How to define nearly net zero energy buildings nZEB

– REHVA proposal for uniformed national implementation of EPBD recast

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Summary

This REHVA Task Force proposes a technical definition for nearly zero energy buildings required in the implementation of the Energy performance of buildings directive recast. Energy calculation framework and system boundaries associated with the definition are provided to specify which energy flows in which way are taken into account in the energy performance assessment. The intention of the Task Force is to help the experts in the Member States define the nearly zero energy buildings in a uniform way.

The directive requires nearly zero energy buildings, but since it does not give any harmonized requirements as well as details of energy performance calculation framework, it will be up to the Member States to define them. In the definition, local conditions obviously will be taken into account. However, the uniform methodology can be used in all Member States.

The directive defines nearly zero energy building as a building that has a very high energy performance and requires the calculation of primary energy indicator. 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.

Based on the directive's definition, a net zero energy building is a building using 0 kWh/ (m^2 a) primary energy. Following the current understanding that nearly zero energy buildings are not cost efficient yet, led to the proposed nZEB definition based on technically achievable energy performance. Nearly zero energy building was defined as **technically reasonable achievable national energy use of > 0 kWh/(m^2 a) primary energy achieved with best practice energy efficiency measures and renewable energy technologies** which may or may not be cost optimal.

In order to end up with a proposed general definition, it was needed to clarify which energy flows shall be included in energy performance assessment and how the primary energy factors should be used for primary energy indicator calculation. For the uniform methodology, a general system boundary definition was established with the inclusion of active solar and wind energy, as well as the guidance for technical meaning of "nearby" in the directive.

Proposed methodology is based on the use of standard energy calculation input data and energy calculation rules that makes it possible to compare objectively the energy performance of different buildings for compliance assessment purposes within the building types listed in the directive.

1. Background

The Energy performance of buildings directive recast (EPBD recast) came into force on July 9th 2010. Member States shall adopt and publish, by July 9th 2012 at the latest, the laws, regulations and administrative provisions necessary to comply with most of the articles. The background for the directive states that buildings account for 40 % of the total energy consumption in the European Union. The sector is expanding, which is bound to increase its energy consumption. Therefore, the reduction of energy consumption and the use of energy from renewable sources in the building sector

constitute important measures which are needed to reduce the Union's energy dependency and greenhouse gas emissions. Together with an increased use of energy from renewable sources, measures taken to reduce energy consumption in the Union would allow the Union to comply with the Kyoto Protocol, and its commitment to reduce, y 2020, the overall greenhouse gas emissions by at least 20 % below 1990 levels.

According to the Directive the Member States shall ensure that by 31 December 2020, all new buildings are nearly zero energy buildings; and after 31 December 2018, new buildings occupied and owned by public authorities will be nearly zero-energy buildings.

In the directive 'nearly zero-energy building' means a building that has a very high energy performance. 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. Since the Commission does not give minimum or maximum harmonized requirements, it will be up to the Member States to define what for them exactly constitutes a "very high energy performance".

National roadmaps towards nearly zero energy buildings are needed for all member states. Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building. Member States shall furthermore, following the leading example of the public sector, develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings, and inform the Commission thereof in their national plans.

The national plans shall include, inter alia, the following elements:

(a) the Member State's detailed application in practice of the definition of nearly zero-energy buildings, reflecting their national, regional or local conditions and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values and may take into account relevant European standards;

(b) intermediate targets for improving the energy performance of new buildings, by 2015,

(c) information on the policies and financial or other measures adopted in the context of for the promotion of nearly zero-energy buildings, including details of national requirements and measures concerning the use of energy from renewable sources in new buildings and existing buildings undergoing major renovation.

The Commission shall by December 31st 2012 and every three years thereafter publish a report on the progress of Member States in increasing the number of nearly zero-energy buildings. On the basis of 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.

A recent bench marking study on implementation on EPBD 2002 by REHVA (Seppänen & Goeders 2010) revealed a large variation in the technical regulations of the different countries. These differences in regulations have a significant effect on the building industry and complicate manufacturing, sales, installation, construction and design of buildings in the common market area. The experience learned from the actions taken by CEN from the year 2002 to help the implementation of EPBD showed that technical development work takes time. Professional assistance is needed in many areas, exchange of information and experience between Member States.

REHVA experts have realized the problem various definition of nearly zero energy building may cause in Europe. An important issue is how to define the various energy flows and how to establish the energy boundaries on the building. This paper reports the results of REHVA Task Force "Nearly Zero Energy Buildings". REHVA hopes that this report that focuses on definitions and energy boundaries will help the

experts in the member states in defining the nearly zero energy buildings in a uniform way. This would help in understanding the policy options and in exchanging information of most energy efficient technical solutions for buildings.

2. Terms and definitions

net zero energy building (ZEB)

Energy use of 0 kWh/(m^2 a) primary energy.

NOTE 1_ A net ZEB is typically a grid connected building with very high energy performance. A net ZEB balances its primary energy use so that the primary energy feed-in to the grid or other energy network equals to the primary energy delivered to ZEB from energy networks. Annual balance of 0 kWh/(m^2 a) primary energy use typically leads to the situation where significant amount of the on-site energy generation will be exchanged with the grid. Therefore a net ZEB produces energy when conditions are suitable and uses delivered energy during rest of the time.

nearly net zero energy building (nZEB)

Technically reasonable achievable national energy use of > 0 kWh/(m^2 a) primary energy achieved with best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal.

NOTE 1_ The Commission shall establish by June 30th 2011 a comparative methodology framework for calculation of cost-optimal levels (Cost optimal).

NOTE 2_ Not all renewable energy technologies needed for nearly zero energy building have to be cost-effective, if appropriate financial incentives are not available.

energy performance of the building (EN 15316-1:2007)
Calculated or measured amount of energy delivered and exported actually used or estimated to meet the different needs associated with a standardized use of the building, which may include, inter alia, energy used for heating, cooling, ventilation, domestic hot water, lighting and appliances.

NOTE 1_ According to EPBD, the energy performance of a building shall be expressed with a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on- site production.

NOTE 2 Appliances (households and outlets) are added to the original definition of EN 15316-1:2007.

delivered energy (EN 15603:2008)

Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (e.g. heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity.

exported energy (EN 15603:2008)

Energy, expressed per energy carrier, delivered by the technical building systems through the system boundary and used outside the system boundary.

net delivered energy (EN 15603:2008)

Delivered minus exported energy, both expressed per energy carrier.

NOTE 1_ Net delivered energy values are expressed separately for each energy carrier, i.e. for electricity, fuels, district heat, etc.

primary energy (EPBD recast)

Energy from renewable and non- renewable sources which has not undergone any conversion or transformation process.

CO_2 emission coefficient (EN 15603:2008)
For a given energy carrier, quantity of CO_2 emitted to atmosphere per unit of delivered energy.

NOTE 1_ The CO_2 emission coefficient can also include the equivalent emissions of other greenhouse gases (e.g. methane).

system boundary (EN 15603:2008) Boundary that includes within it all areas associated with the building (both inside and outside of the building) where energy is used or produced.

NOTE 1. All areas associated with the building typically refers to footprint of the building site.

3. National examples of low and zero energy building definitions

At the moment there are no official definitions of nearly nZEBs available, but the work with the national plans for nZEBs is ongoing and few results have been published.

Denmark

In the Danish Building Code (BR10), a class 2015 is defined, which fulfills the future energy performance requirements in 2015.

The total primary energy use in the energy frame consists of heating, ventilation, cooling, domestic/service hot water, and lighting (except in residences). Tenants' or users' electricity is excluded. Heating (natural gas, oil or district heating) has a primary energy factor of 1, but a factor of 0,8 can be used for district heating for buildings fulfilling class 2015. Electricity has a primary energy factor of 2.5. The floor area, A, used is the gross floor area measured outside the external walls. As a small country, there is only one climate zone.

Table 1. Primary energy frames for new buildings in Denmark 2008, 2010 and 2015

	Energy frame [kWh/(m² a)]	Energy frame [kWh/(m² a)]	Energy frame [kWh/(m² a)]
Building Code	BR08	BR10	BR10 - Class 2015
Residential	70 + 2200/A	52,5 + 1650/A	30 + 1000/A
Non-residential	95 + 2200/A	71,3 + 1650/A	41 + 1000/A

France

The new French regulation (RT2012) issued on October 26th 2010, addresses low energy buildings targets for residential buildings, office buildings, school buildings, kinder gardens etc.

The total primary energy consumption is defined for heating, cooling, hot water production, lighting, ventilation and any auxiliary systems used for these domains. It is given by an overall coefficient Cep kWh/(m^2 a) using the net floor area of the building defined by the French building code.

The target maximum value of Cep, Cepmax is fixed to 50 kWh/(m^2 a) with various correction coefficients depending on the climatic zone, the altitude, the total area of the building and the type of energy used.

Furthermore, in order to ensure a good quality of the design of the envelope, another constraint is added. A new parameter Bbio is added in order to check the "bioclimatic" quality of the design. This Bbio parameter measures the energy need of the building for heating, cooling and lighting for a whole year. It has no dimension and is evaluated by a certain number of points. It has to be lower to Bbio max defined in the new regulation as a function of the location, altitude, type of building etc.

Finally, the air tightness of the building is also imposed to a maximum value depending of the building type and in summer, a limit for indoor summer temperature has to be checked if no cooling is used.

Germany

The current requirements (EnEV2009) for new residential buildings are calculated depending to a so called reference building. For the reference building there are standard U-values for the bottom floor, walls, windows and the roof and standard installation engineering given in the EnEV. The energy demand for residential buildings could be calculated with two different standards. On the one hand with DIN V 18599, on the other hand with a combination of DIN V 4108-6 : 2003-06 and DIN V 4701-10 : 2003-08. The primary energy demand of the new building must be below or equal to the energy demand of the reference building. Also a limit value for the specific transmission heat loss must be reached. A weighting factor for electricity consumption of 2.7 is being used.

Official definitions concerning the public subsidies for (residential) Low Energy Buildings are subject of the programs run by the (state-owned) Kreditanstalt für Wiederaufbau Frankfurt (KfW). These programs are mainly fed by public sources. The current requirements are KfW 70, KfW 55 and KfW 40. The primary energy demand of these buildings has to be 70%, 55% and 40% of the reference building. In addition, there is also a subsidy program for "Passiv-Häuser", which is defined in accordance with the Passiv-Haus-Institute as "KfW-40-buildings with an annual heat demand lower than 15 kWh/m2".

This figure can't be directly compared with the low energy classes from the other countries as passive houses only have requirement to energy for heating combined with a requirement to the overall use of primary energy to be maximal 120 kWh/m2 including energy for appliances.

Next step of enforced requirements in 2012 will be another 30% reduction for both residential and non-residential buildings. In 2020 new buildings shall be "climate friendly" with less primary energy demand.

Norway

A Low Energy Commission delivered a number of suggestions for increased energy efficiency of all sectors in Norway in the summer of 2009. The thick report also included suggestions of future net energy frame values for new buildings as well as for major renovations. The Norwegian Building Code, TEK is proposed to be sharpened every fifth year. TEK 07 was published in 1 February 2007 and is fully enforced from 1 September 2009. This building code was the first in Norway with an energy performance approach. The net energy use in the energy frame consists of heating, ventilation, cooling, domestic/service hot water, as well as tenants' or users' electricity. The net energy includes cooling supplied to air-cooling coils or fan coils in the rooms.

The floor area used is the heated floor area measured inside the external walls. Norway has a number of climate zones. The values given below are valid for the "standard" climate zone around Oslo, which is in the southeastern part of the country. The annual energy use of the proposed building is first modeled for the actual climate zone and then for the "standard" climate zone. The results for the standard climate zone must fulfill the energy frame. The current energy frames are specified for one-family houses, multi-family houses and eleven types of non-residential buildings.

Table 2. Proposed future net energy frames for new buildings in Norway

	Energy frame [kWh/(m² & a)]				
Building Code	TEK07	TEK12	TEK17	TEK22	TEK27
Residential	130	100	65	30	0
Non-residential	155	110	70	40	0

Sweden

A report of the draft Swedish plan for nZEBs was delivered by the Swedish Energy Agency to the Ministry of Enterprise, Energy and Communications on October 18th 2010. The report wants to keep the energy performance values, expressed as delivered energy per heated floor area, since the property owner cannot

control how the delivered energy is "produced". Primary energy factors are typically policy based and may be changed over time and a future report is suggested to define Swedish primary energy factors. These are mainly proposed to be used for official purposes, such as reporting to the European Commission.

The proposed maximum values for annual delivered energy per heated floor area are goals for the year 2020. They are more or less half the values in the current Building Code from February 1st 2009. The report also contains values for major renovations in 2020. The first such values in Sweden will be found in the coming Building Code of 2011. The Building Code from 2006 was the first in Sweden with an energy performance approach.

The midterm goal for 2015 is that at least 25% of the floor area of all erected buildings in 2015 should fulfill the energy requirements for the year 2020. For new buildings owned or used by the state the requirements are for the year 2019 and the portion in 2015 that should fulfill them is at least 50%. The delivered energy in the energy performance value consists of heating, ventilation, cooling, and domestic/service hot water. Electricity for technical building systems is also included. Tenants' or users' electricity is excluded. Electricity to chillers in non-electrically heated buildings shall be multiplied with the factor 3 in order to make possible comparisons with district cooling. Electric heated buildings are defined as having an installed electric power for heating of at least 10 W/m². For non-residential buildings the energy performance value is depending on the average outdoor airflow rate during the heating season. The floor area used is the heated floor area (A_{temp}) measured inside the external walls. Sweden has three climate zones. About 80 % of the population lives in southern climate zone and less than 10 % lives in the northern climate zone.

Table 3. Proposed energy performance numbers for new buildings in Sweden in 2020

Max energy performance [kWh/(m² & a)]	**Climate Zone**		
	Zone I - North	Zone II - Middle	Zone III - South
Residential (non-electric heating)	75	65	55
Residential (electric heating)	50	40	30
Non-residential (non-electric heating)	70 to 105	60 to 90	50 to 75
Non-residential (electric heating)	50 to 75	40 to 60	30 to 45

4. Proposed general definition format for nearly net zero energy buildings

The following general definition format is proposed to clarify the exact technical meaning of EPBD recast requirements in order to support national implementation. EPBD recast requires nearly nZEB buildings, defined as buildings with **a very high energy performance** and where energy need is covered to **a very significant extent by energy from renewable sources** (original wording given in Ch. 5). Since EPBD recast does not give minimum or maximum harmonized requirements as well as details of energy performance calculation framework, it will be up to the Member States to define what "a very high energy performance" and "to a very significant extent by energy from renewable sources" for them exactly constitute.

EPBD recast requires the evaluation of the cost optimality of current national minimum requirements by June 30th 2012 (Articles 4&5). This cost optimal policy launched by EPBD recast will instruct MS to shift minimum requirements to cost optimal energy performance level. Cost optimal policy does not say that nZEB has to be cost optimal, because nZEB is another, next political target established by EPBD. According to current understanding, nZEB is not cost efficient yet, however this may depend on available incentives. Therefore, these both requirements (cost optimal and nZEB) will have to be reconciled so that a smooth transaction from cost optimal requirements to nearly zero energy buildings could be guaranteed in near future. Currently it is suggested to define nZEB performance level rather through the bases of reasonable achievable technical solutions instead of cost optimal bases, which may be the situation in the future. Cost optimal calculations are

straightforward for the solutions with well-established costs that do not apply for renewable technologies where rapid developments expected make such calculations uncertain.

The following proposal includes energy calculation framework specifying how to define the various energy flows and how to establish the energy boundaries on the building, affecting the performance levels of nZEB building definitions. This guidance will help the experts in the member states in defining the nearly zero energy buildings in a uniform way.

Nearly net zero energy building definition shall be based on delivered and exported energy according to EPBD recast and EN 15603:2008. The net delivered energy, which is delivered minus exported energy per energy carrier, is shown in **Figure 1** and described with detailed system boundary definition in Ch. 5, **Figure 4**. This system boundary definition is a general form modified from the one of EN 15603:2008. Suggesting the inclusion of energy use of appliances (households and outlets), the system boundary proposes that all energy used in buildings will be accounted in net delivered energy as well as in nearly net zero energy building definition. According to that, energy use in the buildings includes inter alia, energy used for heating, cooling, ventilation, hot water, lighting and appliances. The last one is an amendment to EPBD recast definition shown in Ch. 5.

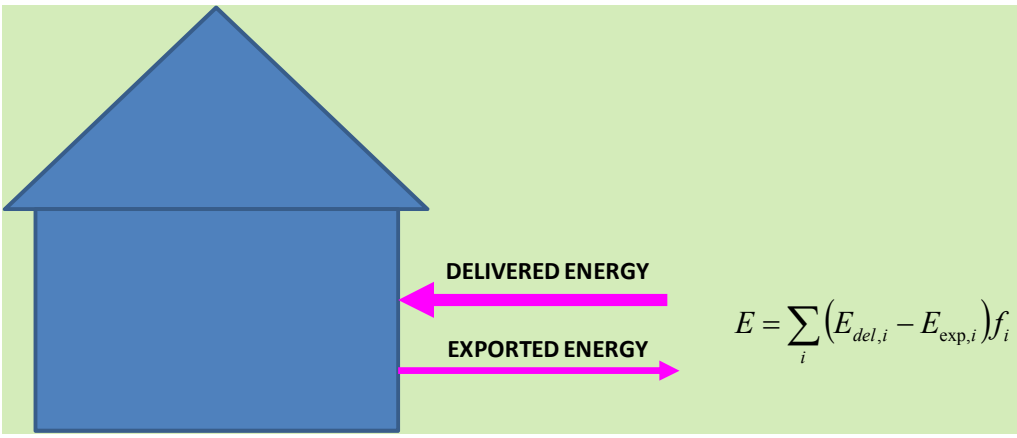


Figure 1. System boundary for nearly net zero energy building definition, connecting a building to energy networks. Net delivered energy is delivered $E_{del,i}$ minus exported energy $E_{exp,i}$ accounted separately for each energy carrier i. Primary energy E is calculated with primary energy factors f_i (the same factors are assumed for delivered and exported energy carriers in the figure, see Equation 1 for more details).

From net delivered energy, numeric indicator of primary energy can be calculated and used to define the performance level of nearly net zero energy building. Primary energy indicator (called often also as primary energy rating) sums up all delivered and exported energy (electricity, district heat/cooling, fuels) into a single indicator with primary energy factors. In a similar fashion, numeric indicator of CO_2 emission may be calculated with CO_2 emission coefficients. CO_2 indicator provides additional information about the consequences of energy use, in the terms of CO_2 emitted to atmosphere in energy production.

In order to be a sound definition, nearly net zero energy building defined through primary energy indicator, shall refer to specified energy calculation framework, including:

- system boundary of net delivered energy (EN 15603:2008 and Ch. 5);
- standard energy calculation input data (EN 15251:2007);
- test reference year to be used in energy calculations (ISO 15927-4:2005);
- primary energy factors for energy carriers (EN 15603:2008);
- energy calculation rules and methods for energy need and system calculations, covered in relevant EPBD standards;

which all affect calculated or measured primary energy indicator.

Net zero energy requirement has exact performance level of 0 kWh/(m_2 a) primary energy. The performance level of "nearly" net zero energy use is a subject of national decision taking into account:

- cost optimal and technically reasonably achievable level of primary energy use
- how many % of the primary energy is covered by renewable sources
- available financial incentives for renewable energy or energy efficiency measures
- ambition level of the definition

The following definitions are proposed:

net zero energy building (ZEB)
Energy use of 0 kWh/(m^2 a) primary energy.

nearly net zero energy building (nZEB)
Technically reasonable achievable national energy use of > 0 kWh/(m^2 a) primary energy achieved with best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal.

Primary energy can be calculated with Equation 1 as:

$$E = \sum_i \left(E_{del,i} f_{del,i}\right) - \sum_i \left(E_{\exp,i} f_{\exp,i}\right) \qquad (1)$$

where

$E_{del,i}$ is the delivered energy for energy carrier i;

$E_{exp,i}$ is the exported energy for energy carrier i;

$f_{del,i}$ is the primary energy factor for the delivered energy carrier i;

$f_{exp,i}$ is the primary energy factor for the exported energy carrier i, which may or may not be equal to the factor of the delivered energy, depending on national definition;

For the national definition of nearly net zero energy buildings, the performance levels of E-values should be specified for each building type, at least for those listed in EPBD recast:

(a) single-family houses of different types;

(b) apartment blocks;

(c) offices;

(d) educational buildings;

(e) hospitals;

(f) hotels and restaurants;

(g) sports facilities;

(h) wholesale and retail trade services buildings;

(i) other types of energy-consuming buildings.

The use of standard energy calculation input data and energy calculation rules makes it possible to compare objectively the energy performance of different buildings for compliance assessment purposes within the building types listed. In actual operation, buildings can be operated and used very differently within the same building type. But as all of these buildings are calculated with the same input data and calculation rules, the results remain reliable for the compliance assessment. Standard energy calculation input data is not suitable for the assessment of actual energy use in a specific building. If energy performance certificates include the assessment of actual energy use, inclusion of actual building operation data as well as actual climate data and in some cases more detailed definition of building types would be needed for better accuracy.

5. Proposed system boundary for net delivered energy

For any low energy or zero energy building definition or indicator, it would be necessary to specify which energy flows are included in the definition and which ones not. Either all energy used in the buildings may be taken into account, or some energy flows, such as electrical energy use of occupant appliances may be excluded. Such energy flow specification is called as system boundary and it provides a general framework for energy indicators. According to EPBD recast, energy performance is defined as (article 2):

> *'energy performance of a building' means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia,* ***energy used for heating, cooling, ventilation, hot water and lighting***

This energy performance definition helps to understand the EPBD recast definition for nearly zero-energy building (nZEB):

> *'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*

According to these EPBD recast definitions, electricity for households and outlets are not mandatory to be included. All other major energy flows are mandatory to be included.

EPBD recast, Annex I states common general framework for the calculation of energy performance of buildings. In this framework, it is said that:

> *The energy performance of a building shall be expressed in a transparent manner and shall include an* ***energy performance indicator and a numeric indicator of primary energy use****, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on- site production.*

This definition means that energy performance indicator may be based on primary energy. But it is let open to use some other indicator for energy performance together with primary energy, meaning that energy performance requirements may also be based on this other indicator. There is no guidance for this "other" energy performance indicator, expect that is given in energy performance definition (energy used for heating, cooling, ventilation, hot water and lighting). In the Annex, it is also referred to the use of relevant European standards:

> *The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC.*

EN 15603:2008 specifies general framework for the assessment of energy performance of buildings that is much more detailed compared to EPBD recast definitions. In this standard, energy performance indicators are called as energy ratings, with comprehensive definition for weighted energy rating:

- Weighted energy rating sums up all delivered energy (electricity, district heat/cooling, fuels) into a single rating with weighting factors
- Weighted energy rating may be based on: primary energy, CO_2 emissions or parameters defined by national energy policy
- Cost is mentioned as one possible parameter

However, this weighted energy of EN 15603:2008 conflicts with EPBD recast if not defined through primary energy, because EPBD recast requires very clearly the expression of energy performance through primary energy.

EN 15603:2008 also discusses energy flows to be included in the energy ratings, **Figure 2**. It is upon national decision to take into account electricity for households and outlets or not.

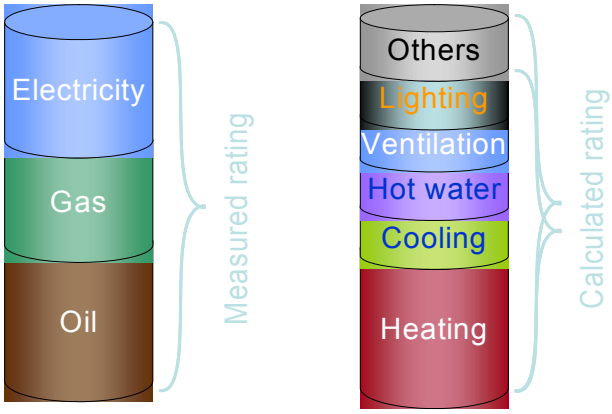
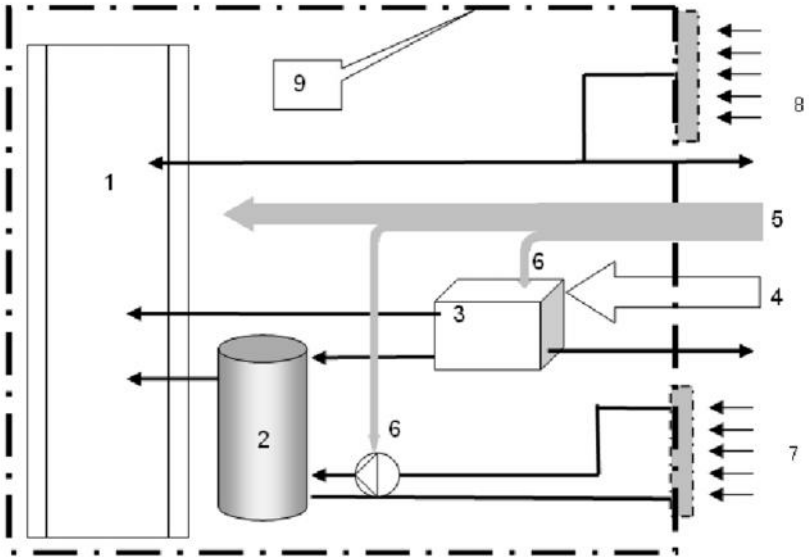


Figure 2. In the measured ratings typically all energy flows are included as measured. In the calculated energy ratings electricity for households and outlets ("others") may or may not be included.

For the energy boundary specification, the guidance is provided in EN 15603:2008. This is mainly general guidance, and again, exact specification is let for national bodies. Example of energy flows are shown in **Figure 3**. Inside the boundary the system losses are to be taken into account explicitly, outside they are taken into account in the conversion factor (=primary energy factor). Technical building systems located partly outside of the building envelope are considered to be inside the system boundary. It is also clearly stated that the assessment can be made for a group of buildings serviced by the same technical systems.



Key

1	user	6	auxiliary energy
2	storage	7	thermal solar collector
3	boiler	8	photovoltaic panels
4	fuel	9	boundary
5	electricity		

Figure 3. Example of energy boundary from EN 15603:2008.

EN 15603:2008 states that for active solar and wind systems only the energy delivered by the generation devices and auxiliary energy are taken into account in the energy balance (i.e. kinetic energy of wind is not). It is to be decided on the national level, if this energy is part or not of the delivered energy. This national decision is mentioned also in Note 1 of delivered energy definition (3.3.4) of EN 15603:2008:

> **3.3.4**
> **delivered energy**
>
> energy, expressed per energy carrier, supplied to the technical building system through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity
>
> NOTE 1 For active solar and wind energy systems the incident solar radiation on solar panels or on solar collectors or the kinetic energy of wind is not part of the energy balance of the building. It is decided at national level whether or not renewable energy produced on site is part of the delivered energy.
>
> NOTE 2 Delivered energy can be calculated for defined energy uses or it can be measured.

Note 1 of (3.3.4) conflicts with EPBD recast, if renewable energy produced on site is considered as delivered energy (meaning that there is no difference between onsite solar electricity and grid electricity, and on site solar electricity is not reducing the amount of delivered grid electricity). In this case, there is conflict with EPBD recast, Annex I, that states that the positive influence of active solar and other renewables are to be taken into account. Thus, this national decision seems not any more relevant and EPBD recast has caused a revision need for EN 15603:2008.

As primary energy indicator is based on delivered and exported energy, the definitions of exported and net delivered energy are important:

3.3.5
exported energy

energy, expressed per energy carrier, delivered by the technical building systems through the system boundary and used outside the system boundary

NOTE 1_ It can specified by generation types (e.g. CHP, photovoltaic, etc.) in order to apply different weighting factors.

NOTE 2_ Exported energy can be calculated or it can be measured.

3.3.6
net delivered energy

delivered minus exported energy, both expressed per energy carrier

NOTE 1_ A balance of the delivered and exported energy per energy carrier can be performed only if the same primary energy factors and/or CO_2 coefficients apply to the delivered and exported amounts of that energy carrier.

NOTE 2_ The term "net" can also be applied to quantities derived from net delivered energy, e.g. primary energy or CO2 emissions.

The definition of energy rating says in the Note that the inclusion of electricity for households and outlets and lighting in residential buildings depends on national decision:

3.4.2
calculated energy rating

energy rating based on calculations of the weighted delivered and exported energy of a building for heating, cooling, ventilation, domestic hot water and lighting

NOTE National bodies can decide whether other energy uses resulting from occupants' activities such as cooking, production, laundry, computer equipment, etc. are included or not. If included, standard input data needs to be provided for the various types of buildings and uses. Lighting is always included except (by decision of national bodies) for residential buildings.

Proposal for energy boundary

Proposed energy boundary is modified from EN 15603:2008 and as stated in EPBD recast, renewable energy produced on site is not considered as part of delivered energy, i.e. the positive influence of it is taken into account, **Figure 4**.

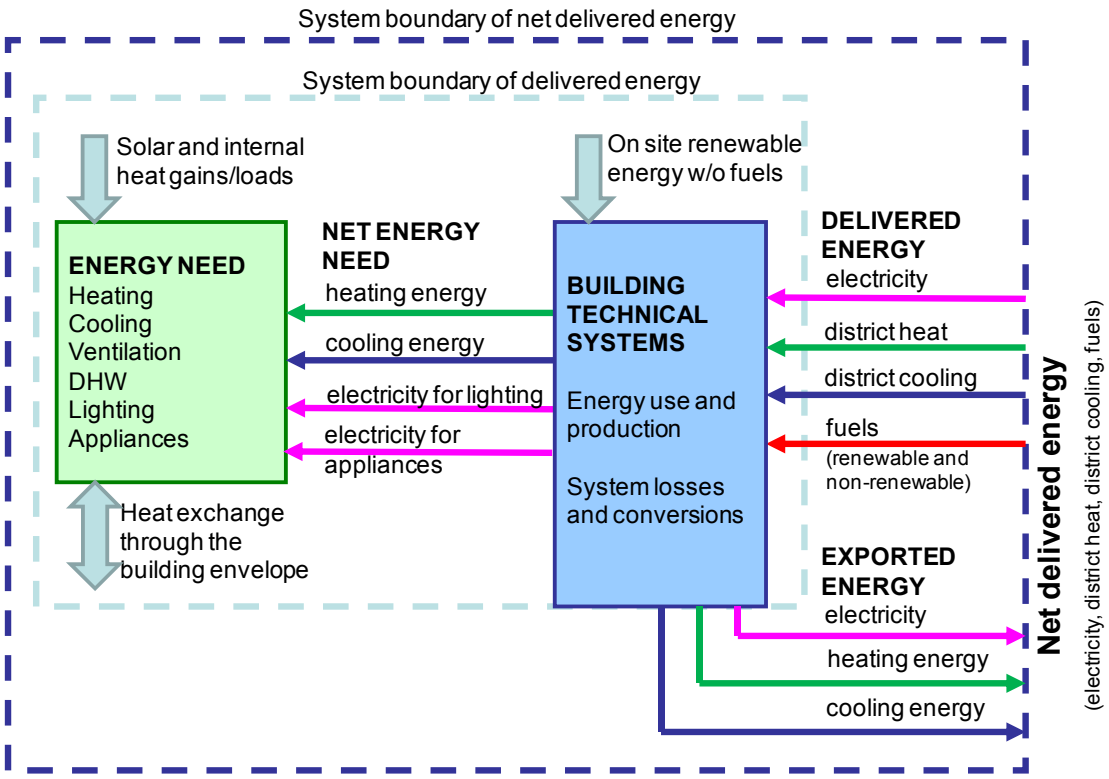


Figure 4. Energy boundary of net delivered energy and how it forms from energy need, energy use of technical building systems, on site renewable energy production, delivered energy and exported energy. The box of "Energy need" refers to rooms in a building and both system boundary lines may be interpreted as the building site boundary.

Energy need represents energy need in a building for heating, cooling, ventilation, domestic hot water, lighting and appliances (if appliances are included in the system boundary as proposed). Energy need for heating is caused by heat losses and is reduced by solar and internal heat gains. Net energy need is the energy need minus heat gains, i.e. thermal energy without any system losses needed to maintain indoor climate conditions. For the lighting and appliances electrical energy is needed.

Building technical systems supply the amount of net energy needs of heating, cooling and electrical energy. To supply these net energy needs, building technical systems use energy and have typically some system losses and energy conversion in some systems (i.e. heat pumps, fuel cells). The energy used by the building technical systems is from delivered energy to the building or from onsite renewable energy (without fuels).

Delivered energy to the building is grid electricity, district heat and cooling, renewable and non-renewable fuels. On site renewable energy without fuels is energy produced from active solar and wind (and from hydro if available). Renewable fuels are not included in this term, because they are treated as delivered energy to the building, i.e. off-site renewables. Energy from heat sources of heat pumps (air, ground, water) is also renewable energy, but this information is not needed for heat pump system and delivered energy calculations which are based on COP data of heat pumps. (However, energy taken from heat sources of heat pumps is needed for calculation of the share of renewable energy, which is additional information).

On site renewable energy production systems may supply other technical building systems, thus reducing the need for the delivered energy to building, or may be directly exported to energy networks. This is taken into account in the net delivered energy balance. Net delivered energy is delivered minus exported energy, both expressed per energy carrier.

Primary energy use is calculated from net delivered energy, per energy carrier, as product of primary energy factor and net delivered energy of that energy carrier.

6. Examples of energy flow calculation

Low energy detached house

Consider a detached house located in Helsinki with net area of 150 m² and the following annual net energy needs:

- 7200 kWh (48.0 kWh/(m² a)) net energy need for heating (including ventilation and DHW)
- 1600 kWh (10.7 kWh/(m² a)) net energy need for cooling
- 1050 kWh (7.0 kWh/(m² a)) electricity for lighting
- 2400 kWh (16.0 kWh/(m² a)) electricity for appliances

In this building, solar thermal provides 2100 kWh/a (14.0 kWh/(m² a)) domestic hot water. The rest of heating need is supplied with ground source heat pump system, which has the seasonal performance factor of 3.2.

Energy calculation results are shown in Figure 5. First, on site thermal energy 14.0 kWh/(m² a) is reduced from the net energy need of 48.0 kWh/(m² a). Heat pump thus produces 34.0 kWh/(m² a) thermal energy with electrical energy input of 10.6 kWh/(m² a). The seasonal performance factor includes circulation pumps of the heating system and the ground loop. It is considered that the ground loop is utilized for cooling, so that the circulation pump operation for cooling and the fan energy of the fan coil is 1.8 kWh/(m² a). Delivered electrical energy is 40.4 kWh/(m² a) There is no exported energy. Primary energy is 101 kWh/(m² a).

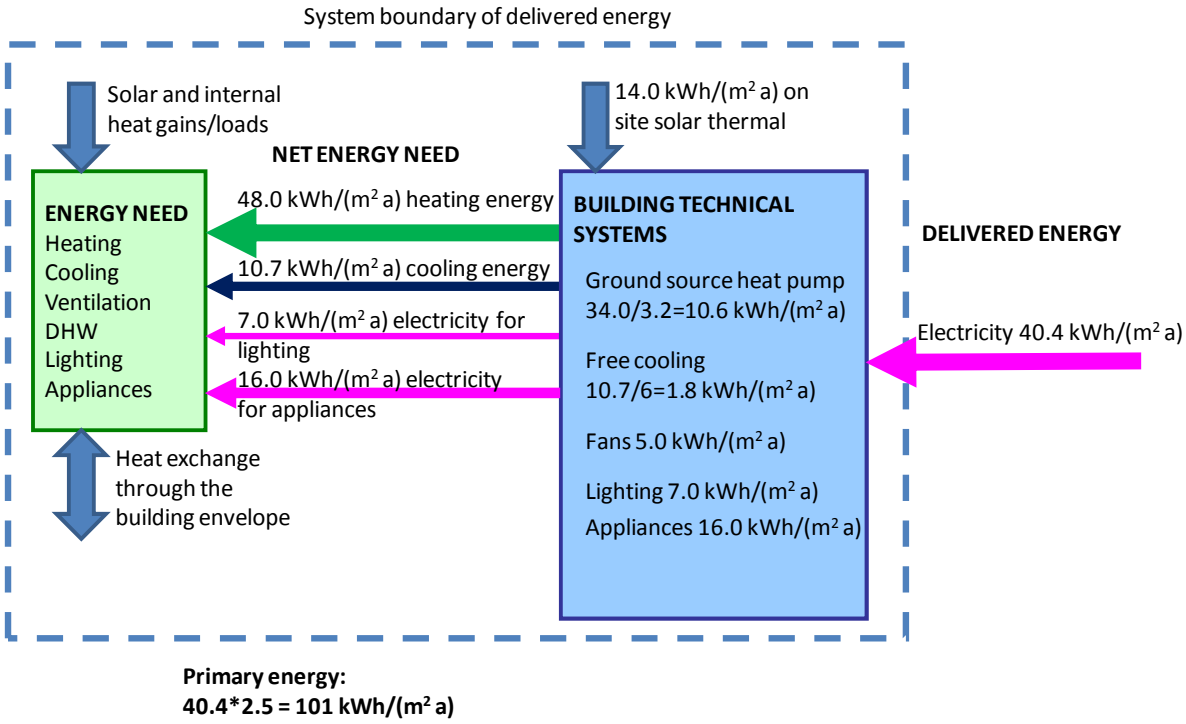


Figure 5. Calculation example of the energy flows of a detached house.

nZEB Office building

Consider an office building located in Paris with following annual net energy needs (all values are specific values in kWh/(m² a)):

- 3.8 kWh/(m² a) net energy need for heating (including ventilation and DHW)
- 11.9 kWh/(m² a) net energy need for cooling
- 21.5 kWh/(m² a) electricity for appliances
- 10.0 kWh/(m² a) electricity for lighting

Breakdown of the net energy need is shown in Figure 6.

The building has a gas boiler for heating with seasonal efficiency of 90%. For the cooling, free cooling from boreholes (about 1/3 of the need) is used and the rest is covered with mechanical cooling. For borehole cooling, seasonal energy efficiency ratio of 10 is used and for mechanical cooling 3.5. Ventilation system with specific fan power of 1.2 kW/(m³/s) will use 5.6 kWh/(m² a) fan energy. There is installed a solar PV system providing 15.0 kWh/(m² a), from which 6.0 is utilized in the building and 9.0 is exported to the grid.

Energy calculation results are shown in Figure 6, in the building technical systems box. Gas boiler with 90% efficiency results in 4.2 kWh/(m² a) fuel energy. Electricity use of the cooling system is calculated with seasonal energy efficiency ratios 10 and 3.5 respectively. Electricity use of free cooling, mechanical cooling, ventilation, lighting and appliances is 39.8 kWh/(m² a). Solar electricity of 15.0 kWh/(m² a) reduces the net delivered electricity to 24.8 kWh/(m² a). Net delivered fuel energy (caloric value of delivered natural gas) is 4.2 kWh/(m² a). From these two net delivered energy flows, primary energy is calculated with the result of 66 kWh/(m² a).

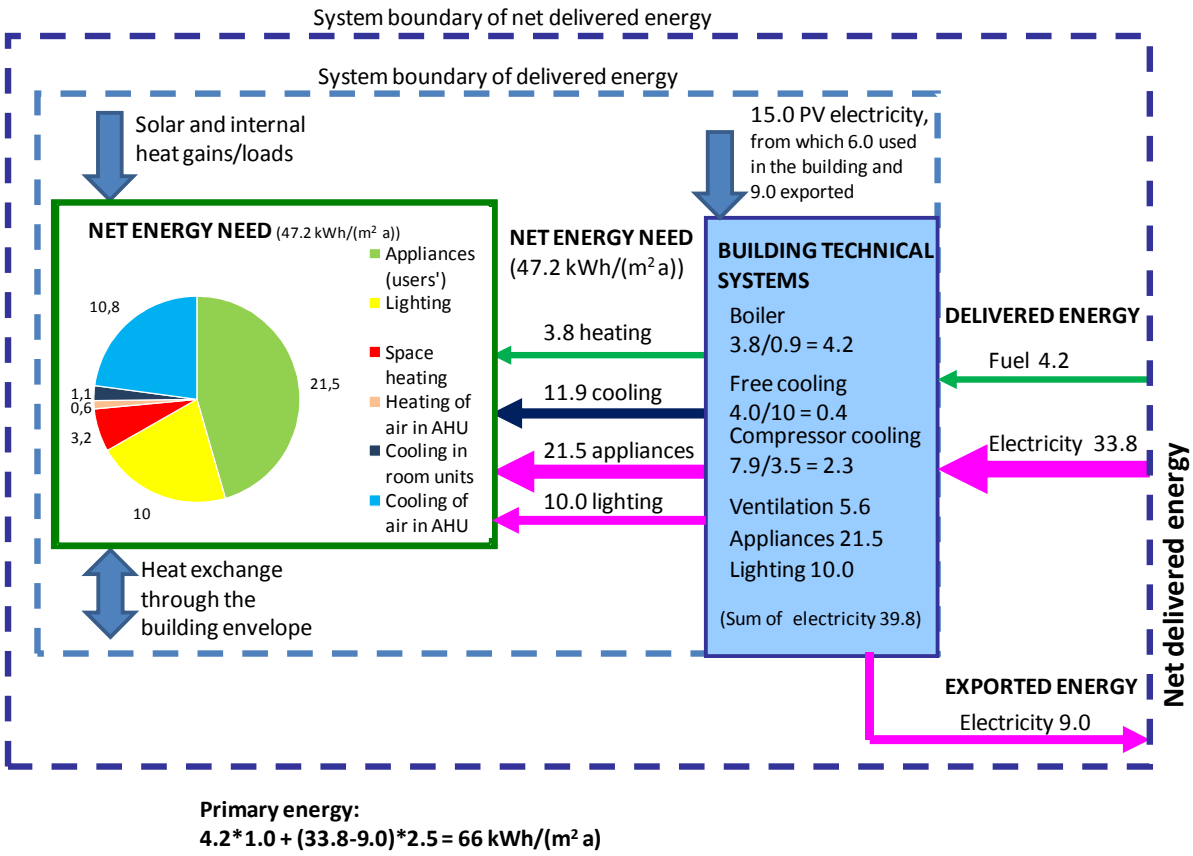


Figure 6. Calculation example of the energy flows in nZEB office building.

7. Conclusions

In this paper a technical definition for nearly net zero energy buildings is proposed. This definition is needed in the member states for the implementation of EPBD recast. In order to propose a general definition, it was needed to clarify:

- which energy flows shall be included
- the use of primary energy factors for primary energy indicator
- system boundary definition with inclusion of active solar and wind
- applicability of the cost optimal requirement on nZEB performance level
- the technical meaning of "nearby" in EPBD recast so that it may mean existing district heating or cooling network or any other technical system serving a group of buildings

Energy performance definition of EPBD recast was followed so that appliances (households and outlets) were included, i.e. all energy used in buildings would be accounted. For the system boundary definition, a general form modified from the one of EN 15603:2008 is proposed. It is proposed to the Member States to use the system boundary shown in Figure 4 and primary energy definition given by Equation 1 in defining the performance levels of nearly net zero energy buildings.

Net zero energy requirement has exact performance level of 0 kWh/(m^2 a) primary energy use. The performance level of nearly net zero energy use depends on national conditions and decisions. The following definitions were proposed:

net zero energy building (ZEB)

energy use of 0 kWh/(m^2 a) primary energy

nearly net zero energy building (nZEB)

technically reasonable achievable national energy use of > 0 kWh/(m^2 a) primary energy achieved with best practice energy efficiency measures and renewable energy technologies which may or may not be cost optimal

In order to be a sound definition, nearly net zero energy building defined through primary energy indicator, shall refer to specified energy calculation framework, including:

- system boundary of net delivered energy (EN 15603:2008 and Figure 4);
- standard energy calculation input data (EN 15251:2007);
- test reference year to be used in energy calculations (ISO 15927-4:2005);
- primary energy factors for energy carriers (EN 15603:2008 and Equation 1);
- energy calculation rules and methods for energy need and system calculations, covered in relevant EPBD standards;

which all affect calculated or measured primary energy indicator. The performance levels shall be specified for each building type, at least for those listed in EPBD recast.

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EN 15251: 2007 Indoor environment input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

ISO 15927-4: 2005 Hygrothermal performance of buildings – Calculation and presentation of climatic data – Part 4: Hourly data for assessing the annual energy use for heating and cooling.

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