, imported biomass, etc.) may have limitations as regards to production or related pollution (e.g. the burning of biomass) in dense urban areas. Finally, the calculation of energy needs does not require any additional assumption on weighting factors to take into account time of use, interaction with the grid (hourly/long-term fluctuating), conversion factors to primary energy, etc. All of those reasons support the usefulness of using energy needs for heating, cooling and hot water and energy use for lighting (and optionally energy use for ventilation, auxiliaries and plug loads) as one important parameter in defining nearly zero-energy buildings and setting corresponding benchmarks.

[2] An example with higher escalation rate of energy prices is also shown

From this analysis it appears that a useful way to establish a definition might include all of the following elements:

A) A performance part and a prescriptive part on energy needs and energy use.[3] Energy needs for heating, cooling and hot water and energy use for lighting (and optionally energy use for ventilation, auxiliaries and plug loads) are based only on physical variables and the choice of thermal and visual comfort set points and hence do not require any weighting factors (performance part). Additionally, a prescriptive approach might indicate minimum requirements for *components* (e.g. U-values for windows and walls, g-values for solar protections, air tightness, (built-in) lighting installations) etc.
   Domestic hot water use is highly dependent on occupant density in a building unit. Therefore specific values are more difficult to establish than for heating and cooling, and should be derived from typical national occupant densities and on typical national per capita water use. Today, specific DHW use equals (single family home) or even exceeds (multi family home) space heating or space cooling needs of e.g. passive houses. With a view to 2020 and beyond, the reduction of DHW needs has to be seriously addressed, e.g. by applying low flow shower heads or faucets and/or heat recovery.
   As for lighting in non residential buildings, careful design of the envelope can maximise daylight availability; reduction of distance of light sources from task areas, use of efficient sources and luminaires, daylight and occupancy controls with low stand-by power may enable very good visual comfort with relatively low annual energy use.
   In the medium term, targets for lighting in residential buildings as well as appliances and plug-loads could be added, including e.g. refrigerators, washing machines, dishwashers, etc.

B) A yearly weighted primary energy balance defined as in EN 15603:2008 - preferably also showing monthly or shorter time intervals. Transparency of the calculation methodology and how primary energy factors are derived is fundamental. If relevant, especially in the case of electricity, the weighting may take into account the sources' actual input to the grid, or even additional factors such as related pollution, impact on the grid, etc. In case a load match index (see below) is not used, a proxy way to take this into account may be to choose a different (lower) primary energy conversion factor for energy exported to the grid in case of on-site generation, although being considerably less precise and thus less preferable than a load match index.
   In the long term, with a view to longer-term climate targets, primary energy might be supplemented with a comprehensive "total emissions" measure including greenhouse gas emissions, acidification, ozone depletion, particulate matter, nuclear waste etc.

C) A value that illustrates the real share of energy from renewable sources. Although being partially integrated in the previous two elements *implicitly*, in the light of the EPBD definition for nearly zero-energy buildings this value should be made *explicit*. The main issues to be

[3] Sartori, I., Candanedo, J., Geier, S., Lollini, R., Grade, F., Athienitis, A., Pagliano, L. (2010). Comfort and Energy Efficiency Recommendations for Net Zero Energy Buildings. Proceedings of EuroSun 2010 - International Conference on Solar Heating, Cooling and Buildings. Graz (Austria).

solved are clear definitions of temporal and spatial boundaries and avoidance of double counting especially for electricity from renewable sources. Here the interaction of the building and on-site generation from PV with the grid should be quantified by means of e.g. a "load matching index" or other similar indices – in the end showing the share of self-consumed locally generated renewable electricity - calculated with time steps of a month , day or (preferably) hour. In the presence of smart meters and smart grids, and the on-going quick reduction of costs of meters and data transfer, metering of generated and exported energy in little time steps and calculation of the load match index seem to cause small investments.

D) One or more long-term comfort indices calculated according to EN 15251 or other relevant literature, because *"an energy declaration without a comfort declaration makes no sense"*[4] . IEA Annex 52 "Towards Net Zero Energy Solar Buildings" has analysed and proposed methodologies for incorporating comfort indexes in the characterisation of zero energy buildings[5]. In any case, energy-related benchmarks for nearly zero buildings must include the underlying comfort level explicitly and quantified.

**Analytical evaluation framework**

EPBD article 9 not only asks the Member States to draw up National Plans but also requires the Commission to evaluate these plans, *"notably the adequacy of the measures envisaged by the Member States in relation to the objectives of this Directive",* to give recommendations to the Member States and to publish tri-annual progress reports summarising the progress and the results of the Commission's evaluation. Based on *"that report the Commission shall develop an action plan and, if necessary, propose measures to increase the number of those buildings and encourage best practices as regards the cost-effective transformation of existing buildings into nearly zero-energy buildings."* To support the Commission in conducting an equitable and systematic evaluation of the national plans, we developed an *analytical evaluation framework*. The Commission will be able to use it for structuring the evaluation process, deriving meaningful recommendations for Member States and as a starting point for the progress reports and action plans mentioned in the EPBD.

Based on the outcomes of task 1, 2 and 3a, for each of reporting template's categories (Task 2), a table, including criteria, indicators for these criteria and benchmarks was developed. We decided to use a grading system allowing the evaluator to give each of the sub-criteria a specific number of points (out of a maximum number of possible points) and afterwards summing these up. Thereby a quantitative evaluation can be conducted which clearly illustrates the difference between achieved points compared to the maximum number of achievable points. This ratio indicates the level of reporting in a transparent way. The gap for each sub criterion should be explained by the Member State and could afterwards be summarised by the evaluator on which basis recommendations for improving the reporting could be issued.

[4] EN 15251 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

[5] Sartori et al. (2010); Carlucci, S. and L. Pagliano (2012). A Review of Indices for the Long-Term Evaluation of the General Thermal Comfort Conditions in Buildings." Energy and Buildings 53: 194-205.

Table 1 summarises the evaluation for requirements 1 – 6 and finally allows for an overall evaluation of the reporting by Member States. This is expressed as a percentage and thus on first view shows how far away a specific Member State is from a 100% fulfilment of the EPBD reporting requirements.

**Table 1 Overall evaluation table for the nZEB reporting template**

| **Overall evaluation** | |
|---|---|
| **Category** | **Sub-evaluation result:** |
| Application of the definition of nearly zero | % |
| Intermediate targets for improving the energy performance of new buildings in order to ensure that by 31 December 2020 all new buildings are nearly zero | % |
| Intermediate targets for improving the energy performance of new buildings in order to ensure that by 31 December 2018, new buildings occupied and owned by public authorities are nearly zero | % |
| Policies and measures for the promotion of all new buildings being nearly zero | % |
| Policies and measures for the promotion of all new buildings occupied and owned by public authorities being nearly zero | % |
| Policies and measures for the promotion of existing buildings undergoing major renovation being transformed to nearly zero | % |
| **Overall evaluation result [(ΣSub-evaluation result)/6]:** | **%** |
| **Summarise main recommendations for decreasing the delta:** | |

Also in this table, the evaluator has space for giving main recommendations to the specific Member State on how to improve the reporting. These final recommendations also facilitate the development of the subsequent action plan that the Commission has to prepare as there is a 'central' position in the evaluation forms where the most urgent issues are clearly stated.

# 5 The link between nearly zero-energy performance of buildings and cost-optimal levels

***Assessment of technological and cost gap***

While cost optimality is the current framework regarding the ambition level for both renovation of existing buildings and new buildings, the principle of nearly zero-energy buildings will be guiding for new buildings as from 2021 (for new public buildings as from 2019) onwards. A smooth and consistent transition of policies and markets from cost optimality to nearly zero-energy buildings is needed. We assessed the estimated gap between the principles of cost optimality and nearly zero-energy buildings in terms of a) Availability/technical feasibility of technologies needed and b) Differences in life cycle (global) cost.

Current technologies related to energy savings, energy efficiency and renewable energies are sufficient to reach, in combination, a suitable target for nearly zero-energy buildings. A real technology gap to be bridged until 2021 is not perceived. Investment cost reductions, improved performance of components and systems or energy storage solutions can positively influence the viability and introduction of nearly zero-energy buildings. Limitations may arise for renewable systems due to disparities in time or place, especially if one technology would be significantly favoured by the market or by policies.

Today, in various cases and depending on the exact national nearly zero-energy building definition, nearly zero-energy buildings are located beyond cost optimality, see virtual example in Figure 6.

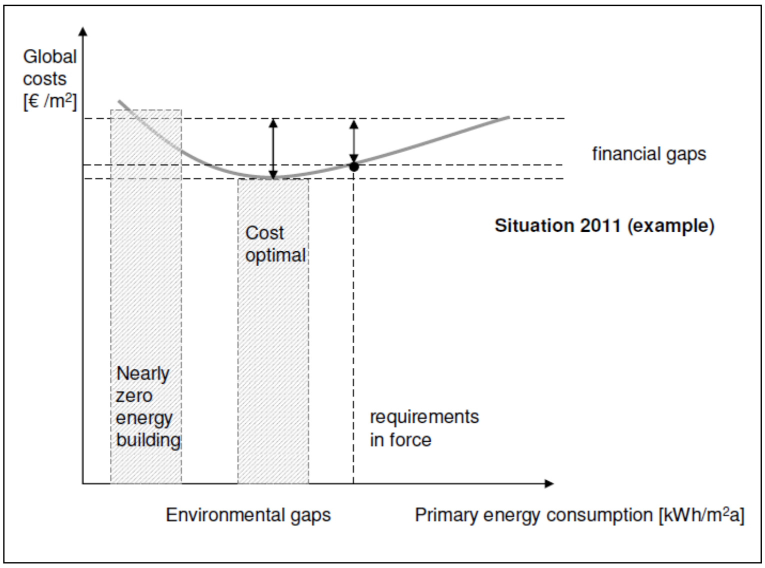


**Figure 6. Example: Financial and environmental gaps between nearly zero-energy building, cost optimality and current requirements in 2011**

It is important to keep in mind, that for the bulk of new buildings the nearly zero-energy buildings concept will apply as from 2021 onwards (for new public buildings from 2019 onwards). Thus the actual gap that might need to be bridged will result from the framework conditions in 2021 (2019). Factors that are likely to be subject to changes are e.g. technology costs as reaction to more mature markets and larger volumes, energy prices (presumably being higher in 2021 – 2050 compared to 2011-2040) and primary energy factors for electricity, gas, district heating, etc. (presumably being lower in 2021 – 2050 than in 2011-2040). This is currently assumed by many experts to lead to a reduction of the gap in relation to the situation in 2011, see graph below.

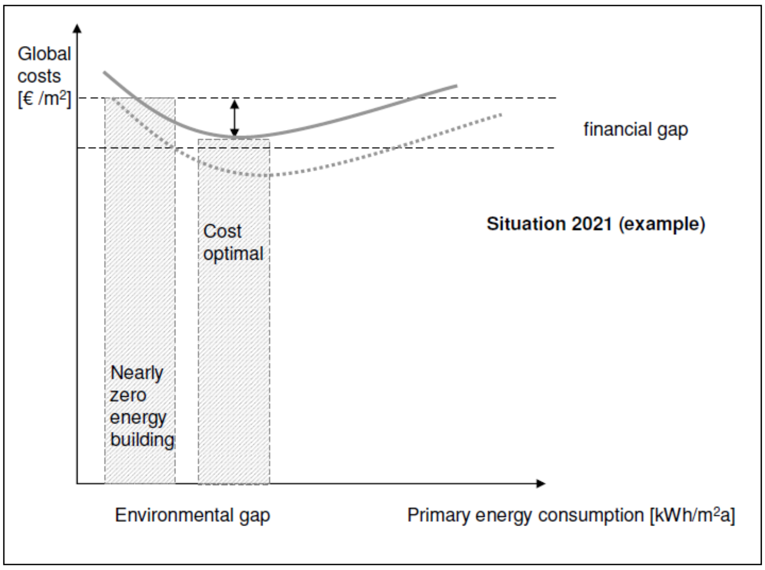


**Figure 7. Example: Financial and environmental gap between nearly zero-energy building and cost optimality in 2021**

Based on examples calculated in Task 3, we assessed possible changes regarding the input parameters between now and 2021. This concerns 3 areas, i.e. system costs, energy prices and primary energy factors (here only assessed for electricity, although of course possible for other energy carriers as well):

- The annual changes in costs for building envelope components and systems can be found in the appendix of task 4.
- The average primary energy factor for electricity was reduced by 20% (for the time frame 2021 – 2050 versus 2011-2040).

In a second step, the impact of these changes on the position of the cost optimum and its relation to the "nearly zero-energy buildings area" was calculated. Two examples of the calculations under Western European conditions and conservative assumptions about available technologies for both new and existing office buildings are shown below:

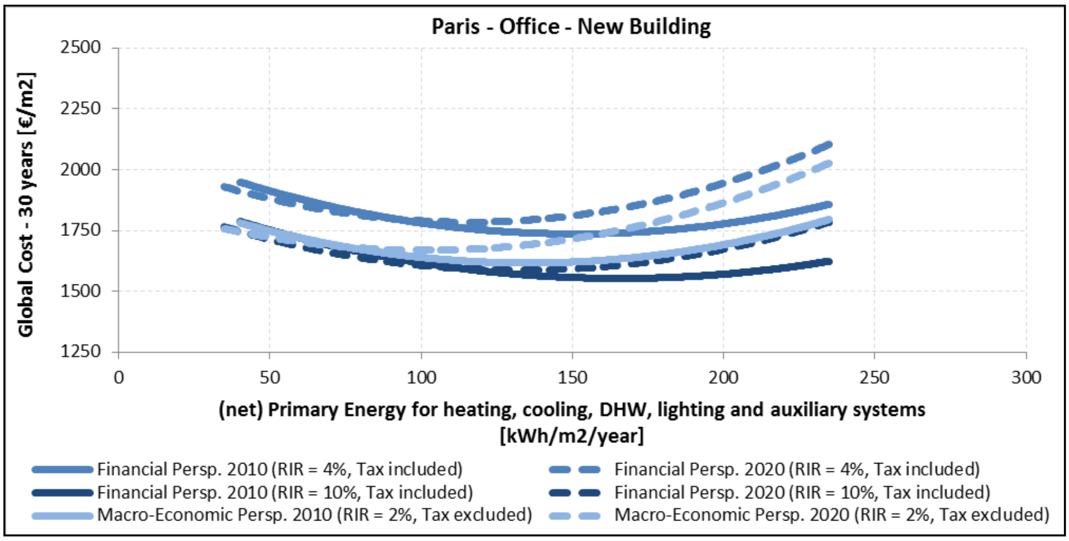


**Figure 8: Impact of assumed changes between 2010 and 2020 on crucial input parameters – Paris – Office - New building**

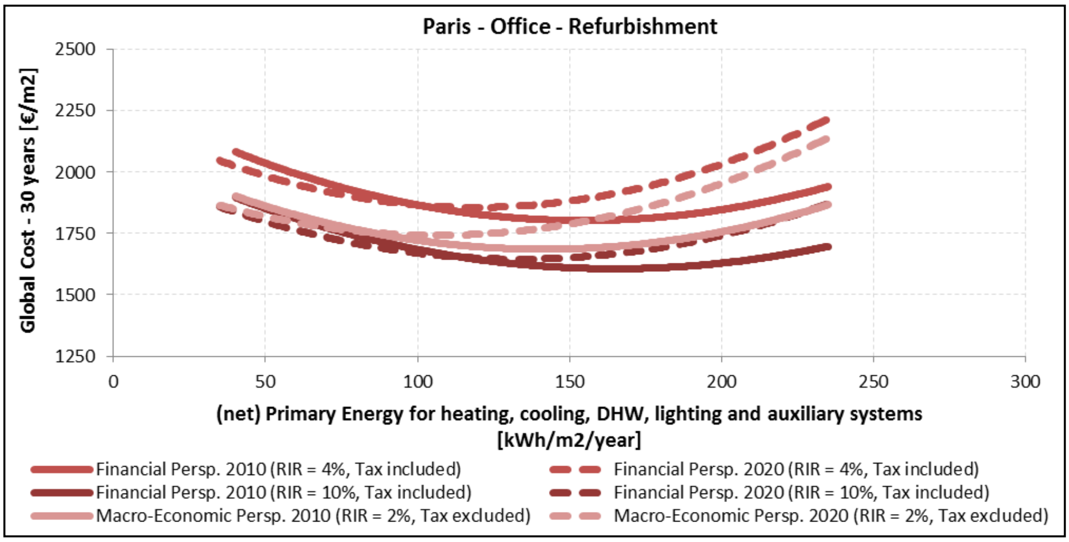


**Figure 9. Impact of assumed changes between 2010 and 2020 on crucial input parameters – Paris – Office - Refurbishment**

A number of uncertainties regarding input parameters (e.g cost of building materials and installation work, etc.) affect the location of the points in the graphs. Hence we should talk of an optimum *zone* (range) rather than an optimum point. In the examples of Figure 8 and Figure 9, the cost optimal zone for the situation in 2010 (for RIR=4%) can be located around 170 kWh/m²a, moving to a zone around 100 kWh/m²a in 2020. In spite of uncertainties about absolute future values the optimum zone clearly and significantly moves towards zero, supporting the view that a smooth transition between cost optimality and nearly zero-energy buildings is achievable.

***Identification of the particular role of renewable energy technologies in the building sector***

Regarding renewable energy technologies the following aspects have been analysed:

- Regional differences in life cycle costs for comparable renewable technologies (different investment costs, strategies to settle disadvantages, external (natural) circumstances).
- Accessibility of certain renewable energy technologies. Assumption: accessibility rises proportionally to the installed capacity; external preconditions in favour of certain techniques support their accessibility.
- Possible savings in energy use and $CO_2$ emissions of specific technologies in different climate zones: analysis of prevalent regional emission factors for electricity being the main form of energy that is also important for renewable energy systems (e.g. heat pumps).
- The combination with demand side measures was also taken into account.

**Table 2. Summary of the distribution of different renewable energy technologies in Europe**

| Renewable Energy Technologies | Northern Europe | Eastern Europe | Western Europe | Southern Europe |
|---|---|---|---|---|
| Solar Thermal Systems | Need for more sophisticated systems. Higher abatement costs than in moderate climates. Small market size. | Installed systems present low capacity. The market is underdeveloped. | The installed systems present high capacity. The market is large and well developed. | Great potential due to high radiation levels; most suitable for less sophisticated Solar Domestic Hot Water preparation (SDHW); and high efficiency compact low-cost thermal storage systems. Large still growing market. |
| Photovoltaic Systems | Actually still low efficiency and high costs due to low radiation levels. Small market size. | The market is underdeveloped. | The systems have a high efficiency. The market is large and well developed. | Great potential due to high radiation levels and short payback times. Medium size, still growing market. |
| Heat Pumps | Due to cold climate, lower system efficiency. However, systems have a very good market penetration | Main challenge for increasing use: difficult license procedures. However: growing market. | Mainly used in heating mode, air conditioning rarely required. The market is large and it is still growing. | Reversible systems are economically attractive in this climate. Combisystems have the biggest potential for market growth. Medium size still growing market. |
| Biomass and Pellets | Main producers and consumers in Europe. Large market size, has been well developed in recent years and is still growing | The market is in an initial development stage. | The market is large, well developed and it is still growing. | Scarce raw materials; buildings just have a relatively low heat demand due to the warm climate. Still quite small market but with considerable growing potential. In areas with low air movement, particulate emissions by direct burning may cause limitations. |

We divided the European market into four different sub-regions in order to consider regional disparities in Europe as regards for example climatic and economic differences. Northern Europe (Scandinavian countries, esp. Sweden), Western Europe (mainly Germany, France, UK), Southern Europe (mainly Spain, Italy) and Eastern Europe (mainly Poland, Hungary, Romania and Czech Rep) have been analysed separately. Table 2 is a summary of the results.

The distribution of the different renewable energy technologies differs. In Northern Europe heat pumps dominate but also biomass technology is gaining importance. In Southern Europe, solar thermal systems and reversible heat pump technologies for heating and cooling purposes promise the largest potentials. In Western Europe, a mature market has developed for all kinds of technologies while in Eastern Europe the renewable technology market is still underdeveloped. Nevertheless, in all regions these different technologies are used and thus available.

***Specifics around maximum contribution of renewable energy***

Renewable energy sources play a prominent role within the nearly zero-energy concept, although the EPBD stresses the principle of energy efficiency first..

Some specific questions need to be answered before 2021:

- Which renewables are allowed?
- What are the allowed spatial disparities between demand and renewable generation?
- What are the allowed temporal disparities between demand and renewable production?
- How to calculate the share of renewables in a nearly zero-energy building?

An approach on how to determine the share of energy from renewable sources in nearly zero-energy buildings is currently under development for prEN15603 (2013) by Technical Committee CEN/TC 371 "Energy performance of Buildings Project Group". The draft is to be published by March 2013 for public feedback. As soon as such a procedure is in place, another question will be: to what extent renewable energy in nearly zero-energy building contributes to overarching EU renewable energy targets beyond 2020. This should be explicitly addressed and solved by aligning different sector targets (industry, transport, buildings, etc.) with each other. The concept of having a renewable share in nearly zero-energy buildings will only fulfil its ultimate target of increasing the overall share of renewables in the EU and thus decreasing $CO_2$-emissions if it leads to real additional use of renewable sources and doesn't just remain a book-keeping exercise without really boosting renewable energy.

# 6 Conclusions and Outlook

Member states have to report their national definition for nearly zero-energy buildings and their national plans for increasing the number of nearly zero-energy buildings.

The in-depth analysis that has been performed in this project revealed a wealth of definitions and schemes related to nearly zero-energy buildings in Europe and beyond. Most of them have in common the objective to achieve a more or less equalised annual energy balance. Nevertheless, calculation procedures differ significantly and are not necessarily in line with CEN standards underpinning the EPBD. Therefore, comparing the energy performance inherent to these schemes and standards turns out to be very difficult.

A similar problem arises when trying to compare *the ambition and measures taken for increasing the number of nearly zero-energy buildings* that should be reported in national plans by the Member States. So far the elements that should be part of such a report are spread over NEEAPs and NREAPs, and the depth and scope of actual reporting by the Member States differ significantly, making comparisons difficult.

It is understood that the definitions and reporting that were analysed in the context of this project can only give an indication of what could be expected in the actual reporting of Member States about their national definitions and plans for increasing the number of nearly zero-energy buildings. The reports that the Commission had received by the end of December 2012 were not included in the analysis for this project.

To facilitate the comparison of different national approaches for *defining* nearly zero-energy buildings, a comprehensive template was developed in this project. The template allows to systematically compare different aspects which are relevant for the scope and ambition for nearly zero-energy buildings' definitions. Another template was developed to facilitate a systematic *reporting on national plans* for increasing the number of nearly zero-energy buildings.

A first major conclusion and recommendation is:

- It should be in the interest of every Member State to follow a uniform, transparent approach for both reporting the national definition and national plans for increasing the number of nearly zero-energy buildings. Implementing nearly zero-energy buildings until 2019/2021 is a major challenge for the Member States. As all Member States face similar challenges and opportunities, only learning from each other by comparing definitions and strategies will create synergies, which do not only speed up the process but also increase the competitiveness of Europe in terms of nearly zero-energy building technology leadership.
- Such a harmonised reporting format should also allow the European Commission to act as a *facilitator* in the Member States' process of achieving nearly zero-energy buildings.

Having done the analysis of many definitions for (nearly) zero energy buildings, there is specific concern about the comparability of ambition target expressed as a *"numeric indicator of primary energy use"* as required by Annex 1 of the EPBD. As Member States are not obliged to use CEN standards for determining such a numeric indicator and even the application of CEN standard leaves quite some flexibility, for example as to the time step used in calculations - not to mention political considerations that may lead to different primary energy factors - the second major conclusion is:

- It seems to be inappropriate to take primary energy as the only basis for creating benchmarks for nearly zero-energy buildings. We strongly recommend always adding the energy need for heating, cooling and hot water as well as the energy use for lighting. Later other performance indicators, e.g. for ventilation, auxiliaries and plug loads, may be added as 'bring to life' the energy performance indicator required by Annex I of the EPBD.

- The energy need is the starting point for calculating primary energy via the additional steps of energy use and delivered energy. In each step additional parameters are included which make the result of the calculation less transparent. This means that the calculation of the energy need of a building is most transparent, while the primary energy is least transparent. Therefore the energy need seems to be well-suited as a (supplementary) benchmark for the energy performance of nearly zero-energy buildings.

Using *2010* prices and technologies and other assumptions we made, the multitude of calculations that were performed for every climate and every new building type, returned a number of building variants *with similarly low minimum global cost* but much less energy need and primary energy than the bulk of analysed variants (having used quite conservative assumptions). Specifically, these *energy needs (being the sum of heating and cooling (sensible & latent))* turned out to be in the following ranges for the different climate zones (new buildings, financial perspective):

- Zone 1: Catania (others: Athens, Larnaca, Luga, Seville, Palermo): 15-45 kWh/m$^2$a (new office), 15-30 kWh/m$^2$a (new SFH)
- Zone 3: Budapest (others: Bratislava, Ljubjana, Milan, Vienna): 15-45 kWh/m$^2$a (new office), <15 kWh/m$^2$a (new SFH)
- Zone 4: Paris (others: Amsterdam, Berlin, Brussels, Copenhagen, Dublin, London, Macon, Nancy, Prague, Warszawa): 30-45 kWh/m$^2$a (new office), here variants having the same *average* global cost were found in the classes <15 kWh/m$^2$a and 15-30 kWh/m$^2$a as well; <15 kWh/m$^2$a (new SFH)
- Zone 5: Stockholm (Helsinki, Riga, Stockholm, Gdansk, Tovarene): 15-30 kWh/m$^2$a (office), <25 kWh/m$^2$a (SFH)

- *Domestic Hot Water* (DHW): DHW is very much influenced by occupant density, thus a *per capita* benchmark would make sense. Nevertheless this may be unpractical, since many other indices are normalised to the floor area and since the number of occupant in a building unit fluctuates significantly. As a proxy Member States could chose to set maximum values for energy *need* for DHW relative to the treated floor area. For example, the German Energy Saving Ordinance assumes a value of 12.5 kWh/m$^2$a, which we deem to be a realistic benchmark for single family homes. For multi-family homes literature shows that maximum values of 15-20 kWh/m$^2$a seem to be realistic considering the usually higher occupant density. Here we are neglecting heat recovery which might reduce these values by up to 50%. In office buildings only DHW should be close to 0 kWh/m$^2$a. A practical general upper limit might be set at 20% of the multi-family homes value, i.e. approximately 4 kWh/m$^2$a.
- *Lighting, non-residential*: This is strongly influenced by daylight availability at a certain latitude. The Norwegian standard NS 3071:2012 "Criteria for passive houses and low energy buildings. Non residential buildings" sets a maximum value of 12.5 kWh/m$^2$a as energy *use* for lighting. A range between 6 and 10 kWh/m$^2$a may be adequate for zones with higher daylight availability.
- From 2020 onward all chosen target values need periodic adjustment to reflect the actual technology progress.

The final question is if cost optimal buildings and nearly zero-energy buildings will already have converged by 2021. To answer this question we assessed the estimated gap between the principle of cost optimality and the principle of nearly zero-energy buildings in terms of a) Availability and technical feasibility of technologies needed and b) Differences in life cycle (global) costs.

The analysis of a) did not reveal a real technology gap until 2021. In general, even current technologies are already sufficient to reach a suitable level for nearly zero-energy buildings.

As cost optimality is focused on primary energy we applied the transparent approach described above using the common "net zero energy limited" variant to assess the convergence. Let’s recall here that in this exercise we thus assumed to include energy for heating, cooling, ventilation and auxiliaries, hot water, lighting; weighting of energy exported to the grid or delivered to the building is assumed to be symmetric; the time interval is assumed to be the entire year. The calculated parameter is hence net primary energy consumption over a year (which does not include in itself information on mismatch between time of generation and time of use).

The conservative assumptions that were applied did not get net primary energy close to zero in the year 2010 for most combinations of climates and building types. The buildings being closest to zero primary energy usually were beyond the cost optimal area. One reason for that is the restriction of energy from renewable sources to photovoltaic or solar thermal systems located on a reasonable area on the roof of the exemplary buildings – these were the systems considered in this study, obviously there are more renewable options, which may be more or less favourable than using PV depending on the situation. Nevertheless, it became very clear that in many cases on-site renewable energy will not be sufficient to reach a primary energy level close to zero without further energy efficiency measures and/or a significant decrease of primary energy *factors* of *off-site* energy carriers *supplementary* to a very low energy need of the building.

The same calculations were performed at 2020 prices. Here we made very cautious assumptions as to decreased real prices for 2010 performance levels. We also assumed only modest energy price increases. Nevertheless, the typical result of these calculations was the relative improvement of low energy *need* variants compared to high energy need variants as to global cost. Taking these assumptions, a “natural”, economically driven development towards buildings with lower energy needs than today can be predicted for the years until 2021. The most attractive energy need class may move to even lower levels than shown for some of the above analysed reference buildings.

From our point of view the class “energy need for heating and cooling“ < 30 kWh/m$^2$a may probably and the energy class < 15 kWh/m$^2$a will almost certainly suffice to be called “nearly zero-energy building” by 2021. A very low level of energy need for heating and cooling is a vital pre-condition for nearly zero primary energy buildings. We also regard this to be a vital precondition to achieve a significant share of energy from renewable sources in nearly zero-energy buildings on a large scale and thus to widely achieve nearly zero primary energy. Anyway without an additional real decrease of primary energy factors and accelerated innovation even this “natural” movement towards zero will neither bring most of the new buildings in Europe really close to zero primary energy nor to zero $CO_2$ emissions *at the same time*.

Therefore the final major conclusions are:

- The future development of primary energy factors and the interaction of energy export from, and energy import to, nearly zero-energy buildings combined with time-dependent primary energy factors should get much more attention in future analyses and research of a building's energy performance.
- The cost optimal methodology uses a complex approach for finding building variants with least life-cycle cost. This includes sophisticated assumptions on future cost. Less focus seems to be on the adequate inclusion of future primary energy consumption. Typically a *constant* primary energy factor and energy mix is taken for the whole period of 30 years. We suggest to explicitly ask for the *sum* of primary energy that will be used by a building variant during the calculation period in order to have an analogy to how cost are treated.This reinforces our proposal to add energy needs as an indicator which is much less by uncertainty on future developments.
- Primary energy as the EPBD's main numeric indicator of energy performance does not directly reflect one of the main targets of European energy policy which is reduction of greenhouse gas emissions. Still greenhouse gas emissions reflect "just" one relevant impact category. Ideally, with a view to long-term climate targets, primary energy should be supplemented by a comprehensive "total emissions" indicator including greenhouse gas emissions, acidification, ozone depletion, particulate matter, nuclear waste etc.
- A real life-cycle balance for nearly zero-energy buildings should take into consideration appliances and plug-loads as well as energy and various pollutant emissions related to the construction and disposal of the building. Otherwise there is a high risk of sub-optimising the total life-cycle impact. This should seriously be taken into consideration for national applications of the EPBD's nearly zero-energy building definition and for updates of the EPBD.
- A numeric value index illustrating the real share of energy from renewable sources should be linked to nearly zero-energy buildings. Such an index should reflect the real additionality of energy from renewable sources in nearly zero-energy buidings. To achieve this, the main issues to be solved are clear definitions of temporal and spatial boundaries and avoidance of double counting especially for electricity from renewable sources.
- Comparisons of the energy performance of different buildings should make very explicit which comfort category is used and how it is defined (e.g. assumptions on clothing); this is requested by the cost optimality methodology as well. The choice of the level of temperature set points (fixed or variable in summer) can have a significant impact on the energy consumption of nearly zero-energy buildings.

All those necessary changes for seeing nearly zero-energy buildings as the standard by 2021 seem to be manageable, especially when Member States exploit the synergies of a joint effort.

ECOFYS

sustainable energy for everyone

ECOFYS

sustainable energy for everyone


ECOFYS Germany GmbH

Am Wassermann 36
50829 Köln

T: +49 (0) 221 27070-100
F: +49 (0) 221 27070-011

E: info@ecofys.com
I: www.ecofys.com