




PRINCIPLES FOR NEARLY ZERO-ENERGY BUILDINGS

Paving the way for effective implementation of policy requirements

Executive Summary






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EXECUTIVE SUMMARY

The European Union (EU) aims at drastic reductions in domestic greenhouse gas (GHG) emissions of 80% by 2050 compared to 1990 levels. The building stock is responsible for a major share of GHG emissions and should achieve even higher reductions of at least 88% - 91%[1]. Therefore, without consequently exploiting the huge savings potential attributed to the building stock, the EU will miss its reduction targets. More than one quarter of the 2050's building stock is still to be built. The energy consumption and related GHG emissions of those new buildings need to be close to zero in order to reach the EU's highly ambitious targets.

The recast of the Energy Performance of Buildings Directive (EPBD) introduced, in Article 9, "nearly Zero -Energy Buildings" (nZEB) as a future requirement to be implemented from 2019 onwards for public buildings and from 2021 onwards for all new buildings. The EPBD defines a nearly zero energy building as follows: [A nearly zero energy building is a] "*building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby.*"

Acknowledging the variety in building culture and climate throughout the EU, the EPBD does not prescribe a uniform approach for implementing nearly Zero-Energy Buildings and neither does it describe a calculation methodology for the energy balance. To add flexibility, it requires Member States to draw up specifically designed national plans for increasing the number of nearly Zero-Energy Buildings reflecting national, regional or local conditions. The national plans will have to translate the concept of nearly Zero -Energy Buildings into practical and applicable measures and definitions to steadily increase the number of nearly Zero-Energy Buildings.

Obviously the qualitative nature of criteria in the above-mentioned nZEB definition leaves room for interpretation. While illustrating the major pillars of future nZEB – drastically reduced energy demand and a major share of renewable energy supply - the terms "nearly zero or very low amount of energy", "very significant extent" (to which the energy required should be covered by renewable energy sources), and "renewable energy produced on-site or nearby" require further examination and definition.

In addition to the flexibility of the general EPBD definition for nZEB, several questions arise concerning the practicalities of a nZEB definition:

- how to keep the nZEB definition sufficiently flexible so as to build upon existing low-energy standards and enable energy-positive buildings?
- how to properly define and set the share of renewable energy?
- how to determine the optimal balance between energy efficiency and renewable energy?
- how to forge the nZEB definition as a 'silver bullet' for reaching the same levels of energy and GHG reduction?
- how to link the nZEB definition to cost-optimality[2] principles in order to have convergence and continuity?

[1] COM(2011) 112 final, A Roadmap for moving to a competitive low carbon economy in 2050.
[2] Cost-optimal methodology will be leading the improvement of the energy performance for new buildings before the implementation of the nZEBs approach in 2021. The cost-optimal methodology is required by Article 5 of the recast EPBD (Directive 2010/31/EU) on 'calculation of cost-optimal levels of minimum energy performance requirements'.

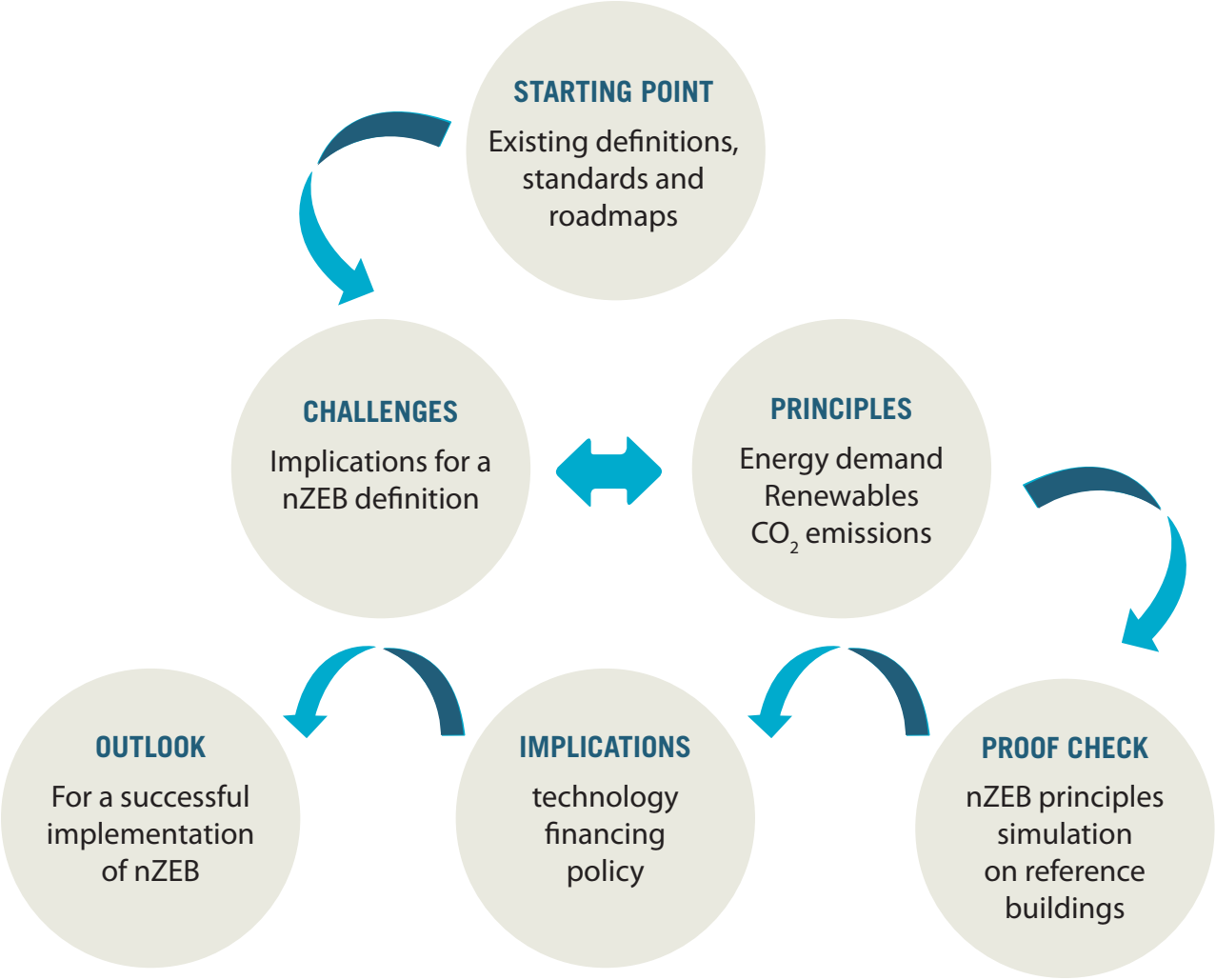
At the present moment, the European Commission, EU Member States, stakeholders and experts are discussing the different aspects of nZEBs. Overall, there is an urgent need to establish common principles and methods to be taken into account by EU Member States for elaborating effective, practical and well thought-out nZEB definitions.

OBJECTIVE OF THIS STUDY

The overarching objective of this study is to contribute to a common and cross-national understanding on:

- an ambitious, clear definition and fast uptake of nearly Zero-Energy Buildings in all EU Member States;
- principles of sustainable, realistic nearly Zero-Energy Buildings, both new and existing;
- possible technical solutions and their implications for national building markets, buildings and market players.

The study builds on existing concepts and building standards, analyses the main methodological challenges and their implications for the nZEB definition, and compiles a possible set of principles and assesses their impact on reference buildings. Subsequently the technological, financial and policy implications of these results are evaluated. Finally, the study concludes by providing an outlook on necessary further steps towards a successful implementation of nearly Zero-Energy Buildings. The structure of the study is presented in the figure below.



FROM EXISTING LOW-ENERGY BUILDINGS CONCEPTS TOWARDS THE EPBD'S NZEB REQUIREMENTS

Throughout Europe there is a large variety of concepts and voluntary standards for highly energy efficient buildings or even climate neutral buildings: passive house, zero energy, 3-litre, plus energy, Minergie, Effinergie etc. In addition, these definitions refer to different spheres: site energy, source energy, cost or emissions. Moreover there may be further variations in the requirements of the above standards depending on whether new or existing, residential or non-residential buildings are under consideration. In a nutshell, the views on how nearly Zero-Energy Buildings should be defined, on which sphere to make the basis, as well as on which means and techniques are adequate, differ greatly.

Typically, low-energy buildings will encompass a high level of insulation, very energy efficient windows, a high level of air tightness and natural/ mechanical ventilation with very efficient heat recovery to reduce heating/cooling needs. Passive solar building design may boost their energy performance to very high levels by enabling the building to collect solar heat in winter and reject solar heat in summer and/or by integrating active solar technologies (such as solar collectors for domestic hot water and space heating or PV-panels for electricity generation). In addition, other energy/resource saving measures may also be utilized, e.g. on-site windmills to produce electricity or rainwater collecting systems.

Today, more than half of the Member States do not have an officially recognised definition for low or zero energy buildings. Various Member States have already set up long-term strategies and targets for achieving low-energy standards for new houses.

The existing low-energy building definitions among EU Member States have common approaches but also significant differences. Aggregation and improvement of the existing concepts is needed in order to align them to the nearly Zero-Energy Buildings requirements indicated by the EPBD and the Renewable Energy Directive. We would like to highlight three main issues to be considered as the existing low-energy buildings definitions evolve towards a nearly zero energy building definition:

- Most of the low-energy building definitions in the European countries specify a maximum percentage of their national building standards' limit for primary energy consumption per square meter and year. However, there are variations between EU Member States on how to calculate and express the primary energy consumption of a building (e.g. using net or gross floor areas).
- The existing low-energy building definitions do not specifically indicate a certain share of renewables in the energy supply. The EPBD Recast indicates that energy required should be covered to a significant extent by renewable sources. Especially this lack of guidance on the share of renewables generates a mismatch between current regulations or definitions and the above-cited EPBD nearly zero energy definition.
- There are various elements of existing concepts that can be used for the development of a nearly zero energy building definition, such as the principle of working with overarching targets accompanied by "sub-thresholds" on specific issues (such as requirements for maximum primary energy demand and additional limits for heating energy demand within the passive house concept).

NEARLY ZERO-ENERGY BUILDINGS: MAIN CHALLENGES AND IMPLICATIONS

The study analyses ten challenges and their implications for setting a sustainable and practical nZEB definition and proposes principles to be considered when setting up a practical definition. The challenges identified are presented as questions that have to be addressed for the transposition of a nearly Zero-Energy Buildings requirement into a practical, consistent and sustainable definition. The analysis of these challenges has led to several important implications for the nZEB definition. The main challenges and their implications are presented on the following page.

Challenge Nº 1:

How and to what extent do current sectoral and overall targets of the EU regarding CO_2 emissions, energy efficiency, renewable energies and other indicators affect the ambition level and set-up of a nearly Zero Energy-Building definition?

Implication for the nZEB definition

If EU countries want to meet the 2050 targets for CO_2 reduction, then the nZEB requirements for new buildings also have to include nearly zero carbon emissions below approx. 3kgCO_2/m^{2}yr[3]. A weaker ambition for new buildings between 2021 and 2050 would necessarily lead to an even higher and almost unrealistic savings requirement of "90% plus" for the renovation of today's building stock.

Challenge Nº 2:

How different are the solutions between nearly zero CO_2 and nearly zero (primary) energy solutions for individual buildings and what are the implications for a suitable definition of nZEBs?

Implication for the nZEB definition

The first nZEB implication identified is the need for a consistent definition, which should contribute at the same time to both energy and CO_2 emission reductions. Hence, the minimum requirements for the energy performance of the building should use an energy indicator that can properly reflect both energy and CO_2 emissions of the building as the reduced energy consumption should lead to a proportional reduction of CO_2 emissions.

In general, the primary energy use of a building accurately reflects the depletion of fossil fuels and is sufficiently proportional to CO_2 emissions. Proportions are only distorted when nuclear electricity is involved. Nevertheless, if a single indicator is to be adopted, then the energy performance of the building should be indicated in terms of primary energy, as in line with current EPBD. However, to reflect the climate relevance of a building's operation, CO_2 emissions should be added as supplementary information.
It should be noted that there are additional requirements for ensuring a match between nZEBs and climate targets.

In particular, it is very important that the conversion factors from final to primary energy are based on reality and not influenced by political considerations or by an inaccurate approximation.
Moreover the conversion factors should be adapted continuously to the real situation of the energy system.

Challenge Nº 3:

Which choices should be made within a definition regarding time disparities (e.g. daily vs. annual balance) and local disparities (e.g. on-site vs. off-site production) between produced and consumed energy?

Implication for the nZEB definition

The nZEB definition should properly deal with local and temporal disparities of renewable energy production. This is necessary in order to, on one hand, maximise the renewable energy share and the emission reductions and, on other hand, ensure a sustainable development of the local heating and cooling systems. Therefore the nZEB definition should address the following:

- As to local disparities, the most obvious and practical solution is to accept and count all on-site, nearby and off-site production from renewable energy sources when calculating the primary energy use of the

[3] Starting from CO_2-emissions for the building sector of approximately 1.100 MtCO_2 in 1990 (direct and indirect emissions for heating, domestic hot water and cooling purposes) and assuming a useful floor area in 2050 of 38 billion m^2 in 2050, a 90% decrease of emissions would require an average CO_2-emissions of maximum 3 kgCO2/(m^{2}yr).: 1,100MtCO2 x (100%-90%) / 38 billion m^2 = 2.89 kg/(m^{2}yr).

building. Allowing for only on-site and nearby renewable energy production could be a considerable barrier in implementing nZEBs. Thus the nZEB definition should be flexible and adaptable to changes in local plans and strategies. For instance, a district heating connection should be mandatory for nZEBs when there are plans for a renewable powered district heating plant that offers supply at a reasonable price. Off-site renewable energy should be allowed as well because this offers more opportunities for 'green' energy production, opening and not restricting the future progress towards energy-positive buildings[4]. However, off-site renewable energy has to be properly controlled and certified for avoiding fraud and double counting.

- Temporal disparities in renewable energy supply may influence the associated GHG emissions of the building when off-site energy is used to compensate for periods with a lower renewable energy supply than the building's actual energy demand. Therefore, the period over which the energy balance of the building is calculated is important. The practical solution, offering at the same time a reasonable compromise, is to accept either monthly or annual balances. If annual balances are allowed, it will be necessary to introduce an additional verification methodology to take into account the associated GHG emissions of the energy supply over the period. The monthly energy balances are short enough to offer a reasonable guarantee for the emissions associated with the energy supplied to the building. In order to keep the concept as simple as possible it seems preferable and sufficient to use for the time being an annual balance, but to leave the option open for a more accurate yet demanding monthly energy balance in the future.

Challenge Nº 4:

How to ensure that a definition of nearly Zero-Energy Buildings avoids lock-in effects and allows the concept to be expanded later towards energy-positive buildings?

Implication for the nZEB definition

In order to ensure maximum flexibility and to minimise the risk of lock-in situations the nZEB definition should take into account the following:

- The evaluation of the buildings energy performance should be based on an annual balance but move towards a more accurate monthly balance in the future.
- The system boundaries should not be too tight, e.g. inclusion of renewable energy from the grid should be possible in specific cases when on-site/nearby capacities cannot be installed due to spatial and building geometry constrictions and/or weather conditions.
- The energy balance must take into account the quality of the energy and be assessed separately for electricity and heating. Hence, the quality of the energy production should be considered as being an important condition for avoiding a misleading nZEB concept with ineffective or counter-productive achievements.

Challenge Nº 5:

How can a definition be shaped to be applicable or transferable to different climates, building types, building traditions etc. in a way that reflects such differing circumstances and allows flexibility without leading to (too) complex rules?

Implication for the nZEB definition

A proper nZEB definition should take into account the climate, building geometry and usage conditions as follows:

[4] Energy-positive buildings are buildings with on-site renewable energy production higher than the building's energy demand.

- **Climate:** Two options are suggested for taking into account climate conditions in the nZEB definition:
  - A first option is to calculate the energy requirement for an average European building located in an average European climate on the basis of the EU's 2050 climate target. This average energy requirement may then be corrected and adapted at national/regional level, e.g. by using the relation of national/regional vs. European cooling degree days (CDD)+ heating degree days (HDD).
  - A second option is to calculate and impose a fixed value, being zero or very close to zero, and the same for each country and all over Europe. Such option would be chosen in the event that the first option appears to be too complicated or it will be necessary to have an absolute zero energy balance for all new European buildings in order to reach the climate targets.
- **Geometry:** It appears unfair for buildings with an "easy" shape to have to compensate for the unfavorable geometries of other buildings. Hence, for new buildings differences in geometry do not seem to be a striking argument for differences in energy requirements (e.g. in kWh/m^{2}yr) and the requirements should therefore be independent of geometry[5]. On the other hand, for the existing building stock this might be seen differently and the geometry aspects should be further analysed in order to avoid additional unfair burdening of the building owners.
- **Usage:** All residential buildings should meet the same requirements as they typically have the same usage patterns. In addition, non-residential buildings with a similar usage pattern as residential buildings may still have the same requirements as residential buildings. The other non-residential buildings should be classified in as few categories as possible (following the main criteria of indoor temperature, internal heat gains, required ventilation etc.) and should have particular energy performance requirements.

Challenge Nº 6:

Should a definition of nearly Zero-Energy Buildings and related thresholds include or exclude household electricity (plug load) and in which way could this be done?

Implication for the nZEB definition

For providing convincing guidance on a nearly Zero-Energy Buildings definition, it may well be questioned if the EPBD lists all the relevant energy uses that are actually related to the ultimate goal of minimising building related CO_2 emissions. Based on an extensive analysis, the following is proposed:

- According to the EPBD only the energy use of equipment providing some selected "building services" which are heating, cooling, ventilation and lighting is to be considered in an nZEB definition. Nevertheless there is some further integrated equipment providing building services, which may be even mandatory by law in most of the Member States, but which is missing in the EPBD and thus should be a part of it. For example lifts and fire protection systems are not within the scope of the nZEB definition from the EPBD, but are part of the default 'building services'.
- At this point in time, including electricity for appliances in the definition of nZEB is not recommended, because it is not in the current scope of the EPBD. However, in the long run, it is advisable to complement the energy uses currently mentioned in the EPBD by all other energy uses in the buildings. Household electricity or electricity for appliances should be included in a future version of the EPBD, e.g. via a given value per person or m^2 (similar to the approach regarding the need for domestic hot water in current regulations) and consequently in the nZEB definition.
- A feasible interim solution for avoiding sub-optimisation might be to systemize all energy uses and clearly show the subset of uses currently included in the EPBD. The energy uses outside the scope of the EPBD do not necessarily need to be integrated in the same energy performance indicator, but

[5] An exception might be made for single family homes with a very small floor area per capita as in the end it is the absolute [kWh/yr] and not the specific consumption [kWh/m^{2}a] that counts.

they might be mentioned using the same unit along with the EPBD indicator in order to get the whole picture.

- To achieve a sustainable nZEB definition it may be important to take into account all the energy uses of a building for two main reasons:
  - In today's very low-energy or passive houses the amount of household electricity or electricity for appliances respectively has the same order of magnitude as that needed for space heating/cooling and domestic hot water. The same is true for the technical systems providing building services.
  - In Europe, on average, electricity consumption represents comparatively high amounts of primary energy consumption and related carbon dioxide emissions. The same goes for energy use in the construction of the building and its supply systems as well as for disposal of the building.

Challenge Nº 7:

Should a definition of nearly Zero-Energy Buildings and related thresholds include or exclude the production and disposal stage of building elements, components and systems and in which way could this be done?

Implication for the nZEB definition

A life-cycle assessment (LCA) approach for nZEB is definitely far beyond the current intention of the EPBD, but might be in a future recast. There are some practical recommendations to be considered for the time being:

- Energy consumption during the construction and disposal phases of a building becomes more important the more the energy consumption during the use phase decreases.
- Due to insufficient consistency of results from different LCA tools it may be too early to require LCA information as part of a threshold value. Nevertheless, in principle, it would make sense to include LCA information in the evaluation of a building's energy performance.
- A practical solution for the near future would be to estimate the energy need for production and disposal and require an informative mention of this value in addition to the indicator(s) reflecting the energy performance of the building. Including the information regarding energy consumption during the phases of construction and disposal of a building will underline the importance of each life cycle phase's energy consumption. However, for the time being it is not suggested that life cycle energy consumption be included within the scope of the EPBD.

Challenge Nº 8:

Should it be possible within the definition of nearly Zero-Energy Buildings (regarding demand side and supply side) to look at groups of buildings rather than at a single building?

Implication for the nZEB definition

The EPBD clearly focuses on the energy performance of individual buildings. However, there may be good reasons to address a group of buildings and to have a common energy balance for them. For assessing the opportunity of considering groups of buildings instead of a single building, the energy demand and the energy supply need to be analysed separately.

- As to the energy demand side, it may be a solution to compensate specific disadvantageous circumstances affecting one or a few selected buildings within a group of buildings (e.g. shading from landscape and thereby reduced solar gains) that do not allow each of these selected buildings to achieve a required very low energy demand with an acceptable level of effort. However, this would

mean that the owner of a building which is part of such a pool would depend on what is actually built and maintained by other owners. Apparently the situation is easier when having one owner for the whole new settlement, e.g. a building complex owned and rented by a real-estate company. However, especially in the case of new buildings, there seems to be little evidence to explain why a certain required threshold should not be reached at the level of the individual building; the energy related or financial synergies from pooling buildings are not obvious. Consequently, there are no sufficiently strong reasons for clustering buildings.

- As to the energy supply side, it is clearly within the EPBD scope to use nearby/on-site central systems as an alternative to individual systems per building. Such central supply can yield benefits e.g. in terms of investment savings, better efficiency and better possibilities for seasonal storage.

Challenge Nº 9:

What guidance can/needs to be given regarding the balance of energy efficiency and renewable energy within the nearly Zero-Energy Buildings definition?

Implication for the nZEB definition

It is necessary and also in line with the EPBD's nZEB definition to have a threshold for maximum energy demand as well as a requirement for the minimum percentage of renewables. For this reason, the renewable energy share should take into account only active supply systems such as solar systems, pellet boilers etc. The passive use of renewable energy, e.g. passive solar gains, is an important design element of nearly Zero-Energy Buildings, but it seems logical - and also in line with EPBD-related CEN standards - to take these into account for the reduction of gross energy needs.

A threshold for energy demand could be set for each country in a given corridor, defined top-down at EU level according to the needs imposed by longer term climate targets and climate adjusted at country/ regional level, e.g. based on HDD/ CDD.

The minimum share of renewables to cover the remaining nearly zero or very low energy demand of the building might be chosen in the range of 50%-90% in order to be consistent with EU energy and climate targets. Moreover, there are two more reasons for choosing a compulsory range of 50%-90%:

- The proposed range is in line with the nZEB definition from EPBD which is asking that the energy demand of the building be covered from renewable sources to a "very significant extent".
- The proposed range is likely to satisfy all the potential requirements for achieving the overarching targets for energy or GHG respectively.

The requirement proposed above for the renewable energy share would contribute to a paradigm change moving from renewable energy being a minor substitute or complement of a fossil fuel based energy system towards an energy system where renewable energy is dominant, while fossil systems exist only to a certain extent, e.g. to secure the supply during peak loads or as a backup source.

Whereas the bandwidth of the necessary share of renewable energy supply can be derived from technical and financial boundary conditions, the exact share to be achieved at EU or country levels is likely to remain subject to political considerations. A possible practical solution is to start with a minimum requirement for the renewable energy share as part of the nZEB definition and to stimulate a further increase of the share.

Challenge Nº 10:

Is there a necessary or optional link between the principle of cost-optimality and the concept of nearly Zero-Energy Buildings within the EPBD recast and what could be the implications?

Implication for the nZEB definition

The recast EPBD stipulates that the EU Member States shall ensure minimum energy performance requirements for buildings to be set 'with a view to achieving cost-optimal levels[6]'. Whereas the Commission is to provide the comparative framework cost-optimal methodology, each EU Member State has to do the calculations at country level, to compare the results with its energy performance requirements in force and to improve those requirements accordingly if necessary.

Beyond delivering information for the update of current requirements over the coming years, the cost-optimal methodology is suitable for gradually steering cost-optimal levels towards nZEB levels by 2021. Indeed, the cost-optimal methodology may be used, for instance, to calculate the needed financial support (soft loans, subsidies etc.) and market developments (cost reduction for certain technology etc.) for facilitating a smooth and logical transition from today's energy performance requirements towards nZEB levels in 2021.

Consequently, when fixing a threshold for the energy demand of a nZEB, it is recommended to leave some freedom for placing this threshold within a certain corridor, which could be defined as follows:

- The upper – least ambitious - limit, defined by the energy demand of different building types, would result from applying the cost-optimal levels according to Article 5 of the EPBD recast.
- The lower – most ambitious - limit of the corridor, would be set by the best available technology that is freely available and well introduced on the market, e.g. as, currently, triple glazing for windows.

The EU Member States may determine their national requirement for the buildings' energy demand within the limits of the above corridor, according to the specific national context. Imposing a corridor and not a fixed threshold, will allow specific country solutions for achieving an overarching target (primary energy / CO_2-emissions), based on the most convenient and affordable balance between minimum requirements for energy demand and renewable energy share.

Today we assume that, on the one hand, there may still be a gap to be bridged between cost-optimal levels and nZEB levels by 2021, at least in some EU Member States. On the other hand, in several Member States it is also possible to reach convergence between cost-optimal and nZEB levels by 2021, mainly due to the estimated increase in energy prices[7] and expected decrease in technology costs[8].

PRINCIPLES FOR NEARLY ZERO-ENERGY BUILDINGS

To achieve a suitable definition, related facts and findings need to be seen in a broader societal context and need to be transferred into a practical standard, taking into account financial, legal, technical and environmental aspects. Analysing the implications identified above, it becomes obvious that most of them interact or require the consideration of one or several societal aspects. Consequently, the principles for a nZEB definition should be built on the same broad perspective, should take into account all financial, legal, technical and environmental aspects and should meet the present and future challenges and benefits. Hence, a proper and feasible nZEB definition should have the following characteristics:

- To be clear in its aims and terms, to avoid misunderstandings and implementation failures.

[6] The cost-optimal level shall lie within the range of performance levels where the cost-benefit analysis calculated over the estimated economic lifecycle is positive. The cost-optimal level is defined in Article 2 and described in Article 5 of the EPBD (Directive 2010/31/EU).
[7] Incl. the national energy tax system development as part of the national activities towards more economic solutions.
[8] Due to volume effects induced by the introduction of the nZEB requirement.

- To be technically and financially feasible.
- To be sufficiently flexible and adaptable to local climate conditions, building traditions etc., without compromising the overall aim.
- To build on the existing low-energy standards and practices.
- To allow and even foster open competition between different technologies.
- To be ambitious in terms of environmental impact and to be elaborated as an open concept, able to keep pace with the technology development.
- To be elaborated based on a wide agreement of the main stakeholders (politicians, designers, industry, investors, users etc.).
- To be inspiring and to stimulate the appetite for faster adoption.

Consequently, there are three basic principles, each one with a corollary for setting up a proper nZEB definition, addressing the three main reasons and aims for regulating the building sector: reduced energy demand, the use of renewable energy and reduced associated GHG emissions. The suggested principles and approaches for implementing them are described in the following table.

First nZEB Principle: **Energy demand**	**Second nZEB Principle:** **Renewable energy share**	**Third nZEB Principle:** **Primary energy and CO_2 emissions**
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.	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.	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.
Implementation approach: This boundary should be the energy need of the building, i.e. the sum of useful heat, cold and electricity needed for space cooling, space heating, domestic hot water and lighting (the latter only for non-residential buildings). It should also include the distribution and storage losses within the building. **Addendum:** The electricity (energy) consumption of appliances (plug load) and of the other building technical systems (i.e. lifts, fire security lighting etc.) may also be included in the nZEB definition as an additional indicative fixed value (similar to the approach on domestic hot water demand in most of the MSs building regulations).	**Implementation approach:** This could be the sum of energy needs and system losses, i.e. the total energy delivered into the building from active supply systems incl. auxiliary energy for pumps, fans etc. The eligible share of renewable energy is all energy produced from renewable sources on site (including the renewable share of heat pumps), nearby and offsite being delivered to the building. Double counting must be avoided.	**Implementation approach:** This is the primary energy demand and CO_2 emissions related to the total energy delivered into the building from active supply systems. If more renewable energy should be produced than energy used during a balance period, clear national rules should be available on how to account for the net export.

Corollary of First nZEB Principle: **Threshold on energy demand**	Corollary of Second nZEB Principle: **Threshold on renewable energy share**	Corollary of Third nZEB Principle: **Threshold on CO_2 emissions in primary energy**
A threshold for the maximum allowable energy need should be defined.	A threshold for the minimum share of renewable energy demand should be defined.	A threshold for the overarching primary energy demand and CO_2 emissions should be defined.
Implementation approach: For the definition of such a threshold, it could be recommended to give the Member States the freedom to move in a certain corridor, which could be defined in the following way: • The upper limit (least ambitious, maximum allowed energy demand) can be defined by the energy demand that develops for different building types from applying the principle of cost optimality according to Article 5 of the EPBD recast. • The lower limit (most ambitious) of the corridor is set by the best available technology that is freely available and well introduced on the market. Member States might determine their individual position within that corridor based on specific relevant national conditions.	**Implementation approach:** The share of energy from renewable sources which is considered to be "very significant" should be increased step-by-step between 2021 and 2050. The starting point should be determined based on best practice, nearly Zero-Energy Buildings serving as a benchmark as to what can be achieved at reasonable life-cycle cost. A reasonable corridor seems to be between 50% and 90% (or 100%).	**Implementation approach:** For meeting the EU long term climate targets, the buildings CO_2 emissions related to the energy demand is recommended to be below 3 kg CO_2/(m^2 yr). The EPBD clearly promotes primary energy as indicator for the energy performance of buildings. However, the buildings should follow also the EU's long-term goals by 2050 and definitively the CO_2 reduction is in close relation to the reduction of energy consumption and energy decarbonisation. Consequently, introducing an indicator on the CO_2 emissions of buildings (linked to the primary energy indicator for the energy demand) is the single way to ensure coherence and consistence between the long-term energy and environmental goals of the EU.

VALIDATION OF NZEB PRINCIPLES: SIMULATION OF REFERENCE BUILDINGS IN DIFFERENT CLIMATE ZONES

To verify and evaluate the proposed nZEB principles and implementation approaches, indicative simulations on reference buildings were performed.

The main challenge of the simulation was to provide robust insights into the nZEB principles' effect by applying them to a set of reference buildings, sufficiently representative of the wide variety of building-types, while considering at the same time the influence of different European climate zones.

Within an extensive BPIE assessment of the European building stock[9], residential buildings turned out to represent around 75% of the EU building stock in terms of floor area, where single family houses account for 64% and multi-storey family buildings for 36%. As to non-residential buildings, 58% are multi-storey buildings consisting of offices and administrative buildings, educational buildings, hospitals and hotels.

[9] Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings, Buildings Performance Institute Europe 2011.

This is a clear indication that the most representative European buildings are single family houses, multi-storey residential and multi-storey non-residential buildings. Moreover, it is likely that new buildings will follow the same typology as the existing building stock from today. Based on the above considerations, two reference buildings were selected:

- New single family residential building (129m^2 net floor area)
- New multi-storey non-residential building (e.g. office building) with a size that also could represent a typical multi-family building (1,600m^2 net floor area)

For each reference building, basic characteristics were defined in terms of geometry, technical systems and usage patterns.

The application of the nZEB principles is simulated by these two representative buildings and takes into consideration the following three locations which correspond to the main European climate zones:

- Copenhagen, (Denmark), cold climate;
- Stuttgart (Germany), moderate climate;
- Madrid (Spain), warm climate.

Within the simulated application of nZEB principles on the reference buildings in different climate zones, the following parameters were considered and calculated:

- Specific primary energy demand detailed by building services, i.e. heating, domestic hot water (DHW), cooling, solar thermal domestic hot water, losses.
- Different technology options for providing a building's heating, cooling and DHW: air source heat pump, brine source heat pump, biomass boiler, gas condensing boiler, district heating, micro-CHP gas, micro-CHP biomass, multi-split cooling units for residential (COP), central cooling system for offices.
- Final energy demands in several technology assumptions and detailed by building services (i.e. heating, domestic hot water, cooling, ventilation and auxiliary energy).
- The primary energy demand, the renewable energy share and the associated GHG emissions of the reference buildings were calculated for each climate zone in two situations with or without considering the electricity consumption of appliances and other building equipment outside the scope of the EPBD.
- Renewable energy: In addition to the basic technical system presented above, the simulation considered several supplementary options such as:
  - One on-site photovoltaic (PV) system of 2kW$_p$
  - Additional use of off-site "100%-green electricity", which is assumed to have 100% share of renewable energy and a CO_2 emission-facor of 0 kg/kWh as well as a primary energy factor of 0 kWh/kWh.
- Specific CO_2 emissions and primary energy: In addition to the above-mentioned assumptions, a PV-compensation was considered to reach a 50% or 90% share of renewables.
- All analysed options assumed a well-sealed and insulated building shell with a highly efficient ventilation system, leading to a very low energy demand.

COMPARATIVE INTERPRETATION OF THE RESULTS

The simulation analysed the impact of all the above-mentioned options within the buildings' energy balance, relative to the thresholds assigned by the proposed nZEB principles and aligned to the EPBD requirements. The general findings of simulating the application of the proposed nZEB principles may be summarised as follows:

Impact of different options	
Renewable energy share between 50% and 90%	**CO_2 emissions below 3 $kgCO_2/m^2yr$**
Fossil fired solutions are already struggling to achieve a renewable share of 50%. The fossil fired systems are not an option in the case of including the energy consumption of appliances in the energy demand and imposing a requirement for a very high share of renewables (90%). A 90% renewable share may be reached by using additional off-site green electricity or, only in regions with very good solar irradiation, by installing additional on-site renewables. District heating impact depends largely on its renewable share; a 50% renewable DH system is not enough in some locations. In single family buildings, heat pump solutions easily achieve a 50% renewable share. By using additional off-site green electricity or on-site renewables, the heat pump option can secure even a 100% renewable energy share. In office buildings, biomass and heat pump solutions reach a 50% share of renewables.	For the single family building, at the basic variants (excluding appliances, green electricity and PV) all fossil fired solutions (gas boiler, micro CHP and district heating with a small renewable share) generally are clearly above the limit of 3 $kgCO_2/(m^2yr)$. Heat pump solutions come close and bio solutions (biomass boiler, bio micro CHP) clearly stay below the threshold. For office buildings, only the biomass micro CHP is below the threshold. Using green off-site electricity significantly decreases CO_2 emissions. For the single family building, the fossil fired solutions generally fail to meet the target (with or without the consideration of appliances), except at locations with very little heating and hot-water demand (in warm climate zones). In office buildings, because of the relatively high share of electricity all related variants stay below the threshold. The consideration of the electricity demand for the appliances and office equipment does not generally change this result.
For single family homes with high heat consumption, it is possible to achieve a 90% share of renewables only by using a 100% heat supply from biomass fired systems (boiler, CHP). Office buildings have a higher relative share of electricity than residential buildings. Therefore green electricity is required by all considered options (expect the fossil fuels options) in order to reach a 90% share, usually even including office equipment (appliances). Due to space restrictions, additional PV systems are less effective than in the case of the single family building.	For the single family building, additional on-site renewables (i.e. PV in this simulation) improve the situation. The fossil solutions are still above the threshold even with the considered additional PV system (which is however quite small, but enough to reach a high renewable energy share). For office buildings, additional on-site renewables (such as the 2 kW_p PV system) is much less effective. The CO_2 threshold is fulfilled only without appliances and assuming additional on-site PV power. Fossil fuel options in moderate and cold climate zone cannot fulfil the condition even with additional on-site PV power.

The average investment costs for using different heating technologies vary largely according to the local market circumstances, contract negotiations, sales volumes etc. and might differ substantially from one case to another. The investment costs identified within the study are in the range of EUR 6,300 - 55,600 for the reference single family building and in the range of EUR 12,400 - 224,000 for the reference multi-storey building. The cheapest option is the district heating; the most expensive option is the biomass micro-CHP.

TECHNOLOGICAL, FINANCIAL AND POLICY IMPLICATIONS OF THE NZEB PRINCIPLES

While a definition of nearly Zero-Energy Buildings needs to deliver the framework for successful implementation of the related principles at building level, any final definition of nearly Zero-Energy Buildings needs to and will have implications at EU level.
This last part of the study therefore analyses the actual status and implications of moving towards nZEB levels from a technical, financial and political point of view.

Technology and resources

The simulations have shown that the proposed nZEB principles are feasible and reachable with already existing technologies. From the simulations performed within this study, most of the cases hint at the need for compensating measures such as green electricity or on-site renewable electricity (i.e. photovoltaic). Fossil fuel based technologies are not consistent with the ambition of the proposed nZEB principles. All-electric solutions (heat pumps) seem to be amongst the most suitable solutions, mainly due to the expected and continuous decarbonisation of the electricity sector and due to on-site renewable electricity. In particular biomass micro-CHPs have shown very good results but this technology needs further development. District heating systems have a great potential as well but only under the condition of higher shares of renewable energy (certainly higher than 50%) than assumed in the simulations.

Further improvements towards highly efficient thermal insulation materials and windows, as well as of heating, cooling and ventilation technologies, will enlarge the available options and will push the nZEB limits towards higher performances and potentially more affordable costs. But for achieving proper levels of market deployment for energy efficiency technologies it is necessary to up-scale the actual levels and to foster the market penetration of promising new technologies.

Based on the Ecofys Built Environment Analysis Model (BEAM^2)[10], the study analyses the future markets for energy efficient technologies and materials. The evaluation indicates that investments in new energy efficient technologies have to increase to satisfy the additional demand created by new nZEBs. However, there are significant differences regarding the different technologies and their barriers. The highest growth rates for achieving a well-developed nZEBs market were identified for ventilation systems with heat recovery and for triple glazed windows. For these components the actual market is really small compared to what it should be to satisfy the necessary demand for full nZEB implementation. As for the other nZEB related technologies, the gap between the actual market and the necessary future market size is smaller. To satisfy the calculated demand, the current market for insulation materials should grow by about two to three times. The market for heat pumps, pellet boilers and solar thermal systems should grow at least in the same range. The following table gives an overview of current market sizes and the factors which today's markets should expand in order to satisfy future demand.

[10] Further information: http://www.ecofys.nl/com/news/pressreleases2010/documents/2pager_Ecofys_BEAM2_ENG_10_2010.pdf

Markets	Required growth factor	Current market size	Unit
Insulation materials	2-3	2 010	Mio EUR
Ventilation systems with heat recovery	8-10	130 000	units
Triple glazed windows	>10	1 500 000	m^2
Heat pumps	2-3	185 000	units
Pellet boilers	2-3	43 000	units
Solar thermal systems	2-3	3 700 000	m^2

Apart from market barriers, barriers regarding know-how and number of professionals also exist. To date, 1% of all new buildings in Germany are built according to the passive house standard. Therefore it can be assumed that at EU level the percentage is smaller than 1%. Even considering that nZEB is not necessarily equivalent to a passive house but close to the energy level of passive houses, the factor by which the deployment of nZEBs across Europe should increase can be assumed to be beyond 100. For reaching this market level for very low-energy buildings it is necessary to improve the skills of and to expand the number of building professionals, from architects, construction engineers to installers and workers. Without systematic efforts at overcoming this barrier, it will be difficult to achieve the nZEB expectations. A successful implementation of nearly Zero-Energy Buildings will also need technology transfer within the EU. This is especially important for technologies to reduce heating and cooling demand.

Financial impacts at EU level

The turnover in the building industry in the EU for non-residential and residential buildings in 2009 was about EUR 1 trillion, about half of that amount (EUR 470 billion) is due to new buildings[11]. Based on several market studies, actual investments in new buildings for heat pumps, pellet heating systems, ventilation systems with heat recovery, triple glazed windows and insulation materials at EU level are estimated to reach about EUR 23 billion[12]. To implement nZEB requirements for every new building, the investments are estimated to reach about EUR 62 billion per year[13]. The difference of EUR 39 billion would represent an overall increase of about 9%, being a considerable growth that seems achievable when taking place over the years until 2020 (approx. 1% increase per year).

nZEB and general EU policies and targets

The definition of nearly Zero-Energy Buildings has to, beyond delivering a method that complies with the EPBD text, also fit in with general and cross sectoral targets connected to activities in the building sector, such as those related to energy conservation and to lowering energy consumption, efficient use of resources, climate protection and job creation or relief of social systems respectively.

The proposed nZEB principles directly fit with the European Union's energy and climate targets. Moreover, the proposed nZEB principles have the potential to strongly support EU job creation targets by stimulating construction activity as well as innovation and production processes in the supply chain industry. The job creation potential of the building activity can be estimated on the basis of the job intensity in the related sectors, i.e. the turnover potential per employee. According to that calculation, the implementation of nZEB as a mandatory requirement in the future would create about 345,000 additional jobs[14].

Bridging the gap between cost-optimal and the nZEB levels

The proposed nZEB principles and approaches to implementing them into practical definitions are consistent with the EPBD by assuming the cost-optimality methodology as a transitory instrument converging towards the future nZEB requirement.

[11] Euroconstruct (2010). 70th Euroconstruct Country Book.

[12] in 2009, during the financial crisis with relatively low new building activities

[13] The necessary investment has been calculated with the BEAM² model from Ecofys. Further information: http://www.ecofys.nl/com/news/pressreleases 2010/documents/2pager_Ecofys_BEAM2_ENG_10_2010.pdf

[14] Assuming an extra investment of EUR 39 billion per year and an average turnover in the EU construction industry of EUR 113,000 (in 2008) per person and year.

While the simulation of the nZEB principles has been made considering the current situation and market conditions, the future evolution will be crucial for the financial gap between cost-optimality and nZEB requirements.

Depending on the specific context by 2021, the financial gap between cost-optimality and the binding nZEB requirements may need to be bridged by additional policies and support measures. This financial gap is highly influenced by the future evolution of numerous economic factors, the most important ones being technology costs as a reaction to more mature markets and larger production volumes.

nZEB implications for national policies of the EU Member States

To comply with the proposed nZEB principles, current national codes in general need to be gradually strengthened towards more ambitious levels. Moreover, beyond tightening the existing requirements it is necessary to adapt and improve the structure of the legal requirements supporting the market deployment of buildings-related energy efficient and renewable energy technologies.
For example, in Germany the national building code (EnEV), the law on renewable heat in buildings (EEWärmeG) and the law that regulates feed in tariffs for grid connected renewables (EEG) coexist and investors need to comply with all related regulations. For supporting the nZEB implementation it would be useful to merge the regulations for renewable energy with the existing building regulations or to broaden the scope of the existing buildings regulations by introducing renewable energy requirements (also indicated by Article 13 of the Renewable Energy Directive, 2009/28/EU).
Another example is Denmark, where current buildings regulations do not present a particular barrier to nZEB but have to be revised particularly by introducing renewable energy requirements. On the other hand, the Danish Building Regulation already includes a 'Low Energy Building 2020' target, which is very well in tune with the proposed nZEB principles in general and with the proposed renewable energy share in particular.

nZEBs and sustainable cities

The effect of local aspects to the energy demand and supply of buildings is quite high especially in relation to new buildings. In a passive house and nZEB design, the free solar gains have a crucial influence on the heating and cooling energy demand of a building. However, solar gains may easily vary by around 25% at the same location, being strongly influenced by the orientation and by potential shading of the building facades. Therefore, before starting the construction of a new building, careful consideration of the positioning and orientation needs to be done in order to maximise or minimize respectively the solar gain.
Typical specificities of an urban area, such as its density, are also very important for the energy supply of a building. The design of central energy supply and district heating systems should already encompass upcoming nZEB requirements. To further support the implementation of nZEBs, local utilities should play an important role in providing nearby renewable energy – heat, cold and power – to the future nZEBs. An integrated approach between the buildings' and local utilities' policies may facilitate a faster and cheaper implementation of nZEBs, compensating at the same time for the potential spatial constrictions of having on-site renewable generation for each building. As an example, the introduction of a "quota regulation" in favour of renewable energies for district heat and power will support simultaneously the market deployment of nZEBs and the predictable development of the district heat and power systems at local level.

Hence, the smart cities policies should consider and facilitate the introduction of nZEB by providing an energy system well-tailored to the future needs of buildings'. Therefore, the energy optimization of urban structures needs to be part of the sustainability concept for European cities.
Knowledge about the huge potential lying within such optimization needs to be spread amongst all stakeholders involved in urban and centralised energy supply planning.
Sustainable policies in European cities have to contribute to the paradigm shift from traditional sector-oriented approach to a more integrated approach which ensures the consistency between the district energy supply and urban development.

Further steps towards a successful implementation of nZEBs

While offering solutions to various questions and proposing an approach for how to define nearly Zero-Energy Buildings in the EU, this study can of course only give indications for a possible direction. However, there are several steps that remain to be made by the EU and its Member States to implement the concept of nearly Zero-Energy Buildings.

Thereby, the following steps could be milestones in the development towards a full and effective implementation of nearly Zero-Energy Buildings:

What to do	Whose responsibility
Agreement on a concrete outline of a definition for nearly Zero-Energy Buildings, based on the EPBD recast text.	EU Member States, EU Commission, EU Parliament, Stakeholders.
Create benchmarks for suitable nearly Zero-Energy Buildings in different Member States as a basis for comparison.	EU Member States, EU Commission, Stakeholders.
Agree on a corridor for the value of an overarching threshold for nearly Zero-Energy Buildings, e.g. the 0-3 kg CO_2 per m^2 and year.	EU Member States, EU Commission, EU Parliament.
Generate a common reporting format for Member States to be used for reporting national plans on how to move towards nearly Zero-Energy Buildings.	EU Member States, EU Commission.
Facilitate and support implementation of new nearly Zero-Energy Buildings already on the way to 2019/2021 by helping investors understand the necessary up-front investment, by helping to build planning and implementation capacities (Commission, Member States).	EU Member States, EU Commission.
Work on a definition for buildings renovated to a nearly Zero-Energy Buildings target. This could be a similar definition, which is softened in specific aspects, acknowledging the different limitations when dealing with existing structures.	EU Member States, EU Commission, EU Parliament, Stakeholders.

Europe will take an important step forward towards a sustainable future by elaborating a consistent and effective nZEB definition and by successfully implementing it. Today we have a great opportunity to define the right directions for the building sector and to exploit the requirements set by the recast Energy Performance of Buildings Directive. Taking into account the long life cycles of buildings (>30-40 years), it becomes obvious that there is probably no second chance if we do not act now, if we do not develop effective requirements and if we do not properly implement them.

Overall, the key to success will be a permanent communication between all the parties involved in order to create wide agreement on future nZEB requirements.

Moreover, it is vital to strengthen the commitment of European stakeholders and citizens by offering the right support and clear explanations on the benefits of living and working in better and greener buildings.

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