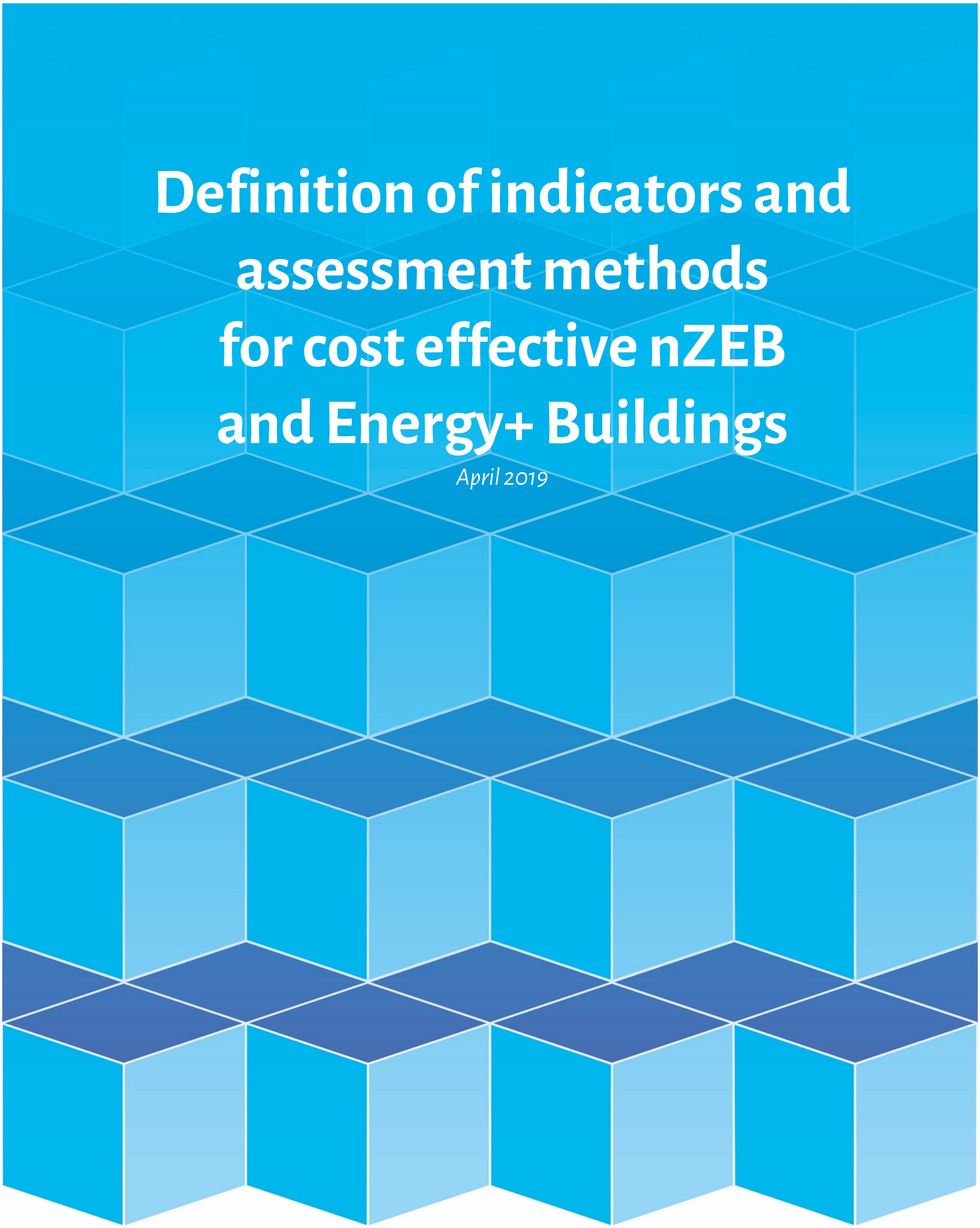

Definition of indicators and assessment methods for cost effective nZEB and Energy+ Buildings

April 2019

Affordable Zero
Energy Buildings

This project has received funding from
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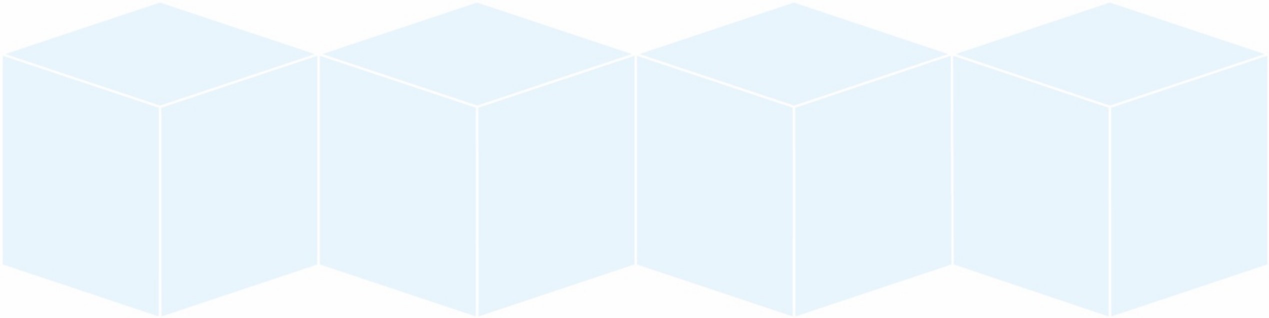

Definition of indicators and assessment methods for cost effective nZEB and Energy+ Buildings

Work package	2 A methodology for developing Cost Effective nZEB with RES
Deliverable	2.1 Definition of indicators and assessment methods for cost effective nZEB and Energy+ Buildings
Responsible	eERG - PoliMi (Energy Department)
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Affordable Zero Energy Buildings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754174

1 Introduction

The A-ZEB project aims at achieving significant construction and lifecycle cost reductions of new nearly Zero Energy Buildings (nZEBs) through integral process optimization in all construction phases. Exit point for the creation of the methodology for cost reduction, is that the methodology improves the total performance of new nZEBs: environmentally, socially and financially.

It is therefore needed to define what an nZEB is, define the relevant aspects of the targeted performance (i.e. energy, environmental and social impacts) and to specify what is meant by cost. For example, when we talk about "*energy needs*" or "*total primary energy* use", how are these energy indicators defined and which *building services* are taken into account: heating, cooling, hot water, lighting, ventilation,..? These definitions then need to be complemented making explicit by which methodology those indicators are calculated.

There are at least two reasons for the importance of clear and explicit indicators and an agreed methodology to measure these. In the first place we may analyze and compare results across different projects and studies. Presently many national regulations provide different indicators or use the same names with different definitions, which prohibits clear comparisons and confuses discussions on different levels, from the policy making level right down to the work floor. The second reason is inherent to the 27 step AZEB methodology. If one wishes to reduce costs and/or increase value for an nZEB project, clear indicators are needed to verify and validate the intermediate and final results in the project. It will facilitate communication across multiple disciplines as well as with the client and it can prevent costly mistakes due to communication errors. When drawing up (performance) contracts, clear indicators obviously are indispensable.

This report provides definitions for the main relevant aspects of building performance and building costs. Also, it shows some available methods to allow these aspects to be evaluated by indicators and relevant measuring units.

The primary goal of the AZEB project is to reduce costs for (nearly) zero energy buildings, so cost and energy are the two main aspects. However, costs may only be evaluated as being high or low in relation to the value (performance) a building creates as a whole for its stakeholders. Energy use is one of these, but at least as important are the aspects of environmental performance and performance on social indicators. Examples of social indicators are comfort, health, functional flexibility, safety and accessibility. These social indicators are about how the user experiences the building on a day-to-day basis. The value of a building to individuals, society and markets is determined by all these different aspects in a balanced combination. Therefore, to be able to judge cost reduction measures, including their effects on building prices, one needs to assess the combined impact on all relevant aspects of the building performance.

This process of balancing the performance on different indicators can be quite complex and overwhelming and requires some specific skills. In chapter 7 of this report we propose three different approaches to deal with this complexity and support decision making in regard to balancing the wider range of performances of the building. The approaches discussed are: Using multi-criteria optimization, using a model for optimization of Total Cost of Ownership and using the method of Value Engineering during the initiative and/or design phase of the project.

The conclusion of this report contains a table with a set of main indicators. This set is proposed with two purposes:

- to test this set of indicators in the A-ZEB case studies, which span multiple European countries;
- to optimize this set based on the feedback from the case studies and propose this optimized set to the EU as a unifying set for all European countries to use.

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2 Definitions and energy indicators

2.1 Introduction

The AZEB project addresses a specific category of buildings, which is called nearly Zero Energy Buildings (nZEB) and has been introduced in the EU Directive on Energy Performance of Buildings. Nevertheless, nowadays this definition is not clear and shared by all European countries and a variety of energy indicators, thresholds and requirements are used to describe it. The current approach of using separate national nomenclatures and definitions in different Member States, and sometimes within different regions of a Member State, creates a market barrier for energy saving envelope materials and components, efficient technical building systems and design strategies for new constructions and retrofits. The new set of EN-ISO standards related to building, which are to be implemented in all jurisdictions[1], proposes well-grounded energy performance definitions that can be used to overcome this barrier. The application of these standards, although they are not legally codified (differently from e.g. legislation enacted by National Parliaments), will be conducive to stimulating innovative energy saving solutions that can be applied everywhere in Europe, tuned to the local climate, because they will be evaluated according to the same principles in a transparent way.

As a consequence, the present chapter aims to provide:

- a complete framework about the appropriate nomenclature and the energy definitions according to EN-ISO building related standards, further clarified by the inclusion of explanatory schemes about the energy levels;
- the current EU definition of nZEB according to EPBD and its different implementations, in accordance with national regulations, in the six countries involved in the project (France, Italy, Spain, Bulgaria, Germany and the Netherlands);
- recommendations about the choice of the indicators which better express the energy and comfort performance of an nZEB, in order to be able to evaluate and compare the different case studies in WP3.

2.2 Nomenclature and definitions about building levels and indexes from EN-ISO 52000-1:2017(E)

NOTE: all the terms defined in ISO or EN Standards or the EU Directives will be written in *underlined italics* in this text. Terms defined in national legislation or in this chapter for use within the AZEB project will be written in *italics.*

It is very important that all the actors involved in development of nZEB in the field, regulators and policymakers use consistently the same set of physical concepts, definitions, nomenclature. This will ensure better results in terms of comfort levels and energy use and will be a prerequisite for devising clear design and construction guidelines allowing to obtain performace at reduced cost. Importantly, it will also reduce the costs involved in communication difficulties and misunderstandings leading to design and construction errors and subsequent costly remediation work.

We present here a selection of the main concepts, definitions and terminology mostly taken form European and International standards. In addition, we provide schemes of the energy levels in order to support and simplify their clear identification.

The following definitions are mainly also available at the ISO Online Browsing Platform (OBP)
https://www.iso.org/obp/ui#search, in English and partly in French, as in the example below:

---

[1] As stated in EPBD Annex I: “Member States shall describe their national calculation methodology following the national annexes of the overarching standards, namely ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1, developed under mandate M/480 given to the European Committee for Standardisation (CEN). This provision shall not constitute a legal codification of those standards.”

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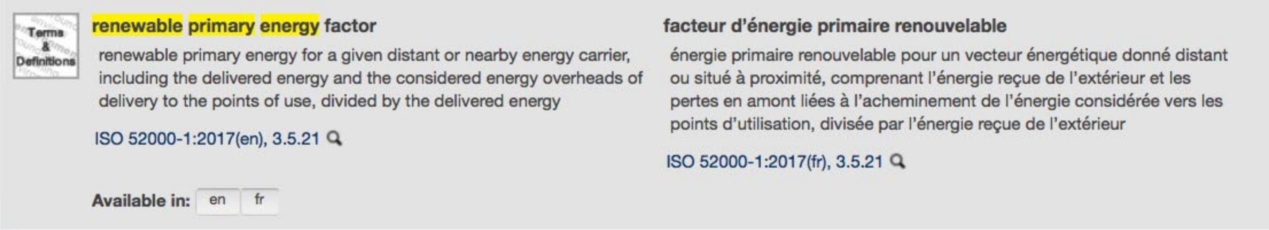
Figure 1 Example of definition available at the ISO Online Browsing Platform (OBP).



renewable primary energy factor

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

ISO 52000-1:2017(en), 3.5.21

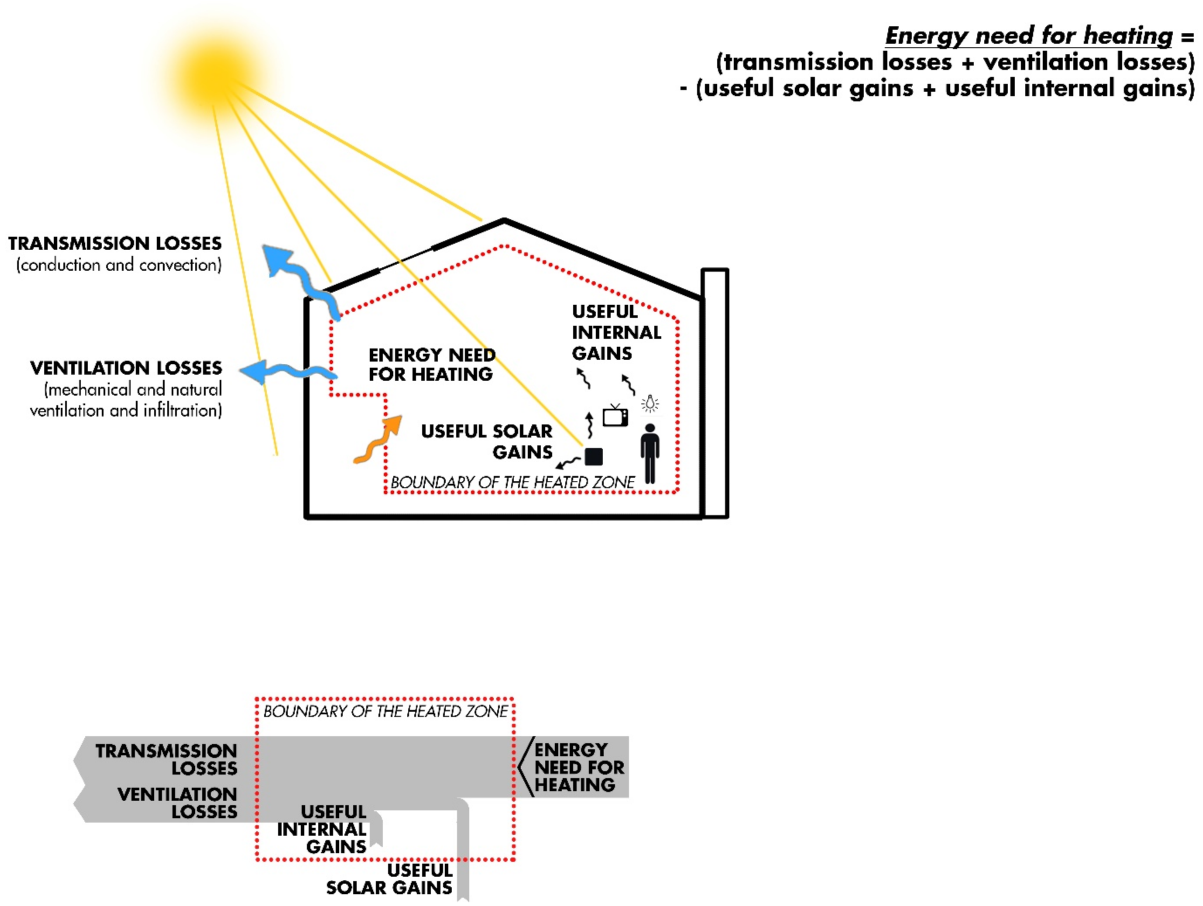
facteur d'énergie primaire renouvelable

énergie primaire renouvelable pour un vecteur énergétique donné distant ou situé à proximité, comprenant l'énergie reçue de l'extérieur et les pertes en amont liées à l'acheminement de l'énergie considérée vers les points d'utilisation, divisée par l'énergie reçue de l'extérieur

ISO 52000-1:2017(fr), 3.5.21

- **"**<u>*energy need for heating or cooling*</u>**"** heat to be delivered to or extracted from a <u>*thermally conditioned space*</u> to maintain the intended space temperature conditions during a given period of time (ref. 3.4.13 in EN-ISO 52000-1:2017)
- **"**<u>*energy need for domestic hot water*</u>**"** heat to be delivered to the needed amount of domestic hot water to raise its temperature from the cold network temperature to the prefixed delivery temperature at the delivery point without the losses of the domestic hot water system (ref. 3.4.12 in EN-ISO 52000-1:2017)
- <u>*"useful heat gain"*</u> part of internal and solar heat gains that contribute to reducing the <u>*energy need for heating*</u> (ref. 3.6.11 in EN-ISO 52000-1:2017)

Figure 2 Scheme of energy levels: energy need for heating.



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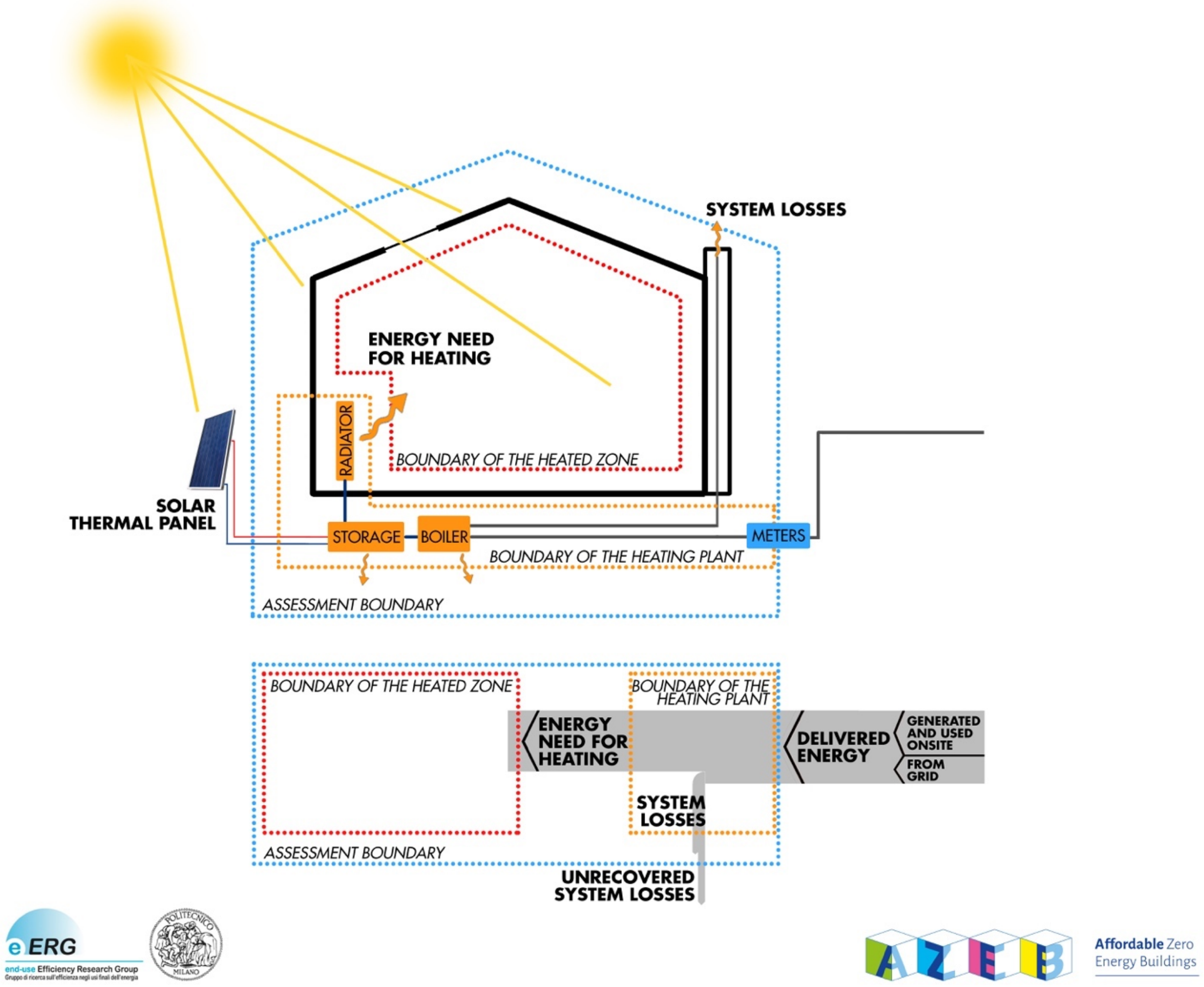
- **“*energy use for lighting*”** electrical energy input to the lighting system (ref. 3.4.16 in EN-ISO 52000-1:2017)
- **“*building service*”** service provided by technical building systems and by appliances to provide acceptable indoor environment conditions, domestic hot water, illumination levels and other services related to the use of the building (ref. 3.3.3 in EN-ISO 52000-1:2017)
- “*EPB service*” building service included in the assessment of the energy performance (ref. 3.5.13 in EN-ISO 52000-1:2017)
- **“*delivered energy*”** energy, expressed per energy carrier, supplied to the technical building systems through the assessment boundary, to satisfy the uses taken into account or to produce the exported energy. (Note that *delivered energy* can be calculated for defined energy uses or it can be measured). (ref. 3.4.6 in EN-ISO 52000-1:2017)

Figure 3 Scheme of energy levels: delivered energy.



- “*energy from renewable sources*” “*renewable energy*” energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases (ref. 3.4.11 in EN-ISO 52000-1:2017)
- **“*non-renewable energy*”** energy taken from a source which is depleted by extraction (e.g. fossil fuels)**.** Note 1 to entry: Resource that exists in a finite amount that cannot be replenished on a human time scale. (ref. 3.4.26 in EN-ISO 52000-1:2017)
- **“*primary energy*”** energy that has not been subjected to any conversion or transformation process. (Note that primary energy includes non-renewable energy and renewable energy. If both are taken into account, it can be called *total primary energy*) (ref. 3.4.29 in EN-ISO 52000-1:2017)

- **“***non-renewable primary energy factor***”** non-renewable *primary energy* for a given energy carrier, including the *delivered energy* and the considered energy overheads of delivery to the points of use, divided by the *delivered energy* (ref. 3.5.17 in EN-ISO 52000-1:2017)
- **“***numerical indicator of primary energy use***”** primary energy use per unit of reference floor area**.** Note 1 to entry: Since primary energy use can be expressed in total primary energy, non-renewable primary energy can be specified in the numerical indicator (e.g., non-renewable primary energy use). (ref. 3.5.18 in EN-ISO 52000-1:2017)
- **“***renewable primary energy factor***”** renewable *primary energy* for a given *distant* or *nearby* energy carrier, including the *delivered energy* and the considered energy overheads2 of delivery to the points of use, divided by the *delivered energy* (ref. 3.5.21 in EN-ISO 52000-1:2017)
- **“***total primary energy factor***”** sum of renewable and non-renewable *primary energy factors* for a given energy carrier (ref. 3.5.25 in EN-ISO 52000-1:2017)

Table 1 Example of primary energy factors chosen by the Italian Legislator [Source: DM 26/6/15, Ann. 1, Art.1.1]. f P,TOT = total primary energy factor, f P,REN = renewable primary energy factor, f P,NREN = non-renewable primary energy factor.

Energy carrier	$f_{P,NREN}$	$f_{P,REN}$	$f_{P,TOT}$
Natural gas	1.05	0	1.05
GPL	1.05	0	1.05
Fuel oil	1.07	0	1.07
Coal	1.1	0	1.1
Solid biomass	0.2	0.8	1
Liquid and gaseous biomass	0.4	0.6	1
Electric energy **from** the grid	1.95	0.47	2.42
District heating	1.5	0	1.5
Municipal solid waste	0.2	0.2	0.4
District cooling	0.5	0	0.5
Thermal energy from solar collectors	0	1	1
Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumption)	0	1	1
Electric energy produced by photovoltaic, small scale wind/hydro electricity (export **to** the grid).	0	1 (only to counterbalance consumption in the same month, NOT in the entire year)	1 (only to counterbalance consumption in the same month, NOT in the entire year)
Thermal energy from the external environment - Free cooling	0	1	1
Thermal energy from the external environment - Heat pump	0	1	1

The *assessment boundary* (which is the one which is crossed by delivered energy and exported energy) is distinct from the on site, nearby and distant *perimeters*

- **“***nearby***”** <the building site> on local or district level (e.g., district heating or cooling) (ref. 3.4.24 in EN-ISO 52000-1:2017)
- **“***on-site***”** the premises and the parcel of land on which the building(s) is located and the building itself. Note that *on-site* defines a strong link between the energy source (localisation and interaction) and the building (ref. 3.4.27 in EN-ISO 52000-1:2017)
- **“***distant***”** <to the building site> not *on-site* nor *nearby* (ref. 3.4.7 in EN-ISO 52000-1:2017)

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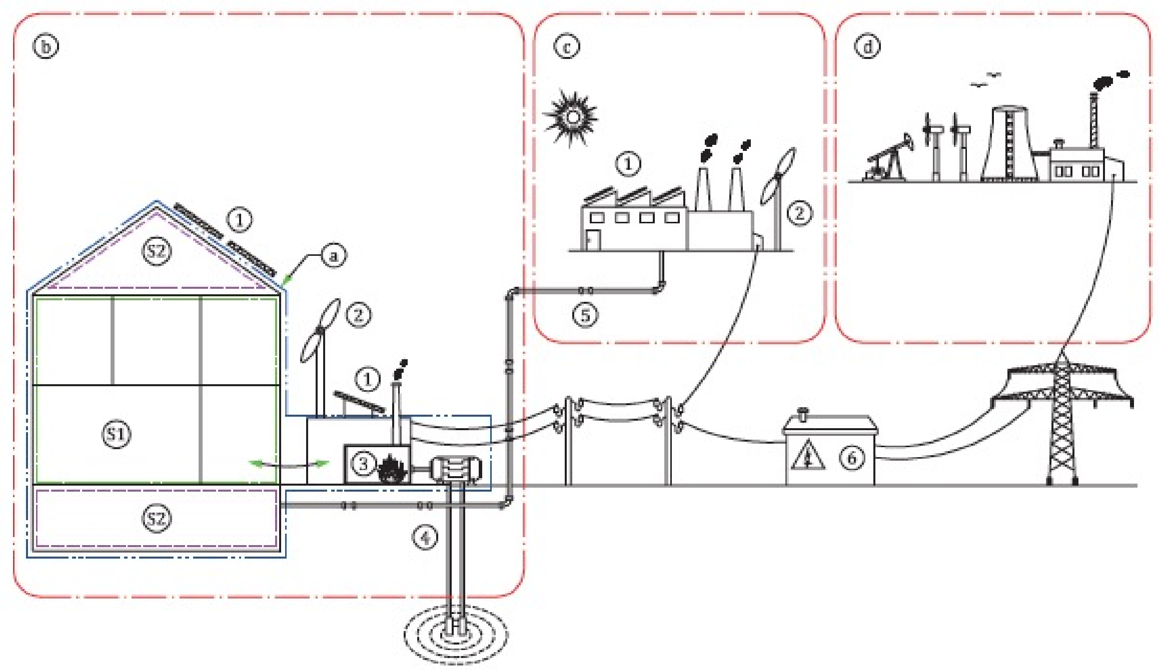
[2] “Energy overhead” stands for the energy used for transporting the generated renewable energy to the building, e.g. the energy losses on the electric grid and energy storage for supplying wind energy from a *distant* wind farm to the building.

The concept of on-site, nearby and distant is schematically shown in Figure 4.

Figure 4 Example of a scheme representing the concept of perimeters and assessment boundary. Source: EN-ISO 52000-1.



Key

a	assessment boundary (use energy balance)	1	PV, solar
b	perimeter: on-site	2	wind
c	perimeter: nearby	3	boiler room
d	perimeter: distant	4	heat pump
S1	thermally conditioned space	5	district heating/cooling
S2	space outside thermal envelope	6	substation (low/medium voltage and possible storage)

Figure 5 Scheme of energy levels: <u>total primary energy</u>, case where the energy service considered is space heating, delivered by a boiler and on-site solar thermal panels.

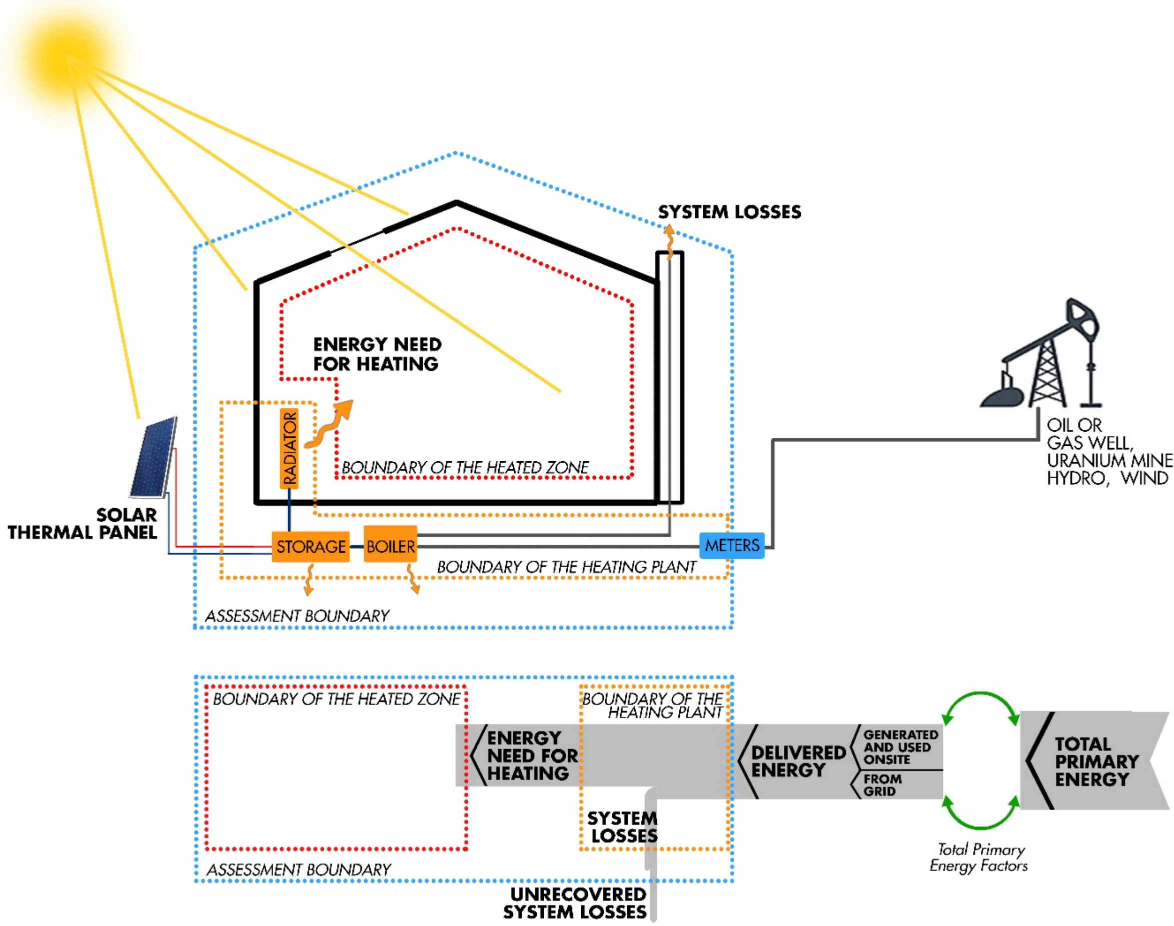
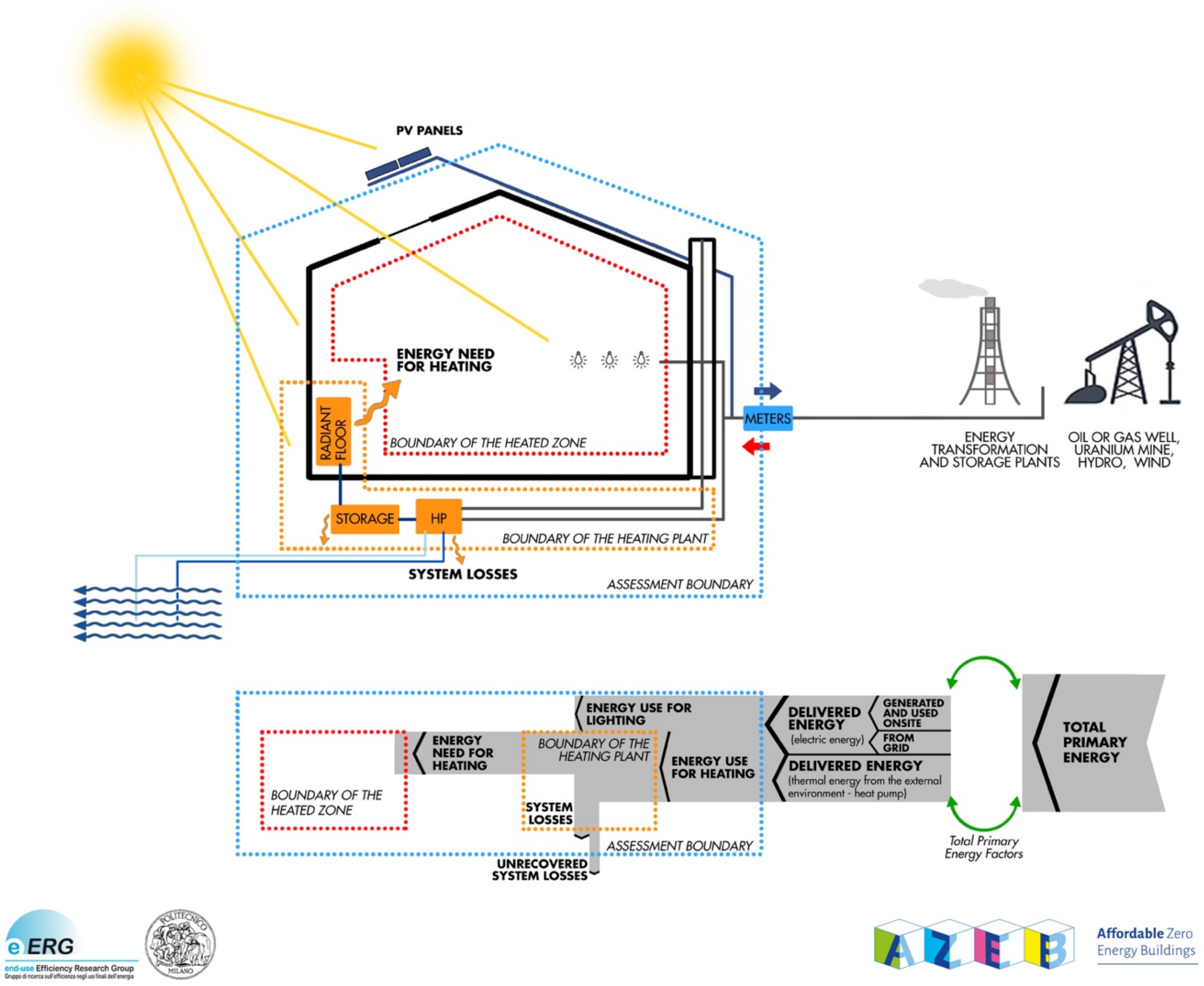


Figure 6 Scheme of energy levels: total primary energy, , case where the energy service considered is space heating and the energy is delivered by a heat pump and on-site PV panels.



- “*building fabric*” all physical elements of a building, excluding *technical building systems*

EXAMPLE Roofs, walls, floors, doors, gates and internal partitions. It includes elements both inside and outside of the thermal envelope, including the *thermal envelope* itself. The fabric determines the thermal transmission, the thermal envelope airtightness and (nearly all of) the thermal mass of the building (apart from the thermal mass of furniture and technical building systems). The fabric also makes the building wind and water tight. The building fabric is sometimes described as the building as such, i.e., the building without any technical building system. (ref. 3.1.5 in EN-ISO 52000-1:2017)

- **“*thermal envelope area*”** total area of all elements of a building that enclose *thermally conditioned spaces* through which thermal energy is transferred, directly or indirectly, to or from the external environment. Note 1: the thermal envelope area depends on whether internal, overall internal or external dimensions are being used. Note 2: the thermal envelope area does not include the area to adjacent buildings; see ISO 13789[9]. Note 3: the thermal envelope area may play a role in the ways to express the overall and partial energy performance and energy performance requirements and comparison against benchmarks. [source: ISO 13789:2017[9], 3.9 — with addition of notes 2 and 3] (ref. 3.1.15 in EN-ISO 52000-1:2017)
- ‘*technical building system*’ means technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity *generation*, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit; [source: EPBD 2018 Art.2, definitions]
- **“*thermally conditioned space*”** heated and/or cooled space (ref. 3.1.16 in EN-ISO 52000-1:2017)
- **“*thermally unconditioned space*”** room or enclosure that is not part of a *thermally conditioned space* (ref. 3.1.17 in EN-ISO 52000-1:2017)

- **“*useful floor area*”** [3] <for EPB assessment> area of the floor of a building needed as parameter to quantify specific conditions of use that are expressed per unit of floor area and for the application of the simplifications and the zoning and (re-)allocation rules (ref. 3.1.18 in EN-ISO 52000-1:2017)

- “*degree-days*” ISO 15927-6:2007 (where they are named *accumulated temperature differences)* specifies the definition and method of computation for the heating *degree-days*, which represents an index of climate severity as it affects energy use for space heating. “Calculation or estimation of accumulated temperature differences is based on the concept of a base temperature. The base temperature reflects the point at which buildings begin to need heating to maintain the required internal temperatures. This is the external temperature below which the heating plant is assumed to come into operation.”

When hourly data are available, heating *degree-days* (HDD) shall be calculated according to the following equation:

HDD = $\sum_{h=1}^{n} \Delta T_h \, (T_b)/24$ where:

$\Delta T_h (T_b) = (T_b - T_{hm})$ if $T_{hm} < T_b$

$\Delta T_h(T_b) = 0$ if $T_{hm} > T_b$

with:

T_b: base temperature [°C]

ΔT_h: hourly temperature difference [°C]

T_{hm} = hourly mean temperature [°C}

When hourly data are not available, the approximate method given in 4.5 (ref. ISO 15927-6:2007), based on the maximum and minimum temperatures each day, may be used.

NOTE: since calculating using daily or hourly data, or different choices of a conventional base temperature, brings to different values of HDD, the exact definition of HDD used in every calculation/project should be made explicit. Cooling Degree Days (CDD) are defined in a similar manner. In this case, it is especially important to specify the chosen base temperature since the potential range for the choice is broader.

2.3 Nomenclature and definitions about area and space indicators from ISO 9836:2017(E) – Performance standards in building – Definition and calculation of area and space indicators.

- The surface areas are expressed in square metres, to two decimal places (ref. 5.1.1.2 in ISO 9836:2017)
- “*covered area”* is the area of ground covered by buildings in their finished state (ref. 5.1.2.1 in ISO 9836:2017)
- “*total floor area”* of a building is the total area of all floor levels. Floor levels may be storeys which are either completely or partially under the ground, storeys above ground, attics, terraces, roof terraces, service floors or storage floors (ref. 5.1.3.1 in ISO 9836:2017)
- “*total floor area”* of each level is obtained from the external dimensions of the enclosing elements, at floor height, above and below ground. These elements include finishes, claddings and parapets (ref. 5.1.3.2 in ISO 9836:2017)
- “*total floor area”* is calculated separately for each floor level. Areas with varying storey height within one floor level (e.g. large halls, auditoria) are also calculated separately (ref. 5.1.3.3 in ISO 9836:2017)
- “*total floor area”* is made up of the net floor area and the area taken up by the structure (ref. 5.1.3.5 in ISO 9836:2017).
- “*intra-muros area”* is the *”total floor area”* less the floor area taken up by the external walls (floor area of the building envelope) (ref. 5.1.4.1 in ISO 9836:2017).
- “*net floor area”* is the area between (within) the enclosing elements (ref. 5.1.5.1 in ISO 9836:2017)

The “*net floor area”* is determined separately for each floor level. It is calculated from the clear dimensions of the finished building at floor height, excluding skirtings, thresholds, etc.

Covered floor areas that are not enclosed or only partially enclosed and have no enclosing elements are determined by the vertical projection of the outer limit of the covering components. Areas with varying storey height within one floor level (e.g. large halls and auditoria) are calculated separately. (ref. 5.1.5.2 in ISO 9836:2017)

Also included in the *”net floor area”* are demountable components such as partitions, pipes and ducts. (ref. 5.1.5.3 in ISO 9836:2017)

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[3] https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/eplabel_operational_ratings_overcoming_the_barriers.pdf page 48

- floor *"areas of structural elements"*, door and window recesses, and niches to recesses in the elements enclosing the area are not included in the *net floor area* (ref. 5.1.5.4 in ISO 9836:2017)

The *net floor area* is divided into *usable area*, *services area* and *circulation area*. (ref. 5.1.5.5 in ISO 9836:2017)

- "*area of structural elements"* is the area within the *total floor area* (on a horizontal section at floor level) of the enclosing elements (e.g. external and internal load-bearing walls) and the area of columns, pillars, piers, chimneys, partitions, etc., which cannot be entered. (ref. 5.1.6.1 in ISO 9836:2017)
- "*usable area"* is that part of the net floor which corresponds to the purpose and use of the building. (ref. 5.1.7.1 in ISO 9836:2017)
- "*services area"* is that portion of the *net floor area* with technical installations which service the building or parts of it. (ref. 5.1.8.1 in ISO 9836:2017)
- "*circulation area"* is that portion of the net area used for circulation within the building (e.g. the area of stairwells, corridors, internal ramps, waiting areas, escape balconies, etc.). (ref. 5.1.9.1 in ISO 9836:2017)

The *net floor areas* of lift shafts and the floor areas of built-in conveying installations for general circulation, e.g. escalators, on each floor level are also included in the category of *circulation area*. (ref. 5.1.9.3 in ISO 9836:2017)

- "*building envelope area"* is obtained from buildings or parts of buildings which are enclosed on all sides and covered, including those parts of the structure which are above the top level of the ground and those below it. (ref. 5.1.10.1 in ISO 9836:2017)

Figure 7 Presentation of principal areas - figure from ISO 9836:2017(E), [Note: colours have been introduced by the authors of this chapter for higher clarity].

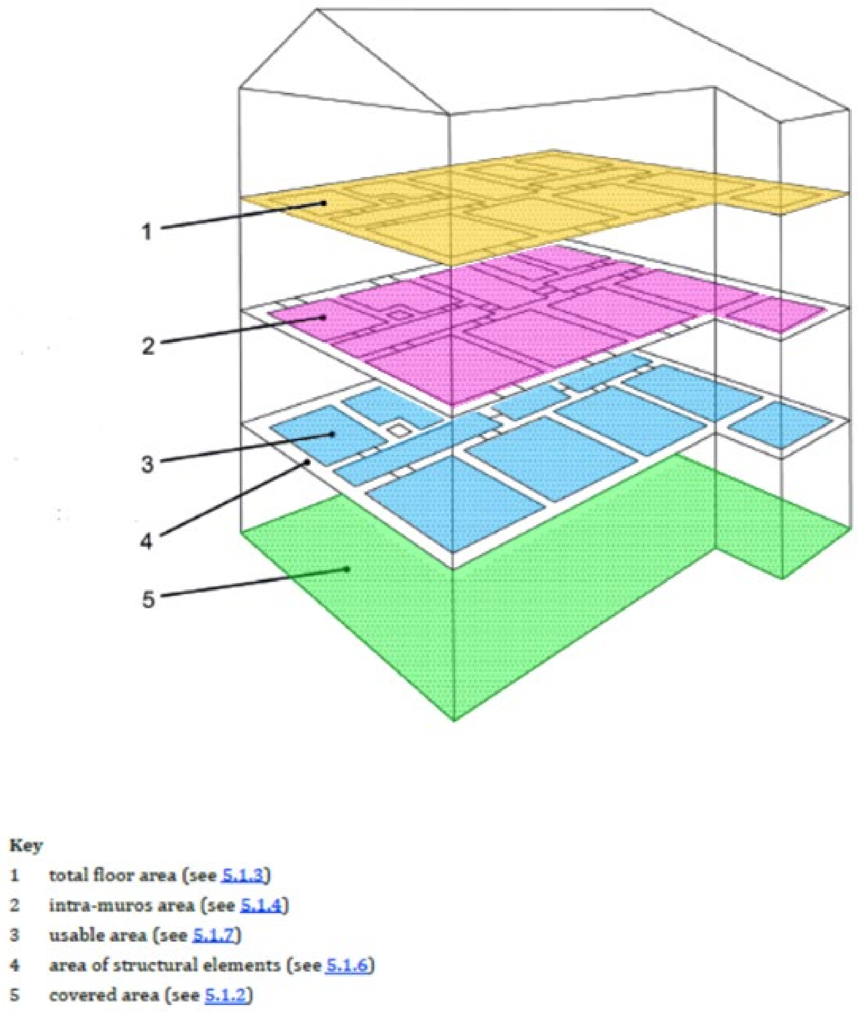
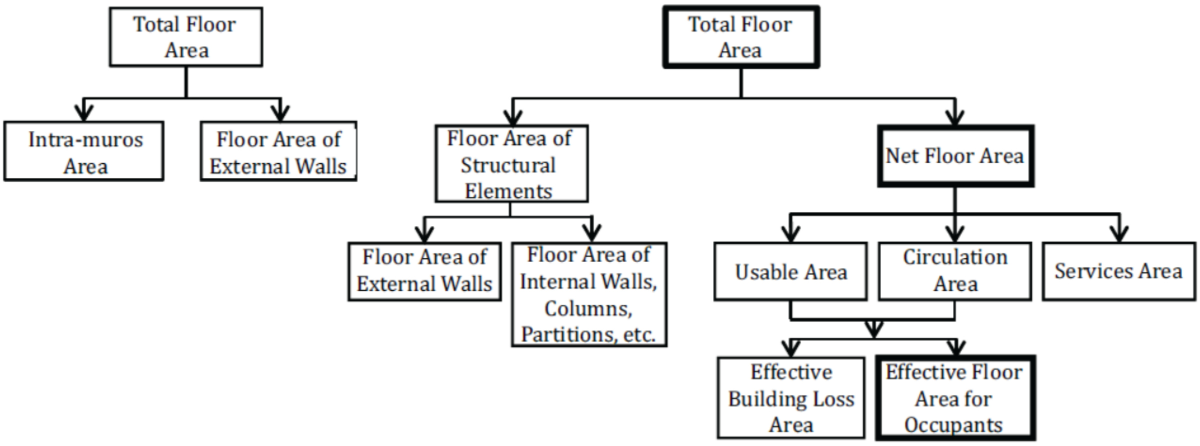


Figure 8 Components of total floor area - scheme from ISO 9836:2017(E).



2.4 Energy Performance of Buildings and nZEB (European standards and Building Directive)

The definition of nearly Zero Energy Building is given in the Energy Performance of Buildings Directive (EPBD) 2018, Art 2:
1. 'building' means a roofed construction having walls, for which energy is used to condition the indoor climate;
2. 'nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
The energy performance of buildings is hence evaluated according to Annex I, which states:
"The energy performance of a building shall be determined on the basis of calculated or actual energy use and shall reflect typical energy use for space heating, space cooling, domestic hot water, ventilation, built-in lighting and other technical building systems.

The energy performance of a building shall be expressed by a numeric indicator of primary energy use in kWh/(m^2.y) for the purpose of both energy performance certification and compliance with minimum energy performance requirements. The methodology applied for the determination of the energy performance of a building shall be transparent and open to innovation.
Member States shall describe their national calculation methodology following the national annexes of the overarching standards, namely ISO 52000-1, 52003-1, 52010-1, 52016-1, and 52018-1, developed under mandate M/480 given to the European Committee for Standardisation (CEN). This provision shall not constitute a legal codification of those standards."

A thorough revision of the European Standards on buildings has been produced under Mandate 480 by the EU Commission, with an investment of two years of intense technical work and about €5m of tax-payers money.

The overarching standard EN ISO 52000 states:
"the use of only one requirement, e.g. the *numerical indicator of primary energy use*, is misleading. In ISO 52000 different requirements are combined to a coherent assessment of nearly Zero-Energy Building".

The standard explains which indicators are needed:

- *energy needs for heating and cooling* (for quantifying and promoting the reduction of energy losses through the envelope and ventilation)
- *total primary energy* use (for quantifying and promoting the reduction of inefficiencies in the systems - e.g. avoid burning biomass in an inefficient burner)
- *non renewable primary energy* use without compensation between energy carriers (for quantifying and promoting the reduction of the non-renewable fraction within *total primary energy* use)
- *numerical indicator of non renewable energy use with compensation*. Only at this stage may be taken into account (or not, depending on National choices) the compensation between different energy carriers for example between gas and *on-site* production and the accounting of exported energy as a compensation of energy use on a hourly, monthly, or yearly basis.

In order to describe the extent to which Member States might choose to consider the accounting of exported energy as a compensation of energy use, the standard introduces a k_{exp} factor, variable between 0 and 1. A value $k_{exp} = 0$ describes the absence of compensation, a value $k_{exp} = 1$ describes the situation where each unit of energy exported compensates for one unit of energy used. Intermediary situations are possible.

Figure 9 Example illustrating the proposal in ISO 52000-1:2017 for nZEB rating.

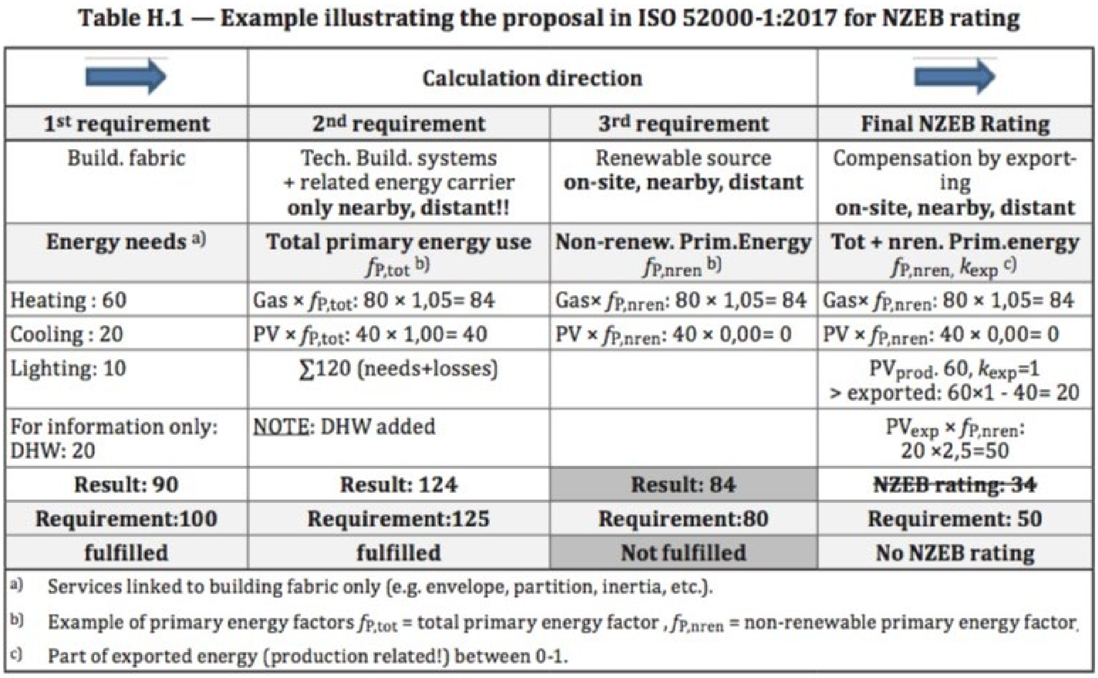


Table H.1 — Example illustrating the proposal in ISO 52000-1:2017 for NZEB rating

→	Calculation direction		→
1st requirement	**2nd requirement**	**3rd requirement**	**Final NZEB Rating**
Build. fabric	Tech. Build. systems + related energy carrier **only nearby, distant!!**	Renewable source **on-site, nearby, distant**	Compensation by exporting **on-site, nearby, distant**
Energy needs [a]	**Total primary energy use** $f_{P,tot}$ [b]	**Non-renew. Prim.Energy** $f_{P,nren}$ [b]	**Tot + nren. Prim.energy** $f_{P,nren}$, k_{exp} [c]
Heating : 60	Gas × $f_{P,tot}$: 80 × 1,05= 84	Gas× $f_{P,nren}$: 80 × 1,05= 84	Gas× $f_{P,nren}$: 80 × 1,05= 84
Cooling : 20	PV × $f_{P,tot}$: 40 × 1,00= 40	PV × $f_{P,nren}$: 40 × 0,00= 0	PV × $f_{P,nren}$: 40 × 0,00= 0
Lighting: 10	∑120 (needs+losses)		PV_{prod}. 60, k_{exp}=1 > exported: 60×1 - 40= 20
For information only: DHW: 20	NOTE: DHW added		PV_{exp} × $f_{P,nren}$: 20 ×2,5=50
Result: 90	**Result: 124**	**Result: 84**	**~~NZEB rating: 34~~**
Requirement:100	**Requirement:125**	**Requirement:80**	**Requirement: 50**
fulfilled	**fulfilled**	**Not fulfilled**	**No NZEB rating**

[a] Services linked to building fabric only (e.g. envelope, partition, inertia, etc.).

[b] Example of primary energy factors $f_{P,tot}$ = total primary energy factor , $f_{P,nren}$ = non-renewable primary energy factor.

[c] Part of exported energy (production related!) between 0-1.

The indicators *energy needs* and *total primary energy* do respond to the "energy efficiency first" principle, while the parameter *non renewable primary energy* responds to the objective of "increasing the share of renewables".

The various building services may be accounted for or excluded in the calculation of delivered and primary energy, possibly in different combinations for different building typologies. For example, the following building services can be considered: heating, cooling, ventilation, humidification, de-humidification, domestic hot water, lighting, appliances, transport in elevators etc. The list of the considered building services may depend on building categories (residential, office, educational, hospital, sport etc.).

We also propose to keep a clear distinction between the definition of *nearly Zero Energy Building* (**nZEB**) given in EPBD and the *Net Zero Energy Building* (**NZEB**) terminology used in some other literature with many different definitions [Attia et al, 2017].

E.g. Italy has chosen not to use compensation for exported energy to the grid, apart from what unavoidable due to the fact that the calculation method is based on a monthly time step. In the wording of EN-ISO the situation might be described by saying that the parameter kexp is set zero in principle, but slightly higher than zero in practice due to the monthly calculation method.

The opposite situation, where all energy exported over a year can be used to compensate (offset) energy taken from the grid over a year coincides with some of the definitions of Net Zero Energy Building (NZEB), where "net" is intended as difference between energy use and energy generation or , equivalently between delivered energy and exported energy, all quantities being considered over a period of a year. In this case the parameter kexp is set to 1.

2.5 Status of implementation of the nZEB concept in six E.U. Member States

2.5.1 Introduction

The following section describes the current implementation (or the ongoing preparation) of the nZEB definition in the six E.U. Member States involved in the AZEB project, in order to define a common ground and a comparison of the languages used in the various countries and possibly their relationship to the language of the ISO 52000.

The use of same concepts and terms is vital for allowing a clear comparison of performances and a diffusion of results in an effective manner. This will avoid costs due to erroneus interpretations, difficulties in transfer and diffusion of technologies across the internal EU market. In particular, it will be useful for describing and comparing different case studies within the AZEB project (in WP3) and make diffusion and replication more effective.

The following chapters describe:

- the definition of nZEB as implemented (or as proposed) in each of the MS involved in AZEB project, e.g. which indicators have been chosen (or are under discussion) to represent the building performance;
- which quantitave requirements have been assigned to each indicator;
- which are the National laws/regulations where the above indicators and quantitative requirements are stated;
- the calculation methodology for assessing the value of the indicators.

Regulations are being modified in most countries. Some new regulations are well advanced in some cases but still in discussion on many points in other member States so that less information is available at the moment.

2.5.2 Situation in France

The nZEB concept is not considered as such in France, but the energy performance of buildings is evaluated in the national regulation as well as in design tools. A new regulation is being elaborated for 2020. The present version of this regulation, which is still under discussion, includes 5 indicators (but the first one "bioclimatic needs" might be suppressed):

- "bioclimatic needs", including the energy needs for heating, cooling, energy use for ventilation and lighting, with the objective to impose a good envelope performance,
- total primary energy use,
- primary energy use including non renewable and limited renewable (e.g. wood, hydro-electricity), with partial compensation (considering local renewable energy generation, but only 1/2.58 of the exported electricity),
- total life cycle CO2 emissions,
- life cycle CO2 emissions of materials (excluding operation and exported energy).

The primary energy factors are still being discussed. Possible values are shown in the table hereunder.

Table 2 Possible values of primary energy factors.

Energy carrier	**$f_{P,NREN}$***	**$f_{P,REN}$***	**$f_{P,TOT}$***
Natural gas	1	0	1
GPL	1	0	1
Fuel oil	1	0	1
Coal	1	0	1
Solid biomass	1	0	1
Liquid and gaseous biomass	1	0	1
Electric energy from the grid	2.58	0	2.58
District heating	1	0	1
Municipal solid waste	1	0	1
District cooling	1	0	1
Thermal energy from solar collectors	0	1	1
Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumed)	0	2.58	2.58

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Electric energy produced by photovoltaic, small scale wind/hydro electricity (exported to the grid)	0	1	1
Thermal energy from the external environment - Free cooling	0	1	1
Thermal energy from the external environment - Heat pump	0	1	1
Solid biomass (pellets)	1	0	1

* *the distinction between renewable and non renewable does not make sense because e.g. using wood in a building reduces the wood resource, which is limited, for other buildings though wood is renewable. The same is true when using hydro-electricity. On the other hand, using electricity produced by PV modules on the roof of a building does not reduce the resource for other buildings.*

Comments and potential improvements

The indicator life cycle CO2 emissions of materials imposes a maximum CO2 emissions threshold regarding the life cycle of building materials, i.e. accounting for the fabrication, maintenance and end of life but not the operation. This is very unfavourable to renewable energy systems, and particularly photovoltaics because a large amount of CO2 is emitted during the fabrication of PV modules, and the indicator does not account for avoided impacts related to the corresponding renewable electricity production.

Another barrier against renewable production is the partial compensation for exported electricity, and partial accounting of avoided impacts by recycling the modules at the end of life. The consequence of such unfavourable calculation is that very little PV is integrated in buildings. In order to achieve the national energy transition objectives, PV is installed on the ground, e.g. a large forest territory is cut down in the South-West of France to build a PV power plant. Using the roofs and facades would be more sustainable than destroying forest or agricultural lands. It would therefore be interesting to compare different methods to account for compensation.

In order to develop scientific knowledge on environmental impacts of buildings, and to answers questions like: what is the influence of adding a photovoltaic electricity production system on the energy and CO2 balance of a building, ARMINES has developed a life cycle assessment tool based upon knowledge based models. For instance, avoided impacts by exporting locally produced electricity are evaluated using a global electricity system model. An optimization module allows identifying compromises between energy efficiency and local renewable production according to the climatic context and use of the building.

The results obtained using this model show that optimal solutions correspond to a high performance envelope associated with a local renewable production using PV. A poor insulation level leads to higher CO2 emissions for a given construction cost, or higher construction costs for a given performance (because more PV has to be installed). On the other hand, triple glazing is not always optimal, depending on the climate zone and solar exposure of the facade.

The project to suppress the threshold regarding *energy needs* could lead to reduce the performance of envelopes both in term of energy and comfort.

2.5.3 Situation in Italy

In Italy, a nZEB is defined according to DM 26/06/2015 (minimum requirements) as a building which has a better performance than a “reference (virtual) building”, which is characterized by the same shape, location, orientation, function, window/wall ratio as the actual real one and has physical properties (e.g. U values) as fixed by law in the definition of the reference building (Figure 10). Consequently, there is no explicit fixed energy thresholds in kWh/(m2y) for being classified as an nZEB but it depends on a series of requirements (Table 3) which must be verified with respect to the reference building.

In addition, the annex 3 of the current Italian legislation about the promotion of renewable energy (Dlgs 28/11), coherent with the Directive 2009/28/CE, describes the minimum mandatory amount of energy provided via the exploitation of renewable sources for nZEBs. In particular: the systems producing thermal energy must be sized and realized to guarantee the contemporary fulfillement of two requests: a) to cover 50 % of the expected primary energy for domestic hot water (DHW) and b) to cover 50 % of the sum of the expected primary energy for DHW, heating and cooling, using energy produced from Renewable Energy Sources (RES).

Moreover, c) the power of the electrical renewable energy systems installed has to be greater o equal to P= (1/K)*S, where S is the footprint surface of the building at ground level (in m2) and K = 50 m2/kW. For public buildings, these obligations are increased by 10 %.

Figure 10: Project and reference building (ref. ANIT 2017).

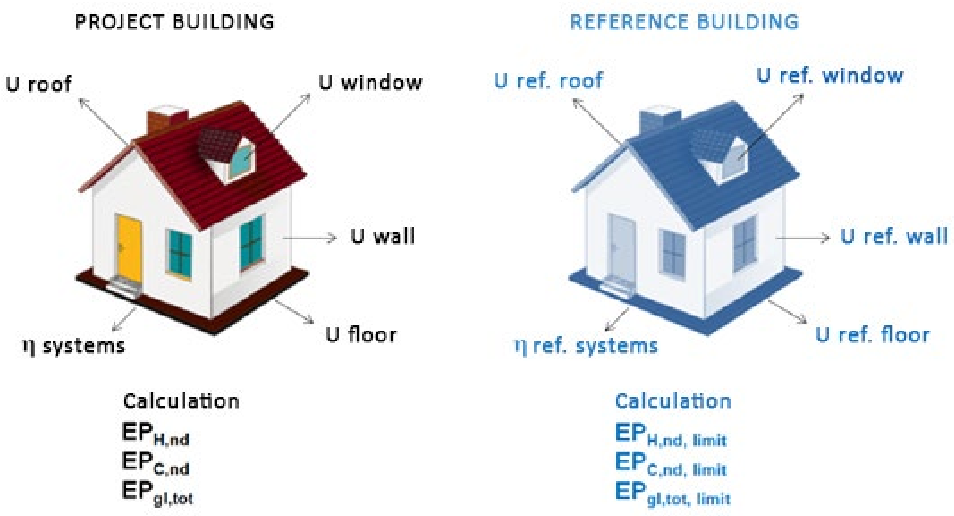

Table 3 Requirements for nZEB buildings according to Italian legislation (DM 26/06/2015 and DLgs 03/03/2011).

DM 26 June 2015 - annex 1			
Number	**Indicator**	**Unit**	**Description**
i	$H'_T < H'_{T,max}$	[W/m^{2}K]	Transmission heat transfer coefficient per unit of *thermal envelope area*
ii	$A_{sol,est}/A_{sup,utile}$ $< (A_{sol,est}/A_{sup,utile})_{max}$	[-]	Equivalent summer solar area ($A_{sol,est}$) per unit of *useful floor area* ($A_{sup,utile}$)
iii	$EP_{H,nd} < EP_{H,nd,limit}$ $EP_{C,nd} < EP_{C,nd,limit}$ $EP_{gl,tot} < EP_{gl,tot,limit}$	kWh/(m^{2}y)	*Energy need for heating* *Energy need for cooling* *Total global primary energy** (includes non-renewable energy and renewable energy)
iv	$\eta_H > \eta_{H,limit}$ $\eta_W > \eta_{w,limit}$ $\eta_C > \eta_{C,limit}$	[-]	Average seasonal efficiency of the winter air conditioning system Average seasonal efficiency of the DHW system Average seasonal efficiency of the summer air conditioning system (includes moisture control)

*includes the following *building services*: winter air conditioning, DHW, ventilation, summer air conditioning, artificial lighting, transportation of people and things

Legislative Decree 3 March 2011 - annex 3	
Number	**Description**
i	cover 50% of *primary energy* for DHW through energy produced by RES (*on-site*)
ii	cover 50% of *primary energy* for DHW, summer and winter air conditioning through energy produced by RES (*on–site*)
iii	power of the electrical renewable energy systems installed > P = (1 / K) * S

(i) The transmission heat transfer coefficient per unit of thermal envelope area is a parameter to control the quality of the building envelope in terms of transmission losses. It is calculated as:

$$H'_T = H_{tr,adj} / \sum_k A_k \qquad [\frac{W}{m^2 K}]$$

where
Htr,adj [W/K] is the transmission heat transfer coefficient of the envelope calculated based on ISO 14683:2007(E) and UNI/TS 11300-1;
Ak= the area of the k-th component (opaque or transparent) of the building envelope [m2].

(ii) The equivalent summer solar area per unit of useful floor area is calculated as:

$$\frac{A_{sol,est}}{A_{sup,utile}}$$

where:

$A_{sol,est} = \sum_k F_{sh,ob} * g_{gl+sh} * (1 - F_F) * A_{w,p} * F_{sol,est}$ [m^2]
and:

- $F_{sh,ob}$= is the shading reduction factor for external elements for the area of actual solar capture of the k-th glass surface, reported in July;
- G_{gl+sh}= is the total solar energy transmittance of the window calculated in July when the solar shading system is used;
- F_F = is the fraction of the area relative to the frame, the ratio between the projected area of the frame and the projected total area of the window component;
- $A_{w,p}$= is the total projected area of the glazing component (window transparent area);
- $F_{sol,est}$= is the correction factor for the incident irradiation, obtained as a ratio between the average irradiance in July, location and exposure considered, and the average annual irradiance of Rome on a horizontal scale.

(iii) Total primary energy $EP_{gl,tot}$ is calculated as:

$$\frac{E_{Pgl,tot}}{A}$$

where:
$E_{Pgl,tot} = E_{PH,tot} + E_{PW,tot} + E_{PV,tot} + E_{PC,tot} + E_{PL,tot} + E_{PT,tot}$

- E_{PH} is the *total primary energy* for winter air conditioning [kWh]
- E_{PW} is the *total primary energy* for DHW [kWh]
- E_{PV} is the *total primary energy* for ventilation [kWh]
- E_{PC} is the *total primary energy* for summer air conditioning [kWh]
- E_{PL} is the *total primary energy* for artificial lighting [kWh]
- E_{PT} is the *total primary energy* for transportation of people and things [kWh]

A: is the useful floor area of the building [m^2]

The DM 26 june 2015 (annex 1) defines exactly how renewable energy produced on-site can be counted in the calculation of the yearly non renewable primary energy use (which appears in Energy Performance Certificate):
- Only to contribute to the same energy carrier (e.g. electricity with electricity, i.e. no compensation between different energy carriers)
- Only as long as the monthly energy use of that carrier is covered. The excess production in one month (produced on site and exported) cannot be used to compensate for energy taken from the grid in another month.

In essence Italy has chosen not to use compensation for exported energy to the grid, apart from what unavoidable due to the fact that the calculation method is based on a monthly time step. In the wording of EN-ISO the situation might be described by saying that the parameter kexp is set zero in principle, but slightly higher than zero in practice due to the monthly calculation method.

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Comments and potential improvements

The Italian National implementation of EPBD, which adopts in the definition of nZEB the indicators energy needs, total primary energy, fraction of total primary energy covered by renewables, and the non renewable primary energy as indicator for the Energy Performance Certificate, is in overall line with the EN ISO 52000 and consistent in the use of nomenclature. There is a shortcoming in the uncomplete alignment between the indicators for the definition of nZEB and for the general Energy Performance Certificate which may create confusion in the building market.

The use of the reference building procedure introduces a series of shortcomings:

- in the design phase it removes the signal to optimize building shape and orientation
- in the design phase it highly attenuates the signal to optimize the window/wall ratio
- in the real estate market it makes very difficult to compare the building under analysis to other buildings since there is no absolut threshold; the comparison on which the energy label is awarded is with the reference building model, which is specific to the building under analysis, rather than with all the other buildings

The choice of calculating the *non renewable primary energy* use essentially with *no compensation* (the excess production in one month - produced on site and exported - cannot be used to compensate for energy taken from the grid in another month for exported energy (a part from what is unavoidable due to the fact that a monthly calculation method is used) has the advantage of:

- focusing on the building and its success in fulfilling the definition of nZEB of EPBD art.2;
- avoiding incentives to use the energy grid as an inter-seasonal energy storage which would transfer cost from the building to the grid and generate new environmental pressure (e.g for construction of large storage facilities).

2.5.4 Situation in Spain

Although some regions in Spain had advanced on “nearly zero energy building” (nZEB) definitions, the first time that requirements for nZEB publicly appeared for the Spanish national context were on 2017, under the Royal Decree 564/2017. This decree has modified the previous Decree 235/2013 in which the procedures for building energy rating were stablished. Article 1 of this new Royal Decree is explicit in explaining the requirements for nZEB, which must be fulfilled for all new buildings after 2020 and for all new public buildings after 2018 to comply with the EPBD. Requirements for NZEB are simply written as “those determined by the Building Regulations” (in Spanish, CTE - Código Técnico de la Edificación).

With this definition is therefore very important to describe building regulations, in particular the new building regulations (CTE 2018), which are expected to be published during 2019.

The new CTE 2018 will follow the general framework from the standard ‘EN ISO 52000-1:2017 Energy Performance Of Buildings - Overarching Epb Assessment - Part 1: General Framework And Procedures (ISO 52000-1:2017)’, and, in line with this, proposes a new indicator of “global total primary energy use”, which was not included in previous building regulations . The new CTE 2018 is expected to give clear reference values for this indicator and the already existing indicator “global non-renewable primary energy use”, to be fulfilled by all new buildings.

Buildings complying with those values will actually be defined as nZEBs according to the decree 564/2017 previously mentioned.

Indicators and values for nZEBs

In the tables below a comparison of requirements in the previous regulations (CTE 2013) and expected values from the new building regulations (CTE 2018) are presented. CTE 2018 values are extracted from a public presentation by Luis Vega (Spanish Ministry of Development), at the V Conference on nearly Zero Energy Buildings on 14-15th December 2017, on which AZEB partners also participated with a presentation.

Table 4 CTE 2013- Indicators and limits/requirements for a residential building, climate zone C.

Affordable Zero Energy Buildings

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Building Services included	**Energy needs (building level) - kWh**	**Requirements on Non renewable Primary Energy**	**Total Primary Energy (renew+ non renew)**	**Requirements Minimum renewable energy contribution**
Heating	YES – limit: Energy needs for heating <20 + (1000/floor area) [kWh/(m^2·y)] (Values range between 20 to 30 kWh/(m^2·y)	NO - No limit	NO	NO
Cooling	YES – limit: Energy needs for cooling <15 kWh/(m^2·y)	NO - No limit	NO	NO
Domestic Hot Water	Standard calculation – number of liters per person at 60 °C.	YES - No limit	NO	YES, 30% of annual energy need for hot water
Global	NO	<50+(1500/ floor area) kWh/(m^2·y) (Values range between 50 to 65 kWh/(m^2·y))	NO	NO

Table 5 CTE 2018- Indicators and limits for a residential building, climate zone C.

Services included	***Energy needs*** **(building level)**	***Non renewable Primary Energy***	***Total Primary Energy*** **(renew+ non renew)**	**Minimum renewable energy contribution**
Heating	NO–but minimum prescriptions for transmittance, air tightness, solar control	YES - No limit	YES - No limit	NO
Cooling		YES - No limit	YES - No limit	NO
Domestic Hot Water	Standard calculation – number of liters per person at 60 °C.	YES - No limit	YES - No limit	YES, 50% annual energy need
Global	NO	<32 kWh/(m^2·y)	<64 kWh/(m^2·y)	NO

It can be observed how the existing indicator for "Energy need" is expected be removed in the new CTE 2018. Some pre-requisites will be however included regarding building envelope, including maximum thermal transmittance, air infiltration requirements or solar protection. The indicator about minimum renewable energy contribution will also be removed in the new CTE 2018. The new indicator "total primary energy", whose limit value is approximately double of the non-renewable primary energy value for new residential buildings, sets a limit so as to prevent inefficient buildings with high energy needs. For example, in Spanish climate zone C (equivalent to Köppen-Geiger Cfb -temperate Oceanic Climate), a residential building could use a maximum of 32 kWh/ (m2·y) of non-renewable primary energy, but could double this value to <64 kWh/(m2·y) total primary energy (non renewable + renewable).

Regarding the building services included in the Spanish nZEB definition, it has to be noted that the definition only covers heating, cooling and hot water for residential buildings. For non-residential buildings, energy use for lighting would also be included.

Comments and potential improvements

With key details of the calculations of the indicators still to be published (eg. primary energy factors of renewable and non-renewable energy sources, compensation for exported energy, etc), the overall methodology and indicators in Spain seem appropriate for defining nZEBs, and follows EN ISO 52000.

A key change proposed in the draft new regulation is the removal of the “energy needs” indicator for heating. It is expected that the inclusion of limits for the“total primary energy” indicator will prevent building designs with very high energy needs, as even with renewable energy use, they should comply with the limits for total primary energy. However, it somehow offers a wider spectrum of solutions which might not make the full advantage of passive design.

Passive design and passive solutions, with generally long service life and low maintenance costs, can offer “future-proof” buildings against changes on energy costs or energy regulations (e.g. self-consumption regulations), and can potentially provide additional benefits related to health and comfort (eg. alleviating the effect of extreme weather events or of climate change). Overall, achieving very low energy needs can be very frequently a strategy that will result on a better life cycle economic and environmental performance, particularly taking into account long service life for some building types.

Therefore, AZEB project recommends the maintenance of limits for the “energy needs” indicator within the new proposed regulation, adding to the new proposed indicator, to explicitly promote passive designs.

2.5.5 Situation in Bulgaria

In Bulgaria, the current version of the national regulations for energy performance requirements is mainly from 2015. In the same year, the government has released a national plan for development of the energy efficiency in the building sector, called “National plan for nearly Zero Energy Buildings 2015-2020”, where the term “nearly Zero Energy Building” has been defined, but the goal of the plan is to develop the nZEB to an attractive alternative for the national construction market. In the following, we will present both topics.

National Energy Performance Requirements / Current status

The national energy performance requirements in Bulgaria are subject of the following 3 national regulations:

- Regulation Nr. RD-16-1058/10.12.09 – regulation for the energy consumption parameters and energy characteristics of buildings
- Regulation Nr 16-1594/13.11.13 – regulation for investigation of energy efficiency, certification and assessment of energy savings of buildings
- Regulation Nr 7 – regulation for energy efficiency, warmth savings and reduction of energy consumption in buildings

Their lasts major revision was done in 2015, which made them completely harmonized to the following European directives:

- Directive 2010/31/EC
- Delegated regulation of the commission (EC) Nr. 244/2012
- Regulation NR. 305/2011

With this, the following two major criteria for energy requirements are defined:

1. Definition of parameters for the energy efficiency categories, which defined Building classes depending on the integrated factor “yearly usage of non renewable primary energy” in kWh/m2y. The energy efficiency categories are defined as follows:

Table 6 Building classes according to yearly usage of non renewable primary energy in Bulgaria.

Building class	EPmin [kWh/(m2 y)]	EPmax [kWh/(m2 y)]
A+	<	48
A	48	95
B	96	190
C	191	240
D	241	290
E	291	363
F	364	435
G	>	435

Currently, for any building, the energy requirements are fulfilled if the integrated factor shows that the building is at least in category “B” (for buildings with first exploitation after 01.02.2010) of category “C” (for buildings with first explotation before 01.20.2010)

2. Requirement for the maximal allowed U values of construction elements in the envelope of the building. These values have been lowered and can be taken from the following table:

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Table 7 Requirements regarding elements, in order to obtain a constrcuction permit.

Nr.	**Type of construction element**	**U [W/(m²K)]**	
		For buildings with average value of inside temperature $\theta_i \geq 15$°C	For buildings with average value of inside temperature $\theta_i < 15$°C
1.	Exterior walls, which are exposed to outside air	0,28	0,35
2.	Walls of a heating space, which are exposed to an unheated space which temperature is lower with 5°C or more	0,50	0,63
3.	Exterior walls of heated parking lot, which are exposed to the ground	0,60	0,75
4.	Base plate of unheated underground parking lot	0,50	0,63
5.	Base plate of heated space, which directly borders to the ground in a building without underground parking lot	0,40	0,50
6.	Base plate of heated underground parking lot, which borders to the ground	0,45	0,56
7.	Base plate of a heated space, which borders to the outside air	0,25	0,32
8.	Any exterior plate or wall, when there is surface heating	0,40	0,50
9.	Flat roof without air layer or with air layer with thickness $\delta \leq$ 0,30 m; skew roof with heated underroof place	0,25	0,32
10.	Flat roof without air layer or with air layer with thickness $\delta >$ 0,30 m skew roof with unheated underroof place	0,30	0,38
11.	Exterior door, exposed to outside air	2,2	2,75
12.	Door, exposed to unheated space	3,5	4,38

Some other changes have been done too, in the following areas:

- Adjustments to different efficiency coefficients of boilers, systems with heat recovery, solar thermal systems and heat pumps
- Definition of rules for heat zones of buildings and certification of buildings in special cases
- Improvement of the energy efficiency parts of project plans

In addition, also a first national definition of an nZEB has been derived. It is main part of the document called national plan for nearly Zero Energy Buildings 2015-2020 and we will have a look into it in the next paragraph.

National Energy Performance Requirements / nZEB plans

As already mentioned, the nZEB definition has been derived in 2015, but the way to making this kind of buildings attractive to the parket and therefore the business and the end users is very unclear. Therefore, a national plan has been drafted, which specifies under which conditions this definition should be used and then analyses different measures how the requirements of the nZEB definition can be achieved. However, these measures do not seek for a cost-efficient solution, but rather show how much investments will be required to meet the energy saving targets for the government. Therefore, the A-ZEB project fits actually very well in this plan.

The definition of a nZEB is as follows: “A nearly Zero Energy Building is a building, which simultaneously fulfills the following two requirements:

- The primary energy use of the building corresponds to at least Category “A” of the energy efficiency categories for such type of buildings

- At least 55% of the used (delivered) primary energy of the building for heating, cooling, ventilation, domestic hot water and lighting is renewable energy, produced onsite or in the proximity of the building"

The definition is done in such a way, that it can be adjusted and changed over time and it is yet not mandatory, but more like a working concept. Furthermore, a framework of conditions for application of this definition is derived, which contains the following components:

A. Energy balance – calculated using БДС EN ISO 13790

- Physical borders – single building
- Components of the energy balance – accounted is for energy use for heating, cooling, ventilation, domestic hot water, lighting, pumps, ventilators, appliances (which consume energy), technical systems
- Parameters of the microclimate – accounted for following current norms, based on European standards and implemented as Bulgarian
- Borders for generation of renewable energy – accounted is only renewable energy produced on site or in the proximity of the building, up to 15 km away. This component will be object of investigation in further phases of the execution of the national plan
- Time period of the calculations – considered is 1year time period

B. Conditions for definition of base values ("base scenario")

- Specific usage of energy in kWh/m2 y – it is calculated based on the thermally conditioned area of the building, whereas its outer dimensions are considered, following БДС EN 15217
- Primary energy usage – it is calculated for each energy type, using the nationally defined coefficients for energy losses due to extraction, transportation and distribution at delivery. The coefficients are considered stable over the year and are found in the following table:

Table 8 Total Primary Energy factors in Bulgaria.

Energy carrier	**e_p**
Natural gas	1,1
GPL	1,1
Fuel oil	1,1
Coal	1,2
Electric energy from the grid	3,0
Standard pellets	1,25
Heat from centralized heating system	1,30
Solid biomass (wooden pellets)	1,05

- CO2 emmissions equivalent - is calculated for each energy using nationally defined coefficients. Is considered as additional information to the primary energy usage. The coefficiets are as follows:

Table 9 Coefficients for the calculation of CO_2 emissions equivalent.

Energy carrier	**f_i [g CO2/KWh]**
Natural gas	202
GPL	227
Fuel oil	267
Coal (different types)	341-364
Electric energy from the grid	819
Standard pellets	351
Heat from centralized heating system	290
Solid biomass (wooden pellets)	43

However, the current values of all energy efficiency parameters for the buildings in Bulgaria are not satisfying and the necessity for improvement is recognized. To address this problem, different scenarios for improvement are defined, then they are simulated and the expected results are calculated. This is done mostly for retrofit buildings, but some scenarios hold also for new buildings. Here some examples:

- Exchange of windows and doors with new ones with better U values
- Thermal insulation of the building's envelope
- Various improvements of the building services
- Installation of renewable energies

The results of the simulations assume that buildings will move from one energy efficiency category to a higher one. Altogether, the expected results (based on these simulations) are summarized in a table for both the results from retrofit and new buildings as follows:

Table 10 Expected results based on simulations from the "National plan for nearly Zero Energy Buildings 2015-2020".

Building type	Gross Floor Area (GFA) [m^2]	Investments [BGN]	Energy Savings [ktoe]	Energy Savings [GWh]	Emmission Savings [t CO_2]
Administrative	492.896	110.907.634	10,6	122,8	14.445,6
Housing	74.570	17.474.562	1,2	13,8	3.314,8
Others	140.598	31.385.202	3,2	36,9	4.722,8
Sum to 2020	708.064	159.767.398	15	173,5	22.483,2

The total savings, which should be achieved under consideration of all measurements until 2020, are 15 ktoe (174 GWh) end energy, which represents 6,52% of the national target for energy saving until 2020. As already mentioned, this plan has been published in 2015 and its implementation is already slower than expected as the norms for energy efficiency are not strictly being followed and controlled.

The plans between 2020 and 2050 are subject of only one document. There it is stated that the government will search for mechanisms to further pursue the targets for energy efficiency. The main goal will be to find effective and structured mechanisms for financing, such that investors decide to invest their own capital in energy-efficient buildings and not rely on non-recourse financing. However, no specific measurements are derived and everything is based on extensive analysis of the circumstances in 2020, which still has to be done. Furthermore, it is stated that these mechanisms should consider buildings, which fulfill the minimal requirements of the current energy efficiency directive, since currently there isn't a new one for after 2020.

Comments and potential improvements

The overall concept for the nZEB definition is appropriate:

- It sets a requirement for primary energy use per square meter per year and thus enforce that the building fits to one of energy efficiency categories
- Request that some portion of the delivered energy to the building comes from renewable energy sources

However, there is problem in the way how the energy efficiency categories are defined:

- First, when speaking about primary energy, there is no specification which component is meant – the one coming from renewable sources, the one from non-renewable sources, or the total primary energy. Stating this explicitly will help avoid misunderstandings.
- Second, the energy efficiency categories are defined only by considering the primary energy use coming from non-renewable energy sources. With other words, a building which is being powered only by renewable sources becomes automatically 0 kWh/m2 y non-renewable primary energy use and thus class A+, regardless if the building actually consumes 100 kWh/m2 y or 1 000 kWh/m2 y. This represents a serious problem that the concept is actually unable to judge whether a building has high energy-performance or not.
- The primary energy coefficients are defined only for non-renewable sources
- Third, using the term "delivered energy" requires very specific explanation how it will be calculated and how for example different quality of the energy streams can be accounted for

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As overall recommendation, we can therefore state that the primary energy coming from renewable sources has to be accounted for as well, when defining the energy efficiency buildings and corresponding coefficients for the losses have to be introduced. The Primary energy factors should be defined as non-renewable, renewable and total as in EN ISO 52000. Furthermore, the rule, that 55% of the delivered energy has to come from renewable sources might be expressed in terms of the primary energy since delivered energy has different exergy values and cannot be summed up directly.

2.5.6 Situation in Germany

National Energy Performance Requirements / Current status

In Germany the requirements for energy efficiency of new buildings are regulated by the Energy Saving Ordinance ("Energieeinsparverordnung" - EnEV). The last time that these requirements were reinforced was in the ordinance in 2013 and this has been in effect since 2016.

The maximum permitted annual energy demand is established using the so-called reference building method. Here the reference building corresponds to the building to be verified in terms of geometry and orientation but constructed with building components and technical systems for the reference building specified in the currently applicable ordinance EnEV. Apart from this, implementation of the reference building is differentiated according to residential or non-residential use. The maximum permitted value for the building to be constructed is defined by the annual non renewable primary energy use of the reference building and may not exceed 75% of the reference building's use.

The energy use must be determined according to the calculation method in DIN V 18599 or alternatively also according to DIN V 4108-6 and DIN V 4701-10 for residential buildings that are not cooled.

As a further requirement, the Energy Saving Ordinance requires that the transmission heat losses (per unit area) through the building envelope should be limited.

Besides the Energy Saving Ordinance, the Renewable Energies Heat Act also requires a minimum share of renewable energy for heat generation in new buildings. In residential ones, this requirement can usually be met by a solar system for domestic hot water generation. (The percentage use of renewable energies with respect to the energy needs for heating and DHW varies between at least 15% for solar radiation energy and at least 50% for geothermal or environmental heat).

Due to the reference building method, the performance requirements depend on the specific building design and its respective use. In new residential buildings the permitted annual non renewable primary energy use is in the range between 65 and 100 kWh/(m²y) (based on net floor area/calculation according to DIN V 18599). This includes the energy use for heating, DHW, ventilation and auxiliary electricity, e.g. for hydraulic pumps.

There is no explicit requirement for the energy needs for heating. Comparative calculations were performed with the PHPP for some buildings according to german regulations. The corresponding energy need for heating resulted in the range of about 45 to 65 kWh/(m²y) (calculation with the [PHPP], based on the net floor area).

Table 11 Summary: energy performance requirement / current status for residential buildings.

National regulations (new buildings)	Energy Saving Ordinance (18.11.2013) https://www.bmwi.de/Redaktion/EN/Artikel/Energy/energy-conservation-legislation.html
Calculation methods	DIN V 18599, and DIN V 4108-6 and DIN V 4701-10 for residential buildings without cooling
Typical heat transfer coefficient of the main building components (values of the reference building)	Roof: 0.20 W/(m²K); external wall: 0.28 W/(m²K), windows: 1.3 W/(m²K), floor 0.35 W/(m²K).
Ventilation (reference building)	Exhaust fan (withour heat recovery)
Heating / DHW (reference building)	For the reference building the heating system is chosen as a condensing boiler and for DHW it is chosen as a combination of a condensing boiler and a solar energy system
Permitted *non renewable primary energy* use (apartment block / single family house)	ca. 65 to 100 kWh/(m²y) (based on net floor area)
Building services included in the *non renewable primary energy* use (residential buildings)	Heating, cooling, ventilation, DHW, auxiliary systems (e.g. for hydraulic pumps)

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Percentage of on-site renewable energy production (local)	Exact ratio depends on the chosen energy source; in the case of solar thermal power 15% of energy need for heating and DHW https://www.erneuerbare-energien.de/EE/Navigation/DE/Recht-Politik/Das_EEWaermeG/das_eewaermeg.html
energy need for heating – the legislation does not set any minimum requirement - threshold values – for this indicator (typical values determined using the PHPP)	Ca. 45 … 60 kWh/(m²a) (based on net floor area for apartment blocks to single family houses)

Table 12 Non renewable primary energy factors for Germany.

Energy carrier	**Primary energy factor total**	**non renewable primary energy factor**
Natural gas	1.1	1.1
Heating oil	1.1	1.1
Wood	1.2	0.2
District heating (CHP 70%)	0.7	0.7
District heating (fossil fuels)	1.3	1.3
Electricity-	2.8	1.8
Electricity-from PV	1.0	0
Solar thermal energy	1.0	0
Environmental energy (ambient air, ground)	1.0	0

National Energy Performance Requirements (Germany) / nZEB

The national application of nZEBs has not yet been adopted in Germany. One draft for this stipulated that the performance requirements for the *non renewable primary energy* use will be increased by ca. 25 % compared to the current requirements. ([GEG 2017]).

However, recent developments indicate that there will be no further increase in the energy relevant quality of buildings compared to the current situation. This has been expressed in agreements by the new federal government.

In the same way, the energy performance requirements as well as the permissible calculation methods will probably be kept as they are.

Comments and potential improvements

The reference building is used for calculating the permissible annual primary energy demand and the structural thermal protection. The energy-relevant requirements for the building will be determined using this based on the initially selected architectural design. However, established successful methods for energy efficient construction and optimisation of the building design are not considered in this way, because the energy use values of the reference building simultaneously also decreases with the energy relevant improvements of the design. This may result in significantly different primary energy demands for buildings with almost the same available space and identical uses.

Proven energy saving potentials with optimisation of the building design which could improve the energy need for heating or daylight usage are ineffective in the reference building method. This eliminates any major incentive for using and further developing these established and often cost-effective architectural means of energy efficient construction.

Proposals of how to apply energy efficiency measures in the design and construction/renovation of buildings on an extensive scale and cost-effectively will be described and discussed in the following chapters.

Passive House buildings implemented on a voluntary basis for about have achieved extremely low energy need for heating of just 15 kWh/(m²y) as calculated with the Passive house planning package (PHPP) as verified in practice through field measurements of delivered energy for heating as a proxy (see [Feist et al. 2000], [Schnieders/Feist 2001], [Reiß/Erhorn 2003]). This represents a reduction in delivered energy of a factor of three to four compared to current new builds in Germany. The solutions applied in Passive House buildings (high thermal insulation of the building envelope including minimised thermal bridges, improved glazing and window frames, elevated airtightness, ventilation system with heat recovery) have proven also extremely durable, as demonstrated in an investigation in the first ever Passive House after 25 years of operation (see [Feist et al. 2016]). In addition, the solutions used in the Passive House are extremely cost-effective, as recent studies relating to subsidised housing in Hamburg have also shown ([F+B Bauforschung 2016]).

The high level of energy efficiency of the Passive House and the use of renewable energy are not mutually exclusive options but rather, they complement each other perfectly, in line with article 2 of EPBD. If the energy consumption is very low in the first place, meeting a significant share of the remaining energy demand through energy that is regeneratively produced on-site becomes technically and economically feasible. This was demonstrated as early as 1999 in a climate-neutral Passive House settlement in Hanover (see [Feist et al. 2005], [Peper/Feist 2002]).

A Passive House is a building with such a low energy need for heating (kWh/m2y) and small heating loads (kW) that the heating system can be greatly simplified. It can be shown that the small residual heating load 10 W/m² (living area) can be easily met via post-heating of the supply air in the ventilation system.

A proposal for the evaluation of Renewable Primary Energy Factors (PEFren) under a 100% renewable scenario

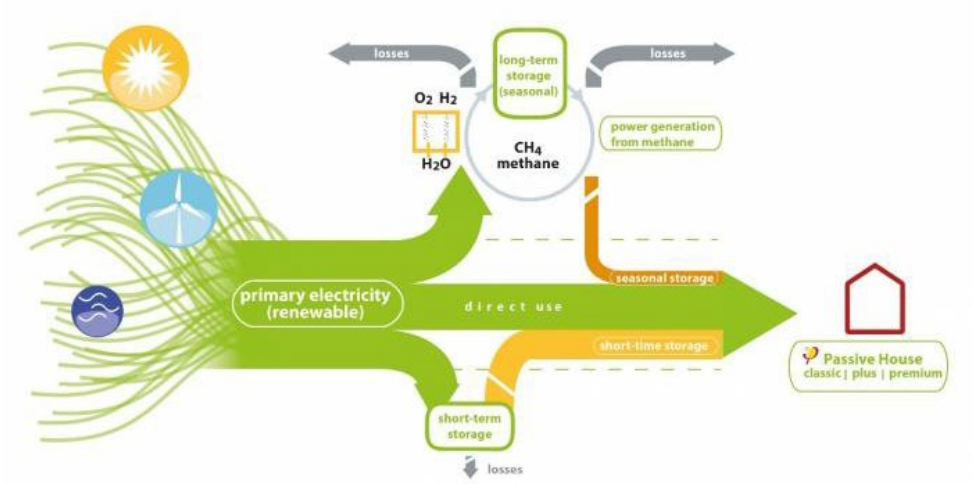
Evaluation of buildings based on Primary Energy Renewable (PER) methodology developed by PHI differs (see [Grove-Smith et al. 2016]) substantially from other evaluation schemes known mainly in two following aspects:

1. The PER evaluation of building is based on 100% renewable scenario. Meaning, it assumes that all the used energy being delivered comes from renewable sources. This brings many advantages compared to other methods using non-renewable PE-factors depending on electricity mix at each particular place at particular time. The advantages are as follow:

- The buildings from different parts of the world can be compared (independently of current electricity mix in that particular location)
- Buildings being build today will be comparable with buildings build in e.g. 10 years.

2. In the PER method, the Primary Energy Factors PEFren = PEFtotal (PEFren and PEFtotal in this case are coincident, since PEFnonren are zero for all sources by definition under this method), take ito account all possible storage losses, i.e. both short-term and long-term storage losses. This is very important fact being very often totally neglected in some other schemes (e.g. yearly net-zero balance approaches, e.g. aiming at minimising non-renewable primary energy with 100% compensation for exported energy). The idea that exactly the same amount of energy being gathered from renewable sources during summer can be used for heating during winter is obviously physically wrong due to the operating storage losses and the embedded energy in the storage systems.

Figure 11 Energy "flowchart" showing renewable energy being supplied variably over time, stored and used at the time it is demanded.



The evaluation is made in optimization tool specially developed for nZEB called Passive House Planning Package (PHPP), based on location and design of the actual building. About 700 different locations worldwide have been evaluated. The variations in PER factors for heating can be seen on the figure hereunder. Example PER factors for few locations and all used building load profiles can be seen on the next figure.

Figure 12 Example of PER factors for heating for different locations worldwide (implemented in PHPP).

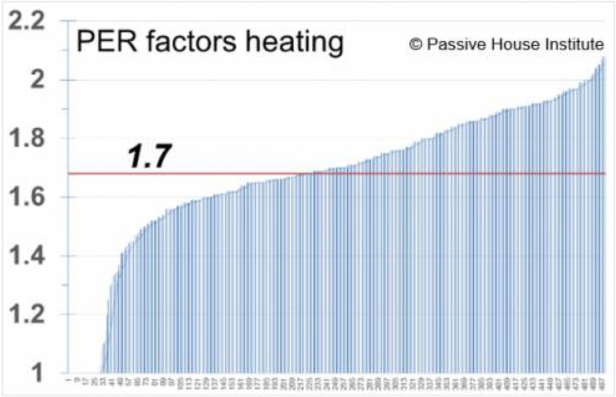
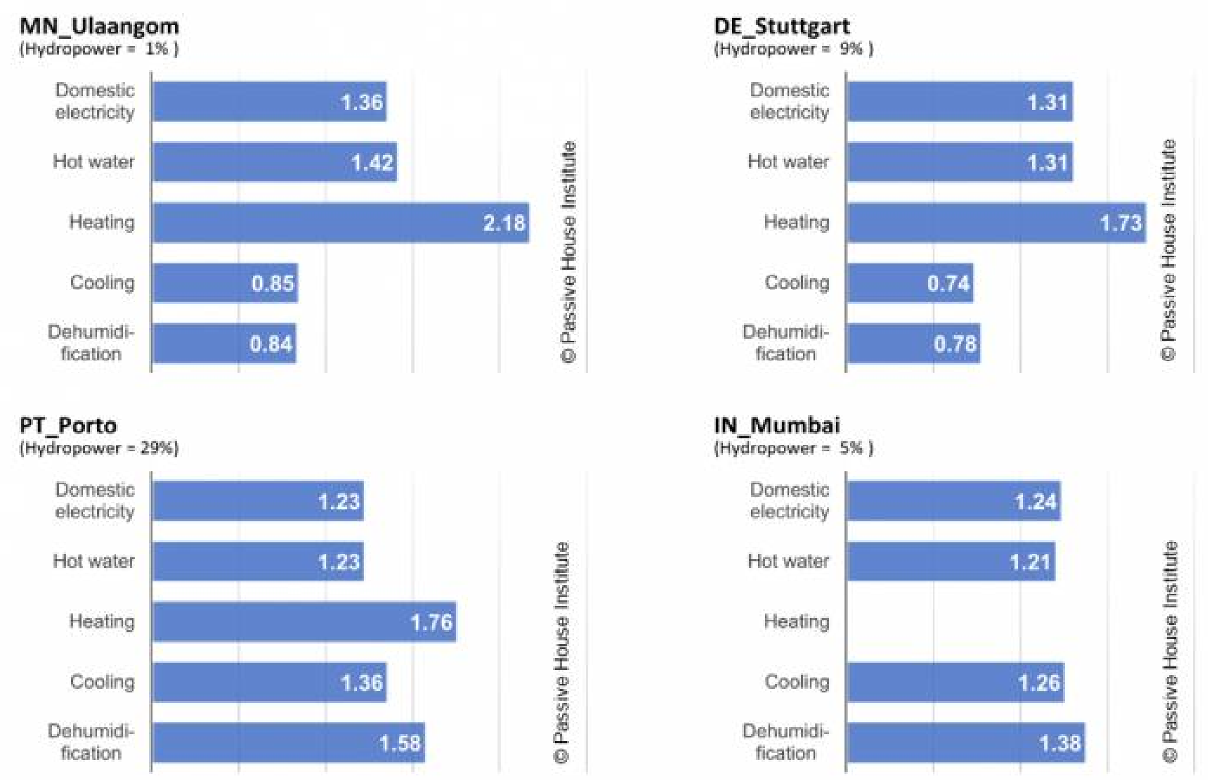
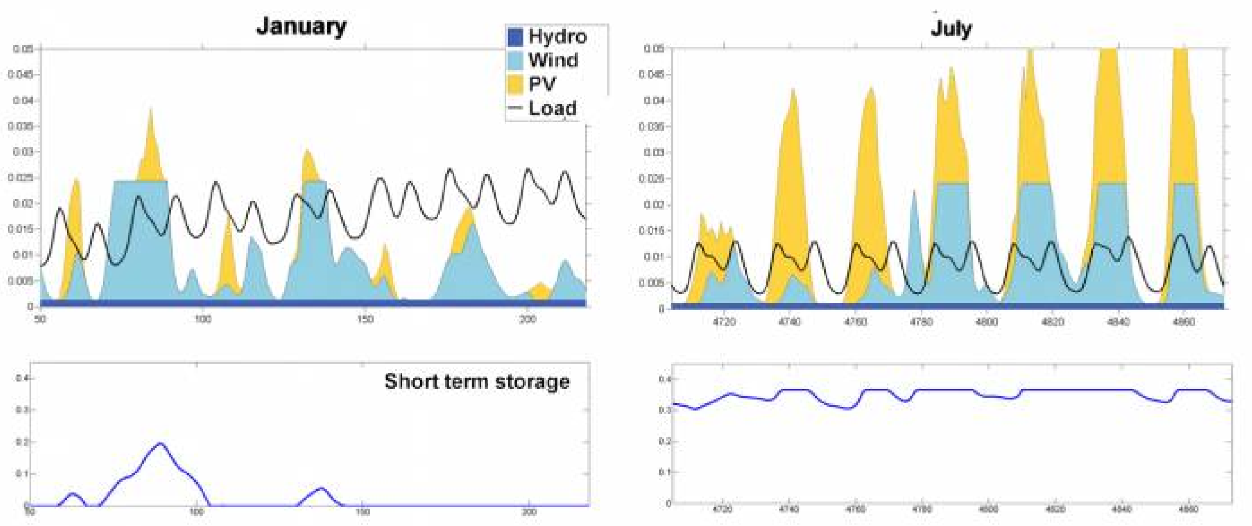


Figure 13 Example of PER factors for different locations worldwide.



Some of generated energy can be used directly (e.g. cooling in summer) but some of it must be stored over some time- even a whole season (e.g. heating in winter). Short-term storage can be done fairly efficiently, long-term storage has higher energy losses.

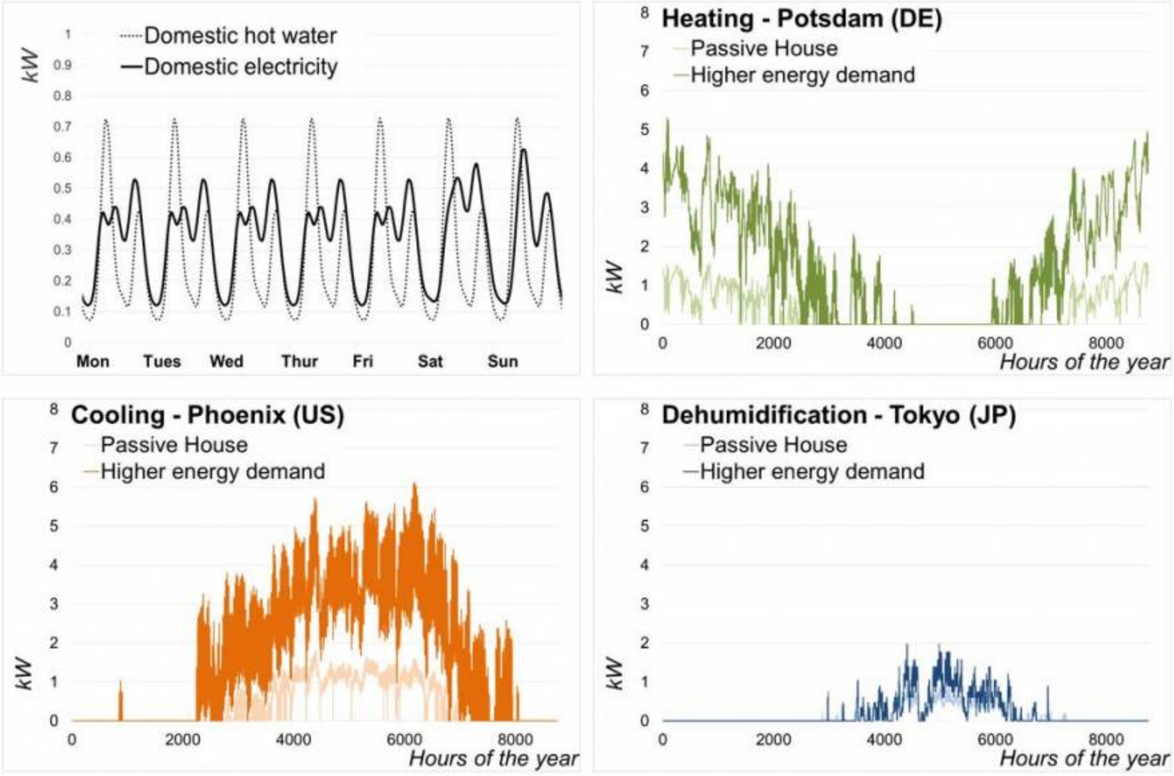
Figure 14 Example of PH load profile and renewable availability for winter (left) and summer (right).



Three different renewable sources are taken into account for the model: photovoltaic, wind energy and hydropower. Biomass is treated differently as it is easily storeable, but at the same time can be applied only in limited way as it "competes" with land area used for growing crops and if used via direct combustion can generate large quantities of PM10 and PM2.5 (e.g. in some areas of Pianura Padana its use is restricted/banned).

On the consumption side, it is being differentiated between heating, cooling and dehumidification, domestic hot water and household electricity. Standard value for energy use of 20 kWh/(m²y) is used for household electricity and and 15 kWh/(m²y) for domestic hot water. The load profile (kW) for heating, cooling and dehumidification is being calculated for reference building based on location/climate, see Figure 15 under the assumption that a heat pump is used for heating, cooling and dehumidification if needed.

Figure 15 Example building load profiles used to evaluate PER factors.



The PER methodology brings also the new classification scheme for nZEB. This can be downloaded at: http://passiv.de/downloads/03_building_criteria_en.pdf. Three different classes of buildings have been created- PH Classic, PH Plus and PH Premium. What is important to mention is that generated energy on building site refers to the ground area of building (foot-print area of building). This measure avoid discrimination of multi storey buildings compare to single storey buildings.

Passive House Criteria

- Energy need for heating ≤ 15 kWh/(m^2y)
- Energy need for cooling and dehumidification ≤ 15 kWh/(m^2y)
- Renewable primary energy use (based on PER system, see above, and referred to floor area)
    - passiv house classic ≤ 60 kWh/(m^2y)
    - passiv house plus ≤ 45 kWh/(m^2y)
    - passiv house premium ≤ 30 kWh/(m^2y)
- on-site renewable energy production (referred to projected building footprint BFP, not to the floor area)
    - passiv house classic ≥ 0 kWh/(m^2BFP y)
    - passiv house plus ≥ 60 kWh/(m^2BFP y)
    - passiv house premium ≥ 120 kWh/(m^2BFP y)

2.5.7 Situation in the Netherlands

Current situation in The Netherlands – BENG replaces EPC

The Dutch national law on building, named "Het Bouwbesluit", poses requirements on energy-efficiency of new buildings: for housing as well as utility buildings. The measure for energy efficiency is called Energy Performance Coefficient (EPC). It compares the amount of total non-renewable primary energy (gas / oil / coal) needed for interior climat e control, domestic hot water and lighting in a new building as a portion to the non renewable primary energy use in average Dutch reference homes of the same size in 1990.

The way the EPC is calculated is regulated by the norm NEN 7120 “Energy Performance of Buildings".

The EPC has turned out to be an inappropriate measure for regulating the energy needs of buildings. Shortcomings of the building envelope can be compensated with renewable energy generation that is then wasted trough a poor envelope. The EPC/NEN 7120 procedure was merely proposed for rough official assessments. Nonetheless this approach was accepted by designers and clients as a valid base for their energy design and to indicate real energy efficiency. Also the minimal requirement of the EPC was seen as the highest target value. This way the EPC-approach unintentionally turned out to be misleading and evoking inappropriate building designs in the perspective of the transition towards a sustainable zero energy built environment.

Currently a new regulation following EPBD, called BENG, is under preparation. The norm NEN 7120 and a set of related norms wil be replaced by the NTA 8800. The EPC-requirements will be replaced by requirements for

- the energy needs for heating and cooling
- the result of non-renewable primary energy use minus the on-site renewable primary energy (equivalent to non renewable primary energy with 100% compensation calculated with time step one year)
- the renewable energy ratio.

EPC-requirements

The applicable EPC is not the same for every building but depends on the function of that building. Below we present the current EPC-requirements as stated in the “Bouwbesluit”. These requirements have been tightened several times, most recently on January 1st of 2015. presently no tightening is expected anymore, because these EPC-requirements will be replaced January 1st of 2020 with the BENG regulation.

Table 13 EPC- requirement (ratio of the result of the non-renewable primary energy use in a new building minus the on-site renewable primary energy generation - equivalent to non renewable primary energy with 100% compensation calculated with time step one year) and the non-renewable primary energy use in average Dutch reference homes of the same size in 1990).

Function	**EPC Index**
Function of meeting (e.g. restaurant, church)	1.1
Function of cell (e.g. prison)	1.0
Function of health care with bed area	1.8
Function of health care other than with bed area	0.8
Function of office	0.8
Function of accommodation in accommodation building (e.g. hotel)	1.0
Function of education	0.7
Function of sports	0.9
Function of shopping	1.7
Houses and buildings for housing	0.4

NEN 7120

Since 1st of July 2012 the determination method for making the EPC-calculation is NEN 7120 "Energy Performance of Buildings". This norm describes the method for schematizing the building, specifies the way the impact of installations in and for the building and the calculation of the energy use should be computed. For specific measures NEN 7120 refers to other sources, among which:

- NEN 1068 "Thermal insulation of buildings - calculation methods": to determine transmission losses of heated or cooled buildings
- NEN 8088-1 "Ventilation and airtightness of buildings": on the energy use in ventilation
- NEN 7125 "Energy Performance Norm on installations on the district level – method of determination" (Dutch abbreviation: EMG): to evaluate renewable energy generation systems in nearby perimeter and regulate the valuation in the energy performance indicator (EPC-index) of individual buildings.

Thermal insulation of buildings

Per January 2015 the following insulation requirements, prescribed by the Bouwbesluit, came into effect:

- Floor Rc: 3,5 (m2K)/W, this corresponds to the U-value 0,272 W/(m2K)
- Facade Rc: 4,5 (m2K)/W, this corresponds to the U-value 0,214 W/(m2K)
- Roof Rc: 6,0 (m2K)/W, this corresponds to the U-value 0,149 W/(m2K)
- Windows and doors U value: 2,2 W/(m2K)

Ventilation and airtightness of buildings

In addition to prescribed minimal insulation values of the building elements, certain standards must be met to control the seams between elements and to prevent the loss of climatised air. The legal requirements for airtightness of buildings are laid down for the Netherlands in the Bouwbesluit:

Section 5.1 Art. 5.4 Air volume flow, establishes a maximum air permeability of at most 0.2 m3/s at a pressure difference of 10 Pa (for building volume up to 500 m3), or a derivative there of.

Section 5.1. Art. 5.2 prescribes an energy performance coefficient determined in accordance with NEN 7120 / NTA 8800, which in turn can lead to a better air-tightness requirement. Here, the required air permeability is also linked to the ventilation system.

Art. 3.21 Prevention of moisture from the outside, establishes a specific air volume flow through the building envelope of no more than 20 · 10-6 $m^3/(m^2 \cdot s)$, determined in accordance with NEN 2690.

The following standards apply to the airtightness of new buildings and their determination, some are going to be/ are already included and established in the new standard NTA 8800:

NEN 7120 / NTA 8800 - Energy performance of buildings - Determination method

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NEN 8088 / NTA 8800 - Ventilation and air permeability of buildings
NEN 2686 - Air permeability of buildings - Measurement method
NEN 2687- Air permeability of homes - Requirements
NEN 2690 - Air permeability of buildings - Measurement method for the specific air volume flow between crawl space and house
NEN-EN-ISO 9972 - Thermal properties of buildings - Determination of air permeability of buildings - Overpressure method

In NEN 2687 air tightness requirements are associated with ventilation. Depending on this, 3 classes where defined with assigned specific qv;10-values: 1: basic, 2: good and 3: excellent. Ventilation systems A and C (see explanation below) require an air tightness of class 1, Ventilation system B and D require an air tightness of class 2. Class 3 is introduced for the qualification of passive building envelopes.
The requirements for qv;10 apply to buildings with a net air volume of 500 m3. If this air volume is greater than 500 m3, the measured qv;10; measured is converted to qv; 10.

Table 14 Maximal air flow other than through ventilation openings for buildings of various sizes both in total air displacement $q_{v;10}$ *and per useable area* ($q_{v;10}/m^2$).

Class	**Building volume From (m³)**	**……up to (m³)**	**Max. $q_{v;10}$ (dm³/s)**	**Max. $q_{v;10,spec}$ (dm³/(s*m²))**
1. Basic	0-	-250	100	1.0
	250-	-500	150	1.0
	500-	-up	200	1.0
2. Good	0-	-250	50	0.6
	250-	-up	80	0.4
3. Excellent	0-	-250	15	0.15
	250-	-up	30	0.15

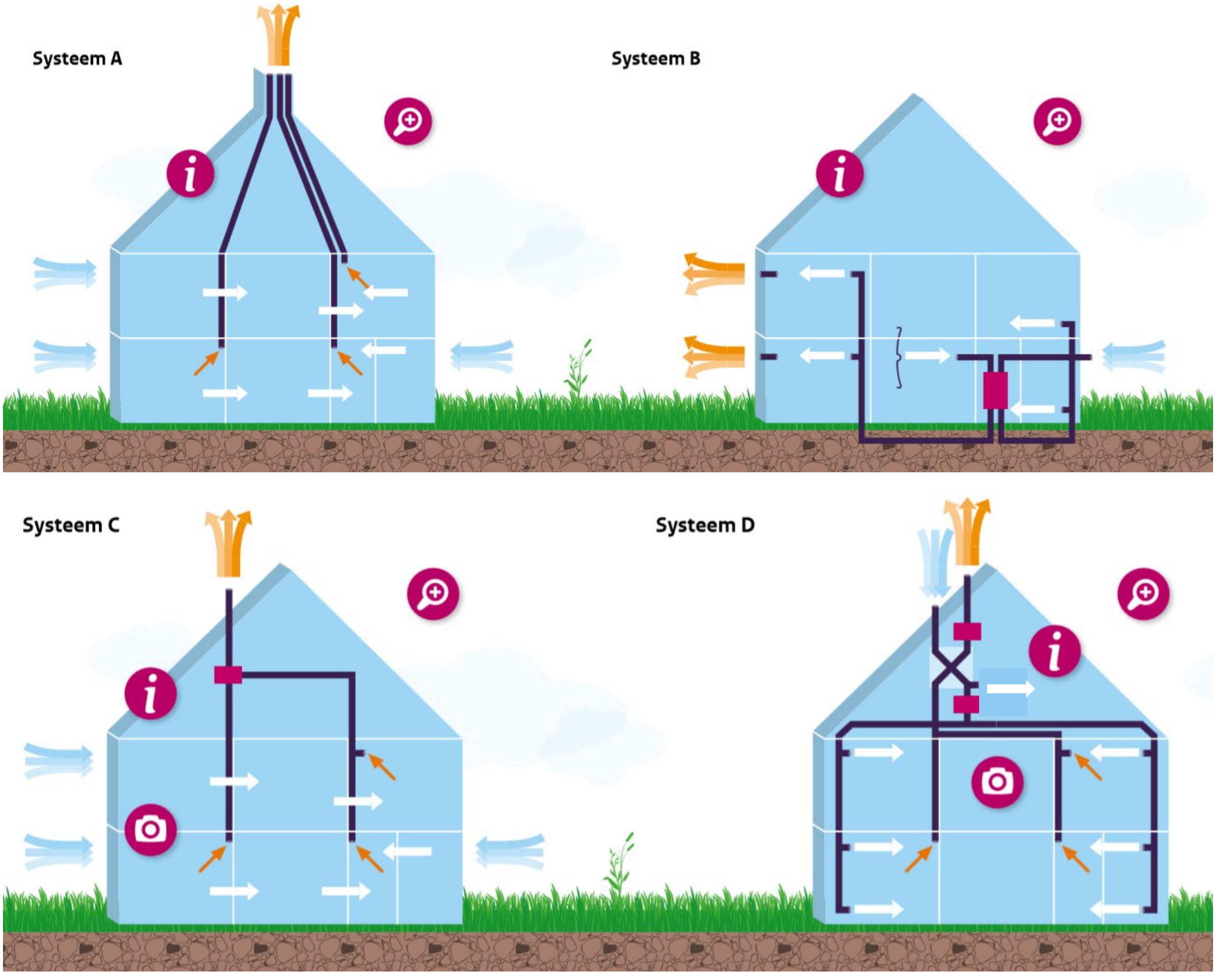
A qv;10,spec of 0,15 dm3/(s*m2) is comparable to an air tightness measure of n_{50}= 0,6 h-1 (Passive House Standard
While the above limits regarding unintended air flow apply to buildings in general, different upper bounds may apply to buildings of a particular kind. Here are the requirements regarding curtailment of air leakage per housing type:

Table 15 Maximal permissible air permeability by housing type.

	Housing type	**$q_{v;10,\ spec}$ (in dm³/(s*m²))**
a	intermediate row-house with slanted roof	0,7
b	end-of-row / half-of-duplex with slanted roof	0,84
c	detached with slanted roof	0,98
d	intermediate row-house with flat roof	0,49
e	end-of-row / half-of-duplex with flat roof	0,59
f	detached with flat roof	0,67
g	intermediate apartment (not directly under roof)	0,35
h	end apartment (not directly under roof)	0,46
i	corner apartment (not directly under roof)	0,49

Four types of ventilation systems are permitted in The Netherlands:

Figure 16 Types of ventilation systems in The Netherlands.



The systems B, C and D include an air fan (red block) and come with an electrical energy use. This energy use for ventilation and, of course, the ventilation heat losses, must be included in the calculation of total or non renewable primary energy use of the building.

Energy Performance Norm on installations on the district level

For energy delivery from sources nearby in June 2017 the norm NEN 7125 was published. However, this norm has not been integrated yet into the Bouwbesluit and therefore can not be used for EPC calculations. The provisional norm NVN 7125, is still applicable instead. The NVN 7125 is used for buildings that make use of energy delivery systems other than the standard electric grid or national gas pipelines. They receive heat, cooling and/or renewable electricity from a district system.

The NEN 7125 norm specifies the area within which external energy sources can be considered relevant to a particular building. The development of the building and that of the energy source must have some simultaneity and relationship. This must be apparent from, for example, contractual agreements. The area boundary of a heating or cooling system is determined, in practice, by the reach of these systems. Electricity from a shared facility must be sourced from within 10 km. For buildings that are linked to several systems at the same time (e.g. a hot water and a refrigeration network), more than one set of perimeters may apply.

Two-step EPC requirement

Whenever the NVN 7125 is called upon regarding a district system, the 'Bouwbesluit' poses an higher preliminary energy efficiency requirement (EPC-index) to the building itself. Computations for this first requirement exclude the district system and thus does not concern specifications from the NVN 7125. This requirement is to make sure that the planned buildings will be adequately energy-efficient, regardless of the operation of a district system. Without this extra step, residents of areas with district systems might be confronted with unexpectedly high energy bills. Probably the district systems are more energy efficient than the standard electrical grid or the national gas pipelines, so the particular equivalent energy generation factors are more lenient than the flat rates of NEN 7120. However, more lenient should not mean totally without bounds: the preliminary step of the requirements provides that new boundary.

Specifics of the first step:
Whenever the NVN 7125 is called upon regarding a district system, the 'Bouwbesluit' poses an additional preliminary primary energy efficiency requirement (EPC-index) to the building itself.
The additional preliminary requirement applies the standard EPC procedure but allows a flat 33% alleviation of the EPC-index. For example, designs for housing need not demonstrate that they meet the normal EPC requirement of 0.4, but only of 1.33 x 0.4 = 0.532. This first assessment does not take the efficiency of the district system into account and makes use of standard primary energy factors, given in NEN 7120.
The efficiency of the district system will be determined and set of at building level in the second step.

Specifics of the second step:
The second step of the procedure according to NEN 7125 is to specify the kind of energy that is sourced from the district system.
Therefore the NEN 7125 norm specifies how to compute the equivalent generation efficiency coefficient of district heating (external delivery of heat), circulation system for domestic hot water (external delivery of heat), of collective district cooling (external delivery of cooling) and of generation of electricity on district level (for example wind-energy or solar-energy). The equivalent generation efficiency coefficients express the total of all contributions and losses of energy in the specific district system, including the energy generation, distribution, up to the delivered energy at the meters. This equivalent generation efficiency coefficient is the reverse of the primary energy factor.
For the computation of district systems, NEN 7125 distinguishes the district systems to their functions, heating, domestic hot water, cooling etc. and allows an accurate approximation of the contribution of a system to a single building, e.g. the actual share of a collective electricity generation system, or the determination of specific losses by delivery of heat to a certain building site.
With this equivalent generation efficiency factor the effects of the nearby energy renewable production will be translated to the energy performance of the individual building and the final EPC-index including the use of renewable energy will be calculated. This final EPC-index has to meet the standard energy performance at building level (EPC-index ≤ 0.4).
Only the equivalent factors specified according to the NEN 7125 will be allowed to be used instead of the standard primary energy factors of NEN 7120 / from 2020: NTA 8800.
This regulation does not provide for a valuation of energy production other than at the building site and nearby. The future energy production of e.g. off shore windmill parks is calculated in the primary energy factor for the general grid.

The implementation of EPBD: nZEB translated into BENG

nZEB, which provides a definition of Nearly Zero Energy Buildings, is included in the EU directive EPBD. The Dutch NTA 8800 committee is transposing the EPBD into the BENG-standard. BENG is short for words in Dutch that are similar to those that make up nZEB: Bijna Energie Neutraal Gebouw. The regulation text is not yet completed, but a 90% version is being established in order to adjust the requirements. Therefore the BENG criteria are currently being tested on cost optimization. In November 2018 the results of the validation procedure and preliminary BENG regulation has been presented. Currently the consultation procedure is carried out.
The NTA 8800 has been set up for regulating both the energy efficiency of new and of existing buildings. According to the committee and despite of the first intentions to introduce a verifiable energy calculation, the NTA 8800 procedure is not provided for estimating the actual energy consumption of buildings. This was accepted in order to avoid too labour-intensive calculations and controlling procedures and also because of the assumption that the behaviour of residents/users will dominate the actual consumption. In general, the comparison with a poorly insulated building of the same size will be replaced by indicators for the energy consumption of the building as a whole.

BENG requirements (under consultation)

In the Netherlands, the energy performance of nearly energy neutral buildings will be determined at three indicators:

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- Indicator 1: A maximum regarding the building's annual global energy need relative to its usable floor area, including the energy needs for heating and cooling.
- Indicator 2: A maximum regarding the result of the subtraction of the non-renewable primary energy use per m2 of usable floor space per year in kWh/(m2a) minus the onsite generated renewable primary energy per m2 per year (equivalent to non renewable primary energy with 100% compensation calculated with time step one year). Energy use and energy generation on the building and the building site multiplied with PEF according to NTA 8800, energy delivered from renewable sources nearby is multiplied with equivalent factors calculated according to NEN 7125.
- Indicator 3: A minimum of the renewable primary energy ratio in %. The fraction of primary energy use that is obtained from renewable sources is determined by dividing the amount of renewable primary energy generated on site or nearby by the sum of the primary renewable energy and primary non renewable energy.

A list of updated primary energy factors and CO2-emission factors have been recently published in the preliminary norm NTA 8800, see table in the annex. The primary energy factors for electric energy, general grid as well as on-site generation, have been lowered from 2.56 to 1.45. Motivation for this remarkable reduction is the anticipation of planned construction of off-shore windmill parks.

Table 16 Recently updated primary energy factors; source: NTA 8800:2018.

Energy carrier (*ci*)	**Delivered energy from the grid** $f_{P;del;ci}$	**Delivered energy from on-site generation** $f_{P;pr;us;ci}$ [a]	**exported energy** $f_{P;exp;ci}$
Electricity (el)	1,45	1,45	1,45
Natural Gas (gas)	1	not applicable	not applicable
Heating Oil (oil)	1	not applicable	not applicable
Biomass (bm) for furnaces fired with solid biomass and boilers covered by the Activities Decree	0,0 [c]	not applicable	not applicable
Biomass (bm) for furnaces fired with solid biomass and boilers that meet minimal quality conditions and remain under maximal emission levels, as specified in appendix M of NTA 8800	0,5 [c]	not applicable	not applicable
Biomass (bm) for furnaces fired with solid biomass and boilers that do not satisfy the above criteria	1,0 [c]	not applicable	not applicable
External heat delivered for space heating (dh) for which a NEN 7125 quality declaration is provided	$f_{P;del;dh}$	not applicable	not applicable
External heat delivered for water heating (dw) for which a NEN 7125 quality declaration is provided	$f_{P;del;dw}$	not applicable	not applicable
External heat delivered for either space heating or warm tap water (dh, dw) for which no NEN 7125 quality declaration is provided	0,9	not applicable	not applicable
External cold delivered (dc) for which a NEN 7125 quality declaration is provided	$f_{P;del;dc}$	not applicable	not applicable
External cold delivered (dc) for which no NEN 7125 quality declaration is provided	$f_{P;del;el}$ / 3	not applicable	not applicable
Heat generated on site			See [b]
Cold generated on site			See [b]

[a] Heat produced from a renewable source on site (thermal solar energy) is subtracted from the energy to be delivered from non-renewable sources for space heating or hot water.

[b] Starting from the principle that on site generation of heat or cold follows the need for heating or cooling, the export of any heat or cold will be a rarity. For the sake of completeness, it is specified that in those cases the primary energy factor should be set equal to the inverse of the generation efficiency of the generator of the heat or cold multiplied by the primary energy factor of the energy carrier involved. This should neutralise any contribution to primary energy.

[c] Open devices and cooking appliances are excluded from the determination procedures for NTA 8800, i.e. they are not taken to make any contribution to space heating or warm water.

Feasible levels for 2019/2020

The Dutch government commissioned a study of the cost optimum of energy related measures in a series of Dutch reference buildings. This study was executed by two Dutch engineering firms. Based on this study new BENG-indicators were proposed. These indicators are significantly more lenient than the first proposal of BENG-requirements. The energy-efficiency-levels proposed by the Dutch government do not correspond to the EPBD-definitions of nearly zero energy buildings. Various comments on this study conclude that the cost optimisation study fails to match very well insulated buildings as the optimum for the total cost of ownership over 30 year periods. The latest proposal is regarded a drawback allowing even less energy efficient buildings than was already required in 2015 with EPC 0.4.

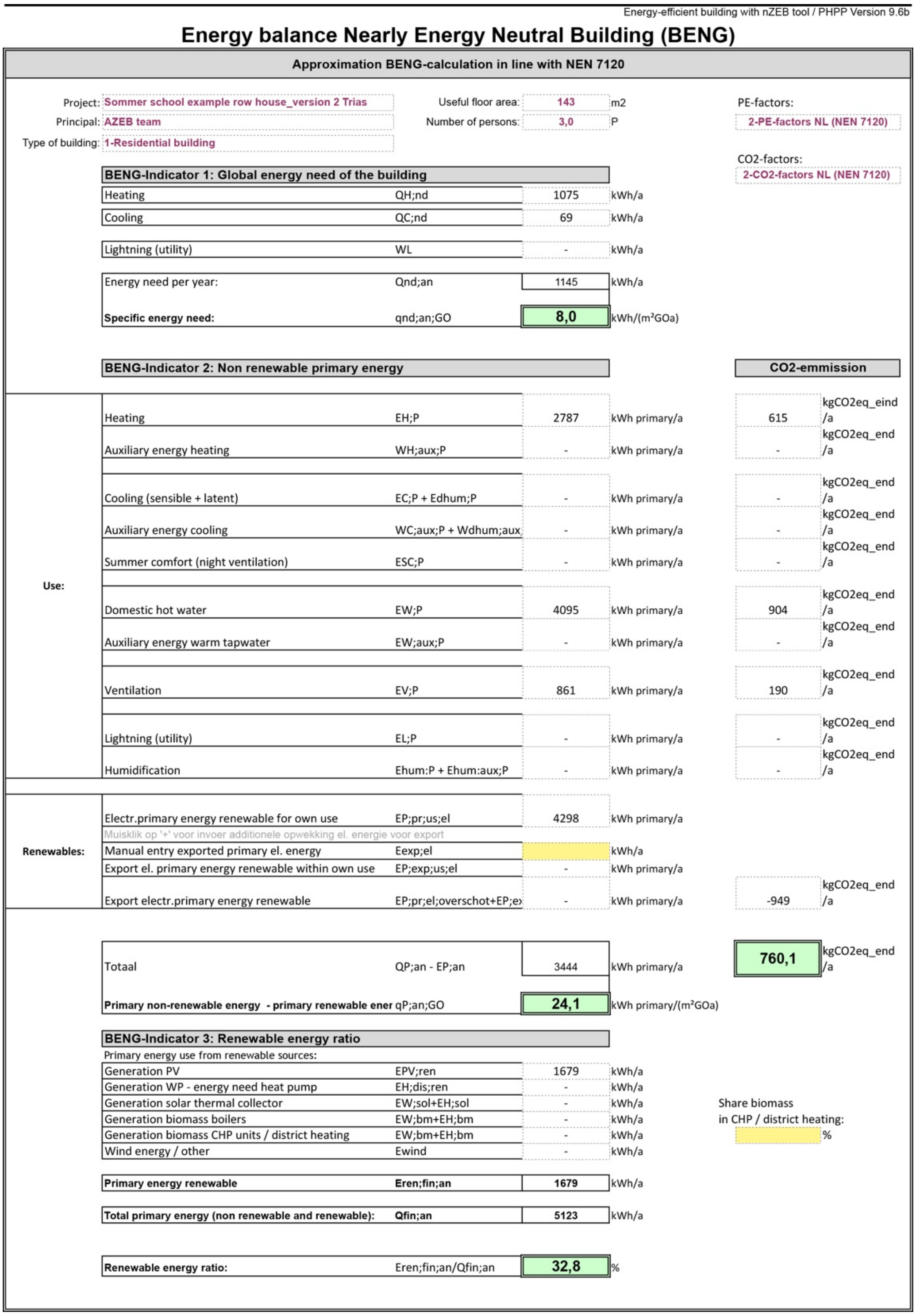
Table 17 Preliminary proposed levels of energy requirements for Dutch buildings for various uses, parenthetical original values from 2015.

Indicator: **Building function:**	**1- Global energy need (GEN, sum of energy need for heating and for cooling) [kWh/m²y]**	**2- non-renewable primary energy use [kWh/m²y]**	**3- Renewable primary energy ratio [%]**
Residential buildings	A_{ls}/A_g(1) ≤ 2,2 -> GEN<= 70 A_{ls}/A_g > 2,2 -> GEN<= 70 + 50 * (A_{ls}/A_g -2,2) [25]	50 [25]	40 [50]
Office buildings	A_{ls}/A_g ≤ 2,2 -> GEN<= 90 A_{ls}/A_g > 2,2 -> GEN<= 90 + 50 * (A_{ls}/A_g -2,2) [50]	50 [25]	30 [50]
Buildings for education	A_{ls}/A_g ≤ 2,2 -> GEN<= 180 A_{ls}/A_g > 2,2 -> GEN<= 180 + 50 * (A_{ls}/A_g -2,2) [50]	80 [60]	40 [50]
Buildings for health services with bed	350 [65]	150 [120]	30 [50]

1) A_{ls}/A_g describes the compactness of the building (surface of the building envelope divided by the useful floor area)

The BENG requirements as presented in the nZEB tool

Figure 17 An example of a provisional Dutch worksheet intended to assist in coping with the BENG parameters.



Energy-efficient building with nZEB tool / PHPP Version 9.6b

Energy balance Nearly Energy Neutral Building (BENG)

Approximation BENG-calculation in line with NEN 7120

Project:	Sommer school example row house_version 2 Trias	Useful floor area:	143	m2	PE-factors:
Principal:	AZEB team	Number of persons:	3,0	P	2-PE-factors NL (NEN 7120)
Type of building:	1-Residential building				
					CO2-factors:
					2-CO2-factors NL (NEN 7120)

BENG-Indicator 1: Global energy need of the building

Heating	QH;nd	1075	kWh/a
Cooling	QC;nd	69	kWh/a
Lightning (utility)	WL	-	kWh/a
Energy need per year:	Qnd;an	1145	kWh/a
Specific energy need:	qnd;an;GO	**8,0**	kWh/(m²GOa)

BENG-Indicator 2: Non renewable primary energy — **CO2-emmission**

Use:	Heating	EH;P	2787	kWh primary/a	615	kgCO2eq_eind /a
	Auxiliary energy heating	WH;aux;P	-	kWh primary/a	-	kgCO2eq_end /a
	Cooling (sensible + latent)	EC;P + Edhum;P	-	kWh primary/a	-	kgCO2eq_end /a
	Auxiliary energy cooling	WC;aux;P + Wdhum;aux	-	kWh primary/a	-	kgCO2eq_end /a
	Summer comfort (night ventilation)	ESC;P	-	kWh primary/a	-	kgCO2eq_end /a
	Domestic hot water	EW;P	4095	kWh primary/a	904	kgCO2eq_end /a
	Auxiliary energy warm tapwater	EW;aux;P	-	kWh primary/a	-	kgCO2eq_end /a
	Ventilation	EV;P	861	kWh primary/a	190	kgCO2eq_end /a
	Lightning (utility)	EL;P	-	kWh primary/a	-	kgCO2eq_end /a
	Humidification	Ehum:P + Ehum:aux;P	-	kWh primary/a	-	kgCO2eq_end /a
Renewables:	Electr.primary energy renewable for own use	EP;pr;us;el	4298	kWh primary/a		
	Muisklik op '+' voor invoer additionele opwekking el. energie voor export					
	Manual entry exported primary el. energy	Eexp;el		kWh/a		
	Export el. primary energy renewable within own use	EP;exp;us;el	-	kWh primary/a		
	Export electr.primary energy renewable	EP;pr;el;overschot+EP;ex	-	kWh primary/a	-949	kgCO2eq_end /a
	Totaal	QP;an - EP;an	3444	kWh primary/a	**760,1**	kgCO2eq_end /a
	Primary non-renewable energy - primary renewable ener	qP;an;GO	**24,1**	kWh primary/(m²GOa)		

BENG-Indicator 3: Renewable energy ratio

Primary energy use from renewable sources:

Generation PV	EPV;ren	1679	kWh/a
Generation WP - energy need heat pump	EH;dis;ren	-	kWh/a
Generation solar thermal collector	EW;sol+EH;sol	-	kWh/a
Generation biomass boilers	EW;bm+EH;bm	-	kWh/a
Generation biomass CHP units / district heating	EW;bm+EH;bm	-	kWh/a
Wind energy / other	Ewind	-	kWh/a
Primary energy renewable	**Eren;fin;an**	**1679**	kWh/a
Total primary energy (non renewable and renewable):	**Qfin;an**	**5123**	kWh/a
Renewable energy ratio:	Eren;fin;an/Qfin;an	**32,8**	%

Share biomass
in CHP / district heating:
%

The figure above is a *provisional* worksheet in the PHPP developed in the Netherlands to assist in coping with the BENG-indicators described above. The example concerns an energy efficient building. The PE-factors have been altered since, also the calculations of the indicators significantly changed.

Comments and potential improvements

Recently the Dutch environmental planning bureau had to conclude that the Netherlands will not meet its climate targets for 2020. In order to make the country independent of fossil fuels by 2050 it is essential to reduce energy consumption in the built environment. The preliminary proposals for the BENG energy standards for new construction provides too little guidance to the construction sector. While there are many smaller procedural and substantive remarks that could be made about the analysis underlying the BENG-proposal, we will discuss below the most principled issues regarding an effective energy transition policy.

The BENG-1 indicator (global energy need = sum of energy need for heating and energy need for cooling) as currently proposed does not provide a realistic view of the energy need that is to be expected for heating and cooling. This is due to the prescribed heat loss in ventilation based on a fixed system of open vents and high ventilation rate and several other parameters. Requirements are eased for buildings with an unfavourable ratio of Als/Ag, the shell surface to usable floor surface (e.g. small ones or buildings with exposed parts).

The BENG-2 indicator (non renewable primary energy with 100% compensation calculated with time step one year) mingles the non renewable energy flows with the onsite or nearby primary energy production without accounting for the actual usefulness of it in order to avoid the consumption of non renewable energy.

Main consequences are:

- the stimulation of the use of the energy grid as an inter-seasonal energy storage which generates technical conflicts (capacity, storage etc.) and moves on environmental problems that should be solved by reducing the energy need through a proper building envelope in the first place.
- The assessment of very low energy buildings does not support adequate measurements in the thermal envelope. The regulation permits buildings with unnecessarily high energy demand and - costs and also comfort issues (thermal discomfort through sub-optimal insulation, dry air due to very high ventilation rates etc.).
- Verification of the BENG-indicators on the realised building is practically not feasible. This extends the poor tradition of the Dutch EPG, which also could not be checked, was not tested and often was not achieved. Worse yet, the BENG-1 indicator sets a limit that, in many cases, is far too lenient. This ratifies an energy performance that can condone construction defects and low quality implementation.
- The proposed BENG standards provide an improper leeway for designs that are not compact. This fosters an architecture that is disadvantageous to energy transition and furthers unfair energy needs.

The following adjustments of the BENG-assessment should be made:

BENG-1 indicator:

Should support and require (very) low energy solutions as long this leads to (equal) low costs of ownership, in accordance with Article 2.1 of the EPBD.

Should allow assessment with realistic energy losses by ventilation through the input of precise ventilation rates and heat recovering.

Should require compact buildings (differentiate between permits for new buildings and renovations).

Should take shadow effects outside the building site into account. As access to solar radiation is extremely effective in reducing energy need in winter this regulation should encourage energy conscious design already on the urban design level.

BENG-2 indicator:

Should stimulate a low energy demand in periods there is less renewable energy production. This can be done by differentiating the direct consumption of onsite or nearby generated renewable energy on an appropriate time step, thus hourly, daily or monthly based with accurate adjusting factors accounting for the real coverage. This should be complemented by a differentiated system of primary energy factors (e.g. monthly or seasonal factors).

In addition BENG-calculations should provide information about peak demand and estimates on energy use during wintergaps (periods of four days without wind at times of clouded cold weather) for an realistic estimation of the future energy demand of neighbourhoods to be delivered by energy suppliers and adequate dimensioning of public short term storage. The emphasis on energy when it comes to nearly energy neutral buildings can go hand in hand with high quality thermal comfort and a healthy indoor climate. The proposed norms do not appear to provide adequate standards in this regard. The government should call for the integral approach to energy, comfort and health by anchoring this in the official Dutch building code. For example adjusted fRsi-factors should be prescribed in the relation to the insulation quality in order to avoid condensation and fungus, and ventilation specifications should properly match the level of airtightness. Dutch regulations already made a first step in this direction but failed to meet the state of the art for highly energy efficient buildings.

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2.5.8 Conclusions on status of implementation

Some regulations are still under discussion but we can summarise the present situation in the analysed countries and some trends as follows:

- the considered building services include generally heating, cooling and hot water supply. In some cases, lighting, mechanical ventilation and auxiliaries (e.g. pumps), transport within the building, are also accounted for;
- a minimum performance level is required for the envelope in part of the countries, using the indicator energy needs for heating and cooling. In others there are minimum requirements on the physical properties of some of the building elements, but not always addressing both the winter and the summer behaviour.
- In all six countries, building regulations addresses one or more indicator of primary energy use, whether total or non renewable, expressed in kWh/(m2 y);
    - a minimum requirement for the share of renewable energy is imposed in two countries. Life cycle assessment indicators are considered in one country;
    - the minimum requirement values of the indicators are generally determined according to a techno-economic study involving many stakeholders.

Based on:

- the above analysis of the national situations,
- the recent (2017 and 2018) approval by all technical committees of MS of the revised EN ISO Standards,
- the analysis of building labels,
- our direct experience of the building construction chain,

we can derive here a few lessons and propose our recommendations in the next chapter.

It is very important that all the actors involved in development of nZEB in the field, regulators and policymakers, all use consistently the same set of physical concepts, definitions and nomenclature. This will not hinder the possibility of each MS to choose minimum requirements adapted to local climate and conditions, but it will be a prerequisite for devising clear design and construction guidelines allowing to obtain good energy and comfort performance at reduced cost. It will allow easier, more effective communication and transfer of lessons learned within a country and across countries. Importantly, it will also reduce the costs involved in communication difficulties and misunderstandings, which are often leading to design and construction errors and subsequent costly remediation work.

The fact that the indicator energy needs for heating and cooling, which existed in previous regulations, might be suppressed in two countries, seems contrary to achieving a complete description of the building energy performance and might constitute an obstacle to the achievement of good levels of comfort, which are strongly influenced by the quality of the thermal envelope.

The use of the reference building procedure (in some of the considered countries) introduces a series of shortcomings:

- in the design phase it removes the signal to optimize building shape and orientation
- in the design phase it highly attenuates the signal to optimize the window/wall ratio
- in the real estate market it makes very difficult to compare a building to another since there is no absolute threshold; the comparison on which the energy label is awarded is against the peculiar reference building model of the considered building rather than against all the other buildings.

A choice of calculating the *non renewable primary energy* use with *no compensation* as e.g. in Italy (the excess on-site renewable generation in one month - produced on site and exported - cannot be used to compensate for non renewable energy taken from the grid in another month), has the advantage of:

- focusing on the success of the building per se in fulfilling the definition of nZEB of EPBD art.2
- avoiding incentives to use the energy grid as an inter-seasonal energy storage, which would transfer cost from the building to the grid and generate new environmental pressure (e.g. for construction of large storage facilities)
- avoid a potential double counting of RES

On the other side the use of renewable energy generated in large facilities distant from the building/city has the disadvantage of requiring large land use of otherwise agricultural or wild areas, and to produce landscape modifications, which in turn have impact on wildlife. Examples of problems and opposition of local communities and Regional Governments to large scale renewable plants are reported e.g. in the South of France, in Sardinia, in Sicily.

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Indicators based on CO2 are also present and the way they are designed has profound impact; for example, an indicator of life cycle CO2 emissions of materials (but excluding operation and exported energy) is under consideration in France. This indicator imposes a maximum CO2 emissions threshold regarding the life cycle of building materials, i.e. accounting for the fabrication, maintenance and end of life but not the operation. This is very unfavourable to renewable energy systems, and particularly photovoltaics because a large amount of CO2 is emitted during the fabrication of PV modules, and the indicator does not account for avoided impacts related to the corresponding renewable electricity production. Another barrier against renewable production is the partial compensation for exported electricity, and partial accounting of avoided impacts by recycling the modules at the end of life. The consequence of such unfavourable calculation is that very little PV is integrated in buildings. In order to achieve the French energy transition objectives, PV is installed on the ground, e.g. a large forest territory is cut down in the South-West of the country to build a PV power plant. Using the roofs and facades would be more sustainable than destroying forest or agricultural lands.

Based on the above discussion of the Italian and French case, it would therefore be interesting to compare different methods to account for compensation for exported energy when calculating the non renewable primary energy use.

The general objective should be in any case that the Indicators should be complete enough to guide the market in the direction stated by EPBD art 2, e.g. a low energy use, covered to a large extent by renewable energy.

The methodology to reduce costs, studied in AZEB, can contribute in progressing towards more ambitious thresholds while at the same time addressing cost barriers.

2.6 Recommendations in the AZEB project on nZEB indicators

According to the European Directive on Energy Performance of Buildings, a ‘ ‘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’.

In the AZEB project, a set of indicators corresponding to the above definition is proposed following EN-ISO standards and the analysis of national regulations, labels and tools presented in previous paragraphs.

These indicators address: the quality of the *building fabric*, the efficiency of active *technical* *building systems* and the use of renewable energy sources. It is also proposed to consider alternative *total primary energy factors* corresponding to a 100% renewable scenario.

The performance of the thermal envelope can be evaluated on the basis of the comfort model (PMV or adaptive) and comfort category chosen as objective of the design, the energy needs for heating and cooling (or summer comfort in free-floating conditions if there is no active cooling), and the energy needs for hot water. Energy use for ventilation and energy use for lighting (by electric lighting systems), day-lighting/visual comfort may also be addressed for some building types (e.g. schools, offices).

The performance of technical building systems (e.g. their efficiency in covering the energy needs starting from non renewable or renewable sources) can be evaluated using the total primary energy use.

Total / renewable / non renewable primary energy is calculated by multiplying each stream of delivered energy for the respective total / renewable / non renewable primary energy factors

The non renewable primary energy use accounts for the part of total primary energy not yet covered by renewable sources (either generated on site or nearby or distant).

Non renewable primary energy use can be additionally calculated with or without compensation between energy carriers and with or without compensations for renewable energy exported to the grid.

The primary energy factors used in the calculation of primary energy should be always explicitly reported, indicating the renewable and non renewable part (see Table 1 as an example). In case there is a choice to adopt compensation for exported energy when calculating non-renewable primary energy, the factors for renewable energy delivered TO the assessment boundary of the building or exported FROM the assessment boundary to the grid should also be reported. The latter two factors may be symmetrical (identical) or asymmetrical (different).

The renewable energy generation on site can be expressed as a primary energy production. In order to evaluate to which extent the energy required is covered by renewable sources, the ratio of renewable primary energy over the total primary energy use is proposed as an indicator.

Questionnaires have been filled by the partners in order to describe which indicators are used in their national regulation, and to identify indicators that can be used in the AZEB case studies. These questionnaires are included in the annex of this report.

Our recommendation is to use a complete set of indicators for describing nZEBs and we propose the following set (in line with EN ISO standards, in particular EN ISO 52000) both for policymaking and for design practice:

- *Energy needs for heating, cooling* and *hot water* and *energy use* for *ventilation* and li*ghting*
- *Total primary energy* use
- *Renewable primary energy* use/*total primary energy* use (which is equivalent to indicating the *non renewable primary energy* use defined in EN ISO
- Indicate explicitly in a table the assumed values of PEF_{total}, PEF_{nonren}, PEF_{ren} (the latter separately for import to or export from the building if they are different).
- Calculate *total and renewable primary energy* in 3 ways: i) without compensation for exported energy, ii) with PEFs corresponding to the PassivHaus method, iii) with 100% compensation (k_{exp} =1)
- Set the National minimum requirements on the value of indicators in absolute terms and not as relative to a reference building
- Use the same indicators in the definition of nZEB and in the general Energy Performance Certificate
- The *building services* considered should be at least heating, cooling, ventilation, hot water and lighting as stated in EPBD.

We will test the above indicators in the evaluation of our case studies

2.7 Literature on energy indicators and legislation

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3 Life cycle costing

3.1 Cost indicator structure

In order to be able to systematically reduce costs and decide on strategies for creating an AZEB, we propose a general cost indicator structure, which closely relates to the execution phases of a construction project. We recognise 5 main phases of the life cycle of a building, which we will use as a framework – Initiative Phase, Design Phase, Construction Phase, Exploitation Phase and End-of-life Phase.

The main challenge when discussing construction projects in general is the lack of comparability between them – the projects may differ massively in size, complexity, quality and design. Furthermore, they strongly depend on local conditions – price for land acquisition, labor costs, et cetera. Our challenge when it comes to comparing costs in the case studies of the AZEB project, but also in general within the building sector, is to organize our costing process and reports in a way that comparison is possible.

3.2 Setting explicit parameters for comparable and reliable cost estimates and calculations in each AZEB project phase

During a project costing practices move from rough estimates in the intial phase through to actual calculating in the final phases. Of course the reliability of the costing practices increases during the project. Early estimates, necessary to initiate projects and create funding, are normally based on studies of reference projects and may be quite reliable. One of the problems of the nZEB projects with costing in this phase, is that there are relatively little reference projects to base the estimates on and even less references that have succeeded in creating AZEB instead of just nZEB. When starting an AZEB project in this time and age, it is important to be aware of this and find suitable work-arounds to this problem until there will be enough references (hopefully the AZEB project will provide some in WP3). In other words, if one wishes to make sound decisions in an AZEB project, one should pay good attention to the costing practices right from the start.

During the first phase of the AZEB project, some case studies have been performed to aid the project team in identifying the main reasons for the extra costs of nZEBs. One of the findings was that cost engineering experts are involved in projects often much too late: by the time they start estimating costs many funds and much time has been "burned" already in the design process and adapting the design is relatively expensive in that stage and imposes a risk on the time-targets of the project.

Also, cost engineers often receive incomplete or even incorrect information on which to base their estimates or calculations, which increases the project risks concerning the budget. Costing appears not to be an integrated part of the project process, but rather a thermometer that is put in sometimes. The costing expert therefore has only limited knowledge of the project (or there is no costing expert and another expert tries to fill in the gap) and lacks opportunities to help optimize the design for cost.

Finally, there is often a "language issue" when it comes to costs: different people use different definitions of objects and the costs associated with it. For example: one party includes mounting a window in the costs of a window whereas someone else leaves this labour factor out and puts it in another part of the budget. This regularly causes unclarity, omissions or doublures, false expectations and unpleasant surprises in the project relating to costs.

In addition to fully involving the costing expert in the project team from the start of a project, standardization of the costing process in all stages of the project is another important solution to these issues.This means that the project team creates clarity on at least:

- the level, depth and reliability in which costs are calculated for the relevant decision moments in the lifecycle of the project
- the definition of each costing parameter used

- the relationships between the different costing parameters (when you change one, which others are impacted?)
- the (preferrably digital) costing tool used by all project team members/ participating organisations
- when references are used for estimates: clarity on the features and costing practices of these references

For the definition of costing parameters it is advised to adopt the use of a specific standard in your project. This may be integrated with for example BIM tooling and highly increase the reliability and traceability and comparability of the costing practices. In addition this kind of standardization, combined with good tooling, offers more opportunities for creating AZEBs. During the contracting phases for example it increases comparability of different quotations and when used in design optimization processes it facilitates real time insights in the effects of design decisions and therefore improves decision making and value creation.

Internationally, three important standards may be used for this purpose:

- EN 16627:2105 Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods
- ISO 9836:2017(E) – Performance standards in building – Definition and calculation of area and space indicators
- ICMS- International Construction Measurement Standards

Research has found that area measurement practices in the building sector vary substantially across local and global markets. Even commonly used descriptions for example for Floor Area, like Gross External Area (GEA), Gross Internal Area (GIA) and Net Internal Area (NIA), are being used inconsistenly in markets across the world. When applying a commonly used ratio to compare costs, such as €/m^2, this inconsistency in measurements then of course leads to uncomparable cost accounting.

Another factor that leads to uncomparability is that costs are classified, analysed, measured and reported very inconsistently, between projects and even within projects. Within the AZEB project we would like to use the ratio of €/m^2 to analyze the effects of applying the AZEB methodology on project costs. However, we want to do this with as much standardization as is possible, so results within the project, across projects and across countries may be compared. In the paragraphs that follow we do four propositions for area measurement and costing practices to use in the case studies of the AZEB project.

3.2.1 Proposition 1: Using ISO 9836:2017(E) for standardizing the area measurements.

This standard is explained in detail in the above paragraph 3.2.

3.2.2 Proposition 2: Using EN 16627:2015 to standardize the main lifecycle cost categories

A-ZEB's main purpose is *"to achieve significant construction and lifecycle cost reductions of new nZEBs through integral process optimization in all construction phases".* Life cycle costing has already been defined in AZEB report 1.1, section 2.2: *"The Life Cycle Cost Analysis is the assessment of all costs (direct and indirect, variable and fixed) associated to a product/service from the conception of the idea to the end of its useful life (...)*; *"The analysis of life cycle costs can be defined as the sum of all life cycle costs that are attributable to a product or service".*

As explained there, and according to, cost categories are classified in: initial costs, production costs, construction and installation costs, use stage costs, end of life costs.

For our AZEB cost indicator structure, we follow this main categorization from EN 16627:2105 as shown in the next table:

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Table 18 : Cost indicator structure (from EN 16627:2105).

	A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
LIFE CYCLE PHASES (EN 16627:2015)		Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction-demolition	Transport	Waste processing	Disposal	Benefits and loads beyond the system boundary
COST CATEGORIES (EN 16627:2015)	**INITIAL COSTS**	**PRODUCTION COSTS**			**CONSTRUCTION & INSTALLATION COSTS**		**USE & MAINTENANCE COSTS**							**END OF LIFE COSTS**				
	Site costs. Costs include purchase or rental costs. (A0)	Product Stage: Aggregated cost of products supplied at factory gate ready for construction (A1-A3)			Transport to site: Costs incurred between factory and site (A4)	Construction: fesibility, planning, design and construction, commissioning and handover. Initial adaptation or fit out of asset. Landscaping (A5)	Operation and Maintenance : Building-related facility management costs, Building-related insurance costs, Leases and Rentals payable to third parties, Cyclical regulatory costs, Taxes, Subsidies and incentives,Third party income during operation, Other economic aspects, Cleaning, Grounds maintenance, Redecoration, Taxes, Disposal Inspections at end of lease period, End of lease. (B2)		Repairs and replacement of minor components/small areas (B3)	Revenue from sale of asset or elements, but not part of a final disposal. Replacement of major systems and components (B4)	Refurbishment (B5)	Energy costs (B6)	Water related costs (B7)	Deconstruction/ Dismantling, Demolition (C1)	All transport costs associated with the process of deconstruction and disposal of the built asset (C2)	Waste processing for re-use, recovery and or recycling (C3)		Recycling (D)
	Professional fee (when not included in construction costs) (A0-A5)													Fees &Taxes (C1-C4)				
		Taxes and other costs related to permission to build (A1-A5)																
		Subsidies and incentives (A1-A5)																
A-ZEB PROJECT PHASES	**INITIATIVE PHASE**				**INITIATIVE PHASE, DESIGN & CONSTRUCTION PHASE**		**USE & MAINTENANCE PHASE**							**DISMANTLING PHASE**				

Costs may be viewed from different viewpoints: owner, user, investor, builder et cetera. In the AZEB project we will focus on the perspective of "owner", assuming that the owner is the party with most direct benefit from a lifecycle cost approach.

The cost approach of *PM book guide (Project Management Institute*[4]*)* adopts this point of view:

- *The "life cycle" of costs and benefits from initial planning through operation and disposal of a facility are relevant to decision making. An owner is concerned with a project from the cradle to the grave. Construction costs represent only one portion of the overall life cycle costs.*
- *Optimizing performance at one stage of the process may not be beneficial overall if additional costs or delays occur elsewhere. For example, saving money on the design process will be a false economy if the result is excess construction costs.*
- *Fragmentation of project management among different specialists may be necessary, but good communication and coordination among the participants is essential to accomplish the overall goals of the project. New information technologies can be instrumental in this process, especially the Internet and specialized Extranets.*
- *Productivity improvements are always of importance and value. As a result, introducing new materials and automated construction processes is always desirable as long as they are less expensive and are consistent with desired performance.*
- *Quality of work and performance are critically important to the success of a project since it is the owner who will have to live with the results.*

The costs of a constructed building to the owner include at least both the Capital Cost (initial costs + production costs + construction and installation costs), and the subsequent Operation and Maintenance costs. Each of these major cost categories consists of a number of cost components, but only some of them can be influenced and reduced. To outline first signs of cost reduction potential, we will use three groups – non-existant, small and large cost reduction potential – and will assign each cost component to one of these groups.

The *Capital Cost* for a construction project includes the expenses related to the inital establishment of the facility:

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[4] Preface. https://www.cmu.edu/cee/projects/PMbook/

- Land acquisition, including land obtaining , holding and improvement – non existant cost reduction potential
- Planning and feasibility studies – small cost reduction potential
- Architectural and engineering design – small cost reduction potential
- Construction, including materials, equipment and labor – large cost reduction potential
- Field supervision of construction – small cost reduction potential
- Construction financing – small cost reduction potential
- Insurance and taxes during construction – small cost reduction potential
- Owner's general office overhead – small cost reduction potential
- Equipment and furnishings not included in construction – small cost reduction potential
- Inspection and testing – small cost reduction potential

These capital costs can also be classified in “Soft costs” and “Hard costs”. “Soft costs” relate to items or services that do not form part of the finished building, but that are necessary components of the development process, and they are usually associated with several kinds of payments and fees: architectural and design fees, inspection fees and permits, legal and valuation fees, environmental certification fees, loan-generated interest, accounting fees, insurance taxes, marketing and project management costs. “Hard costs” relate to tangible items that need to be procured to complete the building: for example cost of acquiring the site, the building structure, finishes, materials and landscaping. In general, we can say that the *design (soft cost)* has a great influence on the *material construction of a building (hard costs)*; and also on the *operation and maintenance cost*s (see below). Then, we can conclude that an increase in *soft costs* (spending more time and budget on the design) can reduce *hard costs* and operation and maintenance costs. As the largest potential for cost reduction in buildings is generally found in hard capital costs as well as in operation and maintenance costs, this may be a good trade-off.

The *Operation and Maintenance Cost* in subsequent years over the project life cycle includes the following expenses:

- Land rent, if applicable – non-existant cost reduction potential
- Operating staff – small cost reduction potential
- Labor and material for maintenance and repairs –large cost reduction potential
- Periodic renovations – small cost reduction potential
- Insurance and taxes – small cost reduction potential
- Financing costs – small cost reduction potential
- Utilities – small cost reduction potential
- Owner's other expenses – small cost reduction potential

Operation and maintenance costs are often more difficult to estimate than other building expenditures. Operating schedules and standards of maintenance vary from building to building; there is great variation in these costs even for buildings of the same type and age. Since these costs only receive recent attention in the building sector, there are limited tools available for good estimations and calculations. It is therefore especially important to use engineering judgment when estimating these costs. Within the AZEB case studies we will follow the cost categories specified in the framework of EN 16627:2105 and use engineering judgment to make good estimates.

3.2.3 Proposition 3: Using ICMS to standardize the capital costs and integrate resulting figures in EN 16627:2105 framework

ICMS basically provides a template with a clear hierarchy of cost categories, so costs can be compared, even internationally. Its aim is to provide global consistency in classifying, defining, measuring and presenting entire construction costs at a project, regional, state, national or international level. ICMS is a cost classification system. The standard offers a 4-level hierarchical framework against which costs can be classified, measured, recorded, analysed and presented:

Level 1 = Project or Sub-project
Level 2 = Cost Category
Level 3 = Cost Group
Level 4 = Cost Sub-group

The latest version of the ICMS standard may be downloaded from the following link: https://icms-coalition.org/the-standard/

Figure *18 Overview of the ICMS hierarchical framework for building costs.*

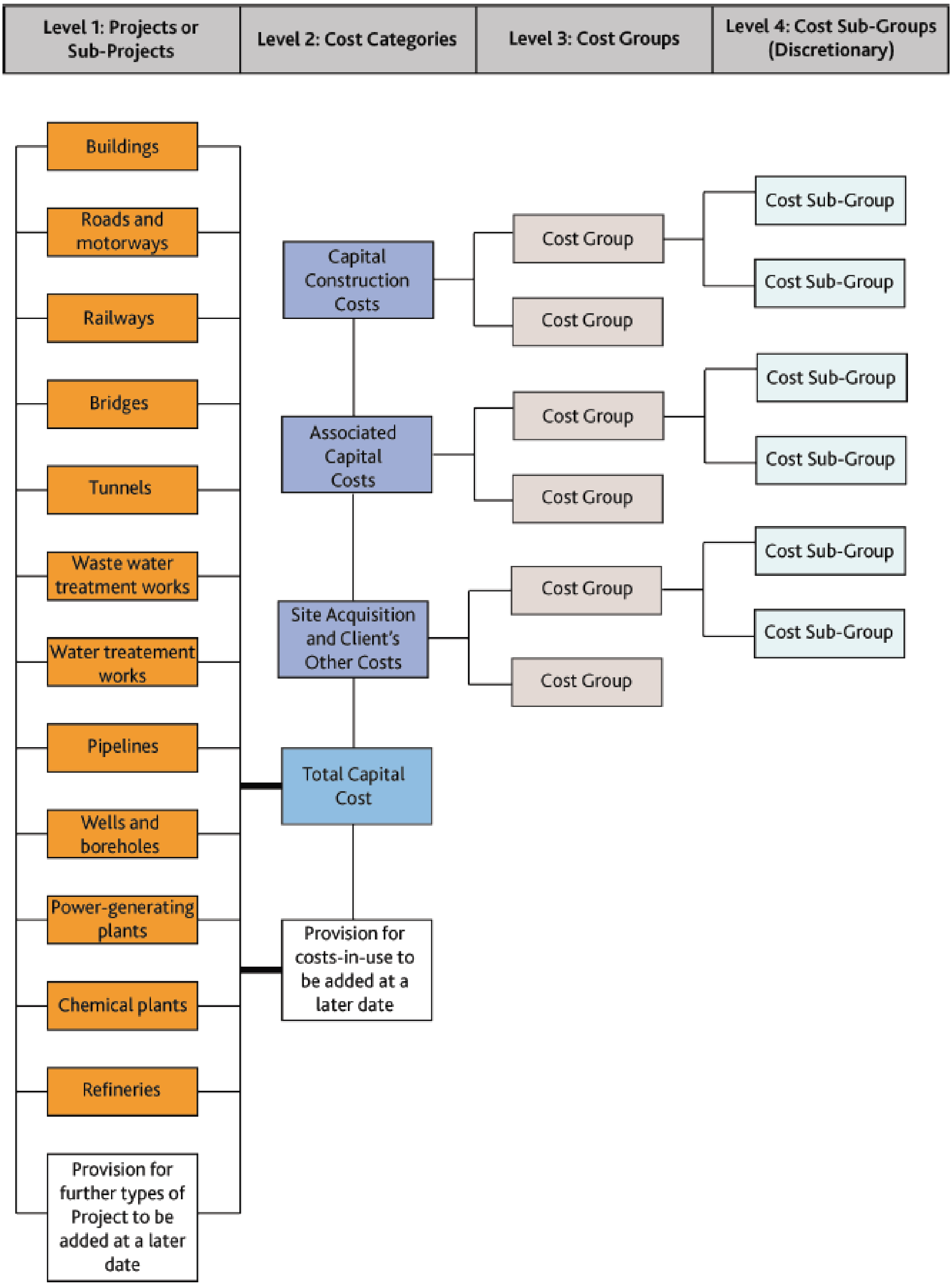
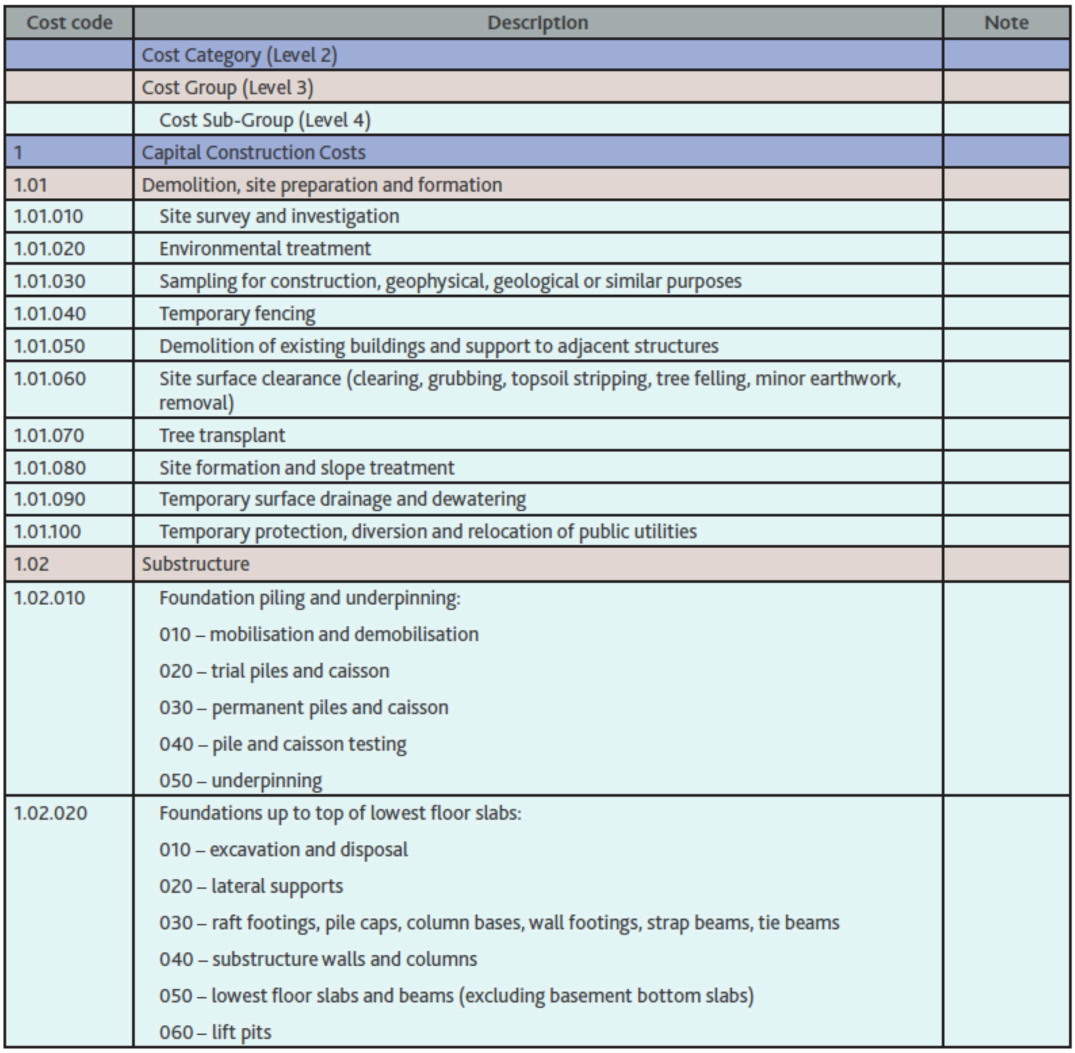


Table 19 Fragment of the ICMS cost breakdown structure for a building.



Cost code	Description	Note
	Cost Category (Level 2)	
	Cost Group (Level 3)	
	Cost Sub-Group (Level 4)	
1	Capital Construction Costs	
1.01	Demolition, site preparation and formation	
1.01.010	Site survey and investigation	
1.01.020	Environmental treatment	
1.01.030	Sampling for construction, geophysical, geological or similar purposes	
1.01.040	Temporary fencing	
1.01.050	Demolition of existing buildings and support to adjacent structures	
1.01.060	Site surface clearance (clearing, grubbing, topsoil stripping, tree felling, minor earthwork, removal)	
1.01.070	Tree transplant	
1.01.080	Site formation and slope treatment	
1.01.090	Temporary surface drainage and dewatering	
1.01.100	Temporary protection, diversion and relocation of public utilities	
1.02	Substructure	
1.02.010	Foundation piling and underpinning: 010 – mobilisation and demobilisation 020 – trial piles and caisson 030 – permanent piles and caisson 040 – pile and caisson testing 050 – underpinning	
1.02.020	Foundations up to top of lowest floor slabs: 010 – excavation and disposal 020 – lateral supports 030 – raft footings, pile caps, column bases, wall footings, strap beams, tie beams 040 – substructure walls and columns 050 – lowest floor slabs and beams (excluding basement bottom slabs) 060 – lift pits	

Unfortunately ICMS up to this day only covers Capital costs and not the complete lifecycle costs. Because it is more detailed then the EN 16627:2105, we propose that in the AZEB case studies the ICMS capital cost breakdown structure is used and the resulting figures are integrated in the EN 16627:2105 framework.

3.2.4 Propositon 4: Cost Indicators for the impact of value chain optimizations

One of the largest opportunities for the building sector to achieve cost reductions, is the actual transformation of the building value chain. Currently, most (both private and professional) developers consider each building as a stand-alone project – the customer has some wishes, the location imposes some constraints and the designer has to develop solution from scratch, the builder has to find unique solutions each time to build each specific design on-site and the installation expert is involved late and improvises with what there is… What if the sector moved towards more (industrialized) standardization and off-site production, while still keeping a maximum of customization? The comparison has been made with the major manufacturing industries like the automotive sector, where deep collaboration structures, thousands of iteration cycles of design, manufacturing and tests have been done in order to drive costs to a minimum while creating very high quality standards ánd having a high diversity of customized end products.

To actually achieve cost reductions associated with value chain transformations, different organisations in the value chain need to start cooperating or merging in ways that are not common in the building sector. This might have a major impact on their business cases, qualitatively as well as quantitatively, and on their accounting practices. The costs incurred for the building owner/user are in part a reflection of the organisation costs of all organisations involved in the building project, from supplier to designer to contractor to maintenance expert. By eliminating out of the entire value chain the, often many, wasteful activities, which don't add value for the ultimate customer, the costs of the final product (the AZEB in this case) may decrease significantly and also the profit margin for the involved organisations might increase significantly. Probably the most well-known method to facilitate this value chain optimization is lean. Lean is promoted as an important instrument within the AZEB methodology.

Within AZEB of course we wish to show in WP3 how these value integrations and the elimination of wasteful activities improves value and decreases costs. However, it is not within the scope of our AZEB project, to dive into the complex world of organisational accounting to assess all reaped (organisational) benefits and losses of the process. Within the case studies of WP3, several projects will apply some kind of value chain optimization techniques, either within one specific organisation (e.g. with different departments representing a part of the value chain) or across organisations.
In these AZEB case studies we will use as indicators for the impact of value chain optimizations, a combination of the projects lifecycle costs analysis and the other performance indicators such as energy efficiency, health and comfort, and try to make a good qualitative argument for the effects of the value chain optimization measures on the project costs, organisational costs and building price.

3.3 Conclusion and recommendation

When attempting to reduce costs in an nZEB project it is very important to have clarity on how costs are estimated and calculated and which indicators are used. We recommend to use for this purpose the standards discussed in the paragraphs before. In addition we wish to emphasize that costing is a separate discipline in the building sector with its own experts. Involving this expertise as an integrated part of the building project team will help optimize the costing process and increase the quality of cost estimates and calculations during the project and this way improve decision making.

3.4 Literature

Previous EU projects (e.g. “Life-Cycle-Cost in the Planning Process. Constructing Energy Efficient Buildings taking running costs into account (LCC-DATA)” project, https://ec.europa.eu/energy/intelligent/projects/en/projects/lcc-data, ENTRANZE project and its cost tool http://www.entranze.eu/tools/cost-tool ,...)

National and international standards (e.g. ISO 15459 Economic evaluation procedure for energy systems in buildings, ISO/DIS 15686-5 Buildings and constructed assets – Service life planning – Part5, Life cycle costing (2006); DIN 276-1 Building costs - Part 1: Building construction, NS 3454 Life cycle costs for building and civil engineering work - Principles and classification)

Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements; http://eur-lex.europa.eu/legalcontent/EN/ALL/?uri=CELEX:52012X. E.g. Cost Optimal methodology of EU-Commission , Davis Langdon “LCC as a contribution to sustainable construction: a common methodology” (2007).

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© 2013 World Green Building Council. “The Business Case for Green Building: A Review of the Costs and Benefits for Developers, Investors and Occupant

ICMS standards: https://icms-coalition.org/the-standard/

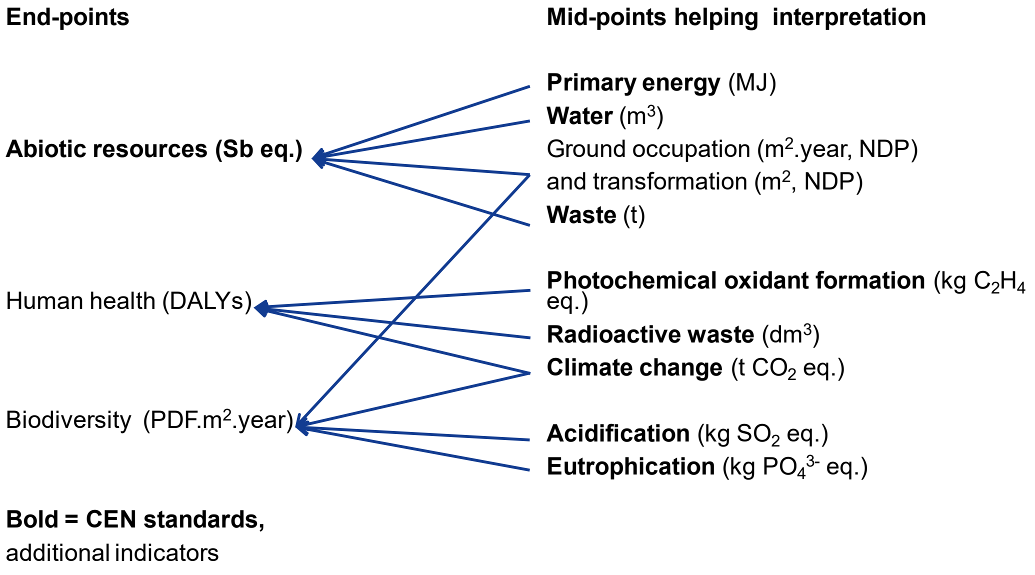
4 Life cycle Assessment

In some countries, nZEB are defined not only in terms of energy performance, but more global environmental indicators are also considered, e.g. CO2 emissions in a life cycle perspective. It is therefore useful to include this type of approach in the AZEB project and to present the related indicators in this report.

The objective of Life Cycle Assessment (LCA) is to evaluate the environmental impacts of a product from its fabrication until its end of life, including possible recycling [EN ISO, 2006]. In general, three areas of protection are considered: human health, natural environment (also named ecosystems), and natural resources, see for instance the ILCD handbook [European Commission, 2010].

Regarding the application of LCA in the building sector, the European standard EN 15978 has been elaborated by CEN [EN, 2011]. This standard is useful to establish a common nomenclature and guidelines to define goal and scope of building life cycle asssessment, for example on defining the functional unit (named "functional equivalent" in contradiction with the ISO 14040 standard) on which the assessment should be based, establishing a reference study period, or stablishing the system boundaries. However, the indicators list is taken from another standard regarding the building products, EN 15804 [EN, 2012], and may not be appropriate for whole buildings. For instance there are seven indicators on energy, detailing e.g. energy used as raw material or for processes, which may be useful for products manufacturers but a reduced number of indicators, perhaps aligning with the previously commented EN ISO 52000 indicators of primary energy (total primary energy and non-renewable primary energy), might be preferred when addressing a whole building. On the other hand there are no indicators on human health and ecosystems, so that additional indicators are proposed in this report, which have been used in practice by several partners in the AZEB project, in order to improve the standard. In this report, we will therefore consider a more flexible set of indicators compared to the present CEN standard. Some of these indicatores are also being discussed in the CEN TC 350 committee, for their inclusion in the upcoming updates of the EN 15978 & EN 15804 standards, planned for 2019. Existing indicators corresponding to the areas of protection are relevant because they provide a synthetic picture of impacts (they are called damage or end-point indicators), but their evaluation is complex and uncertain. It is therefore useful to evaluate also problem oriented (also called mid-point) indicators, which address specific contributions in a global impact but are less uncertain. For instance, climate change, ozone and ionising radiation are contributing in human health impacts. Climate change also contributes in damaging ecosystems. A structure of end point and mid-point indicators is provided in the figure below, based upon the CEN standards mentioned above but complemented with additional indicators.

Figure 19 Example end points and midpoints structure, based upon CEN standards on building LCA. NDP is the Natural Degradation Potential (Bentrup, 2002).



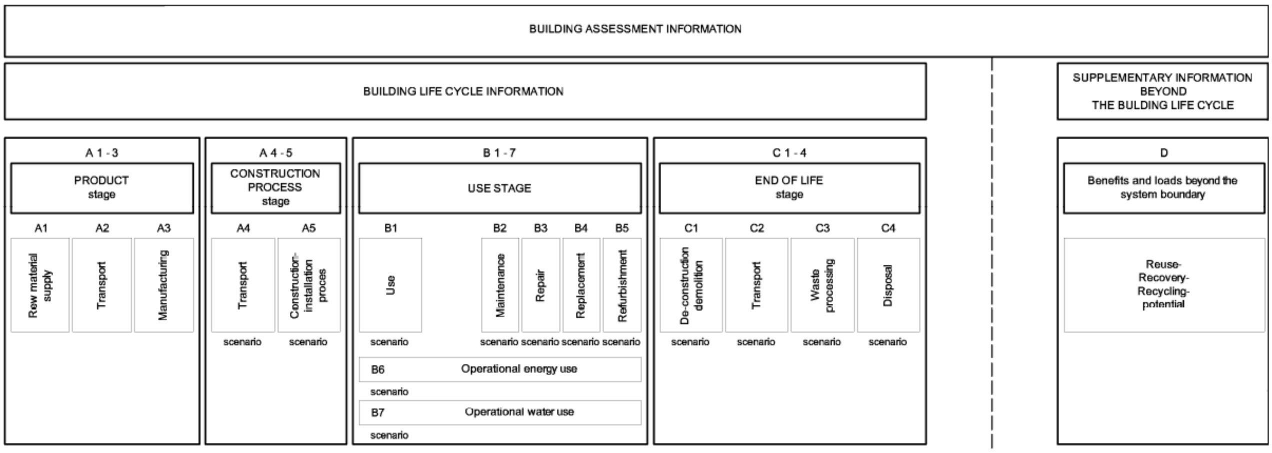
Stakeholders pay more attention to performance criteria if the underlying objectives are explained to them. A list of objectives resulting from a participative process involving engineers, architects-urban planners, companies and residents as part of the European project e-co-housing [Stoa, 2005] is shown in the table below as an example.

Table 20 Example set of objectives and related indicators.

Example objectives	Example indicators	Units	References
Preserve raw materials	Abiotic resource depletion	kg antimony eq.	[Guinee, 2001]
Save energy	Cumulative energy demand	GJ	[Frischknecht, 2007]
Save water	Water used	m^3	[Frischknecht, 2007]
Manage land use	Land occupation , Transformation	m^2.year , m^2	[Frischknecht, 2007]
Limit toxic emissions	Damage to health	DALY	[Goedkoop, 2001]
Protect the climate	Greenhouse effect (100 years)	t CO_2 eq.	[Forster, 2007]
Protect fauna and flora	Damage to biodiversity	PDF*m^2.an	[Goedkoop, 2001]
Protect forests	Acidification	kg SO_2 eq.	[Guinee, 2001]
Protect rivers and lakes	Eutrophication	kgPO_4^{3-} eq.	[Guinee, 2001]
Improve outside air quality	Photochemical ozone production	kg C_2H_4 eq.	[Guinee, 2001]
Reduce waste	Waste production	t	[Frischknecht, 2007]
Reduce radioactive waste	Radio active waste	dm^3	[Frischknecht, 2007]

These indicators are calculated accounting for the different elements of buildings (walls, floors, roof etc.), and the stages of their life cycle (fabrication of materials, construction, operation, renovation, end of life), as describe in the European standard EN 15978 [EN, 2011] (see figure below, but assuming that recycling -in module D- is "beyond the building life cycle" may be considered in contradiction with the ISO 14044 standard on LCA). The functional unit (named "equivalent" in EN 15978) defined as the quantified functional requirements and/or technical requirements for a building or an assembled system (part of works) for use as a basis for comparison can be related to 1 m^2 of floor area (and possibly one year) so that the building performance can be compared to reference values (e.g. kWh/m^2/year). Several building LCA tools have been developed in different European countries. Some have been compared in the frame of the European thematic network PRESCO [Peuportier, 2004].

Figure 20 Different stages of the building life cycle in the EN 15978 standard, but module D can be considered in the building life cycle according to the ISO 14044 standard (system expansion and allocation).



In addition to the indicators described so far, which have been derived from the standards, the paragraphs below present some additional indicators, which have been used by the AZEB consortium partners for assessing their own projects. These might also be of use for projects with specific similar goals to be achieved in the areas of respectively human health, ecosystems and resources.

4.1 Human health

a) mid-point indicators

- Climate change, Global warming potential (GWP)

This indicator includes greenhouse gases accounting for their optical properties and life time in the atmosphere. It is studied by the Intergovernmental Panel on Climate Change (IPCC), and expressed in kg eq. CO_2, see e.g. [Forster, 2007]

- Depletion potential of the stratospheric ozone layer (ODP)

The stratospheric ozone layer is a protection against cancer and some eyes problems. The involved substances are now forbidden in most countries to that this indicator, expressed in kg eq. CFC11, may be considered with a lower priority.

- Formation potential of tropospheric ozone photochemical oxidants (POCP)

Tropospheric ozone produces respiratory problems, so that this indicator, also called "summer smog" and expressed in kg eq. C_2H_4, is useful when addressing human health issues [Guinée, 2001].

- Radioactive waste

This indicator, expressed in kg or m^3 of waste, is simpler to understand than e.g. an ionizing radiation indicator expressed in Bq. It can be derived from life cycle inventory databases like ecoinvent [Frischknecht, 2007].

b) end-point indicators

- Disability-Adjusted Life Year (DALY)[5]

This indicator integrates the mid-points listed above, but also the contribution of particulate matter and toxic substances. It is expressed in DALYs, corresponding to a loss of years of life in good health [Goedkoop, 2001].

4.2 Ecosystems

a) mid-point indicators

- Climate change, Global warming potential (GWP) (see above)
- Acidification potential (AP)

Acid rains damage forests. This indicator is expressed in kg H+ or SO2 [Guinée, 2001].

- Eutrophication potential (EP)

Substances like phosphates are fertilizers and their emission in water increase the growth of algae. When these algae die, their mineralisation absorbs oxygen, killing fishes and other fauna in rivers and lakes. The corresponding indicator is expressed in kg eq. PO_4^{3-} [Guinée, 2001].

b) end-point indicators

- Potentially Disappeared Fraction of species (PDF)

This indicator integrates the mid-points listed above, as well as eco-toxic substances. It is expressed in PDF.m^2.year, the percentage of species that disappear over a certain territory and a certain duration [Goedkoop, 2001].

4.3 Resources

a) mid-point indicators

- Primary energy demand (PED, possibly split into various categories), expressed in MJ or kWh
- Use of net fresh water, expressed in m^3
- Waste production (possibly split into various categories), expressed in t or kg of waste

These three indicators can be derived from life cycle inventory databases like ecoinvent [Frischknecht, 2007].
Land use indicators can also be considered, and derived from the same databases.

b) end-point indicators

- Abiotic Resource Depletion Potential (ADP)

This indicator is based upon the quantities of raw materials used in a project related to the reserves, i.e. accounting for the scarcity of each material, and possibly the speed of depletion. This indicator is expressed in MJ or kg eq. Sb [Guinée, 2001].

4.4 Conclusions and recommendations

When taking a broader perspective on sustainability of buildings, it is inevitable to start asessing buildings over their lifecycle for global environmental impacts beyond just energy indicators. In this chapter some recommendations have been done for

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[5] see for instance http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754174

indicators covering the areas of human health, ecosystems and resources. There is much work still to be done to standardize and properly calculate or assess these indicators. The AZEB team nevertheless recommends considering setting some targets for environmental performance in any nZEB project, which may be supported by using some of the indicators discussed before. This way the project can ensure that design decisions are made including consideration of the wider impact on the global environment.

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5 Social impact

As one of the objectives of AZEB is assessing the social impact of the forthcomming nZEBs, there is an important work to be done within the social indicators definition for affordable nZEBs.

"Social indicators can be defined as statistics that usefully reflect important social conditions and that facilitate the process of assessing those conditions and their evolution. Social Indicators are used to identify social problems that require action, to develop priorities and goals for action and spending, and to assess the effectiveness of programmes and policies"[6]. This definition made by the United Nations is ambitious, since it considers the uses of social indicators not merely in description and trend monitoring, but also in taking action to make them evolve. Following this spirit the next points will try to get a set of social indicators, within the framework of the nZEB design, construction and use, that would help to monitore the impact of this activities on the people and to see what social impact any improvement by using the AZEB methodology would eventually have.

5.1 State of art of existing social indicators

In order to move on this direction, social impact assesment should be a must in any nZEB construction work. In that sense, while the environmental performance of buildings is a quite well-studied field of expertise, as commented in the previous point of this document, social impacts and aspects have usually had lower weight in assessment systems.

In relation to this development, it is true that there has been an increasing interest for the inclusion of social aspects into the environmental life cycle assessment of products and systems in recent years. In a literature review it can be stated that several social aspects are covered in assessment schemes developed in the past. To mention the most known: BREEAM (by BRE, UK), LEED (by US-GBC, US) and DGNB (Deutsches Gütesiegel für Nachhaltiges Bauen, DGNB, Germany)[7]. These building rating schemes contain a variety of social aspects although they are not considered in a rather systematic manner.

Framework

In 2014, EN 16309, which contains some directions for social performance assessment at building level, was published. This standard provides a structured quantification of social performance of buildings but does not provide a rating scheme for the quantified results, neither quantification of social performance in both product and process levels. EN 16309 clasifies the social issues at building level in some main axes: accessibility, adaptability, health & comfort, impacts on neighbourhood, maintenance and safety & security. Within these axes or categories several aspects try to determine the social performance of any building on its use phase.

1) Accessibility:

I. approach to,
II. entrance to
III. movement in

2) Adaptability of the building for eventual forthcoming uses

3) Health and comfort

I. Acoustic comfort

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[6] "Social indicators and quality of life research: background, achievements and current trends" Heinz-Herbert Noll. Genov, Nicolai Ed. (2002) Advances in Sociological Knowledge over Half a Century. Paris: International Social Science Council

[7] "Social performance criteria for buildings according to the CEN TC 350: Case study of the assessment of the VELUX SunlightHouse, Austria" World SB14, Barcelona, October 28/30th 2014

II. Indoor Air Quality
III. Visual comfort
IV. Water quality
V. Electromagnetic characteristics
VI. Thermal comfort

4) Maintenance and maintainability
5) Safety and security
I. Against climate change consequences
II. Accidents
III. Intruders and vandalism
IV. Against supply disruption

6) Impact on the neighbourhood
I. Noise
II. Emissions
III. Glare and shadowing
IV. Shocks and vibrations
V. Localized wind effects

7) Materials and services sources: sustainable sources
8) Involvement of stakeholders

Taking this structure and following existing methodologies, described in regular environmental assessment processes (i.e.: Life Cycle Assessment), next points should be defined as well:

- Intended use of the building
- Functional unit
- Study period
- System boundaries
- Possible scenarios

The system boundaries can usually be summarized in the building, its foundations and external works within the area of the building's site and temporary works that could be eventually associated with the building's construction or refurbishment.

And regarding to the scenarios, when facing any assessment it is suposed to be done on the basis of time-related information of building life cycle stages. Selected scenarios shall be realistic and technical aspects such as operating time, operating frequency, maintainability, frequency of maintenance, replacement aspects, lifetime, etc., shall be taken into account as well for the social performance assessment.

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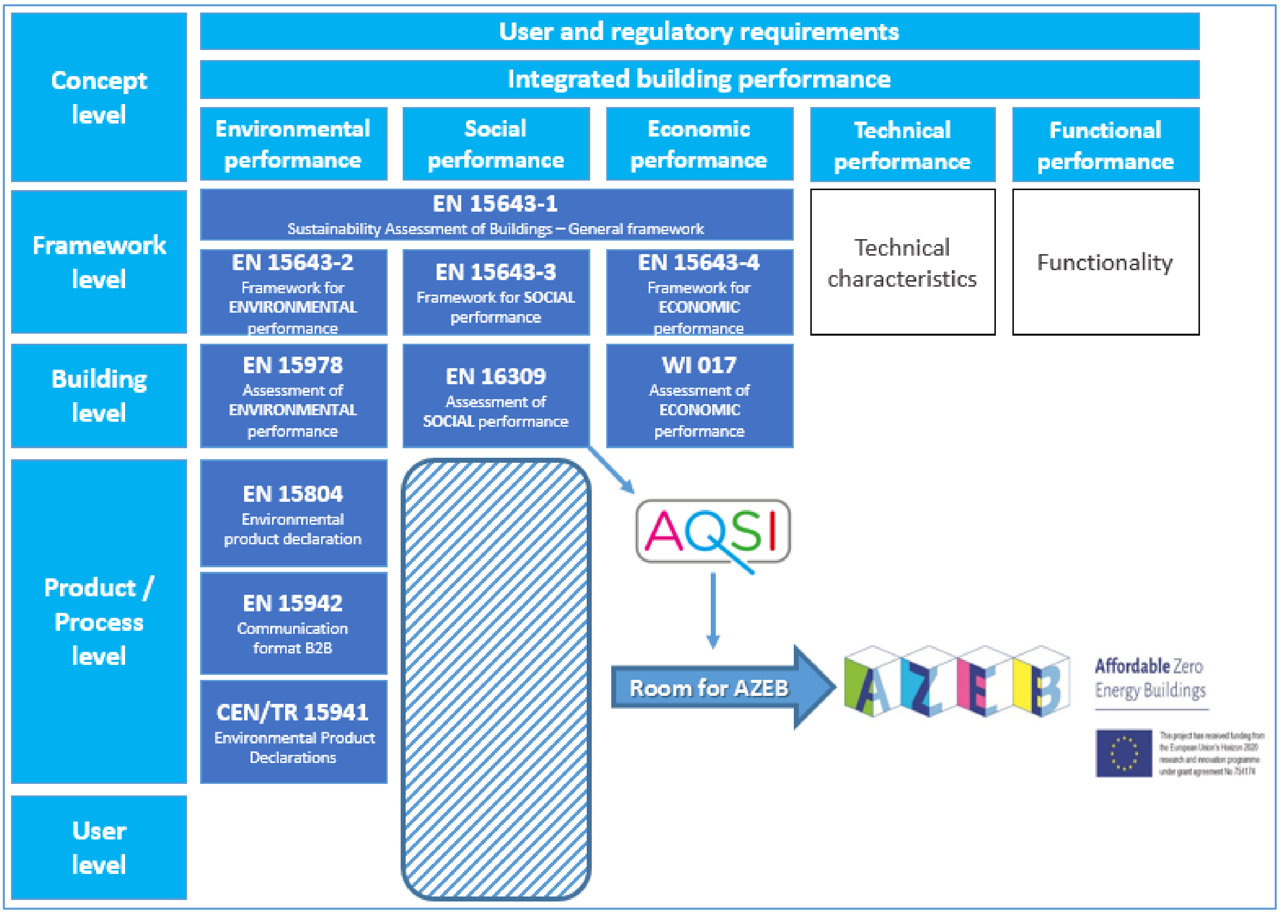
Figure 21: Existing framework and room for developing social indicators.



Tool

Based in the aforementioned EN 16309 and with the aim of translating this framework into a more specific application, a tool has been developed, based on the use of the building, called AQSI that can be useful for social impact assessment and has been put at the disposal of AZEB Consortium. AQSI is an open tool that was developed by the Nieman Group pursuant to an initiative by ROCKWOOL and together with the consumer organisation VACPunt Wonen from the Netherlands.

As commented, AQSI is based on the European Standard EN 16309,2014; 'Sustainability of construction works – Assessment of social performance of buildings – Calculation methodology'. Although the title of this standard suggests it to be a calculation method, it is in the first place a very well-structured assessment method. Consequently the standard is rather conceptional and it provides rules for the social performance of new and existing buildings.

An assessment of any building could be considered incomplete without a thorough examination of the social impact, as humans are the main purpose to create a building. EN16309 provides the framework to assess this social impact and AQSI makes it more tangible and applicable. AQSI assesses not only the building and its construction, but also aspects of operating, maintenance, replacement and refurbishment. Both architectonic design and materialisation are key issues, and AQSI puts social impact in the spotlight, so the social impact of the building becomes visible.

Figure 22: AQSI tool starting screen.

Taking EN16309 as the framework and starting point, and AQSI as an useful example and tangible tool for implementation of this standard, in the next paragraph, a set of additional social indicators for process, product and user level will be proposed for social impact assessment based on the partners experience and known good experiences.

5.2 **Proposal for new social indicators at process, product and user level**

As reported in the Guidelines and Principles for Social Impact Assessment (1994, 107), Social impacts are: “the consequences on human populations of any public or private actions that alter the ways in which people live, work, play, relate to one another, organize themselves so as to meet their needs and generally cope as members of society.”

Within this framework, and considering as the mentioned “public or private actions” the nZEB design, construction and use, here there are some definitions for social impact indicators based on partners’ experience. The standarized social performance indicators from EN 16309 are defined only at building level but the next proposed indicators are mainly divided in terms of:

- level of indicator: PRODUCT / PROCESS / USER
- phase when they may take place: DESIGN / CONSTRUCTION / USE
- quality: QUANTITATIVE / QUALITATIVE
- and subjectivity: OBJECTIVE / SUBJECTIVE

5.2.1 Social indicators at PRODUCT level

Safe construction materials use (PRODUCT / CONSTRUCTION/ QUAN / OBJ):

Objective**:** At present, technical information related to some aspects of social and economic performance are included under the provision of EN 15804 to form part of Environmental Product Declarations (EPD). Materials certification can help construction companies to comply with international and regional directives and regulations.

An example of hazardous substances that can make a construction material unsafe are the CMR. CMR (Carcinogenic, mutagenic and reprotoxic) substances are often referred to as a group, due to the fact that a substance may present all three types of hazards but also due to similarities in classification and in legal approach. CMRs are chronically toxic and have very serious impacts on health. Over 30 million tonnes of CMRs are produced in Europe yearly. The number of workers exposed to CMRs and the severity of effects call for coordinated scientific, technical and regulatory actions to be taken in order to protect health and improve working conditions: for example the prohibition of asbestos use, a widely used constituent in buildings and building materials, came into force at different times in the different EU Member States. Since 1st January 2005, the use of asbestos has been banned throughout the whole European Union.

Other examples could be Benzene, Formaldehyde, Carbon monoxide, Radon, etc , that are hazardous substances emitted from buildings, construction materials and indoor equipment or due to human activities indoors, such as combustion of fuels for cooking or heating, and lead to a broad range of health problems and may even be fatal.

Example of indicators:

- Occupational Exposure Limits (OELs) are one of the major control instruments for workers' exposure to chemicals: they belong to the most important tools for exposure assessment and management. At European level two lists of substances with indicative OELs set are established in Directives 2000/39/EC and 2006/15/EC. There are 2 types of OELs: Atmospheric (A) and Biological (B), and 2 main legal levels: binding or Constraining (C) and Indicative (I).
- % of materials used in the nZEB project that have a certificate (SGSS, TÜV,...)

5.2.2 Social indicators at PROCESS level

Socially responsible public procurement: Public bodies are being encouraged to procure sustainably, to reduce their social and environmental footprint and in order to stimulate sustainability in the private sector. Public procurement processes must face a day to day struggle with how to improve performance, increase efficiency and get the best value for public money while they strive to protect the environment, conserve resources and treat people fairly. Achieving this objective requires focused efforts along these proposed five dimensions of socially responsible procurement:

I. Community involvement (PROCESS / DESIGN/ QUAN / OBJ):

Objective: Community involvement is the process of engaging in dialogue and collaboration with community members to bring positive, measurable change to both the communities in which the stakeholders operate and to the steakeholders itself. One of the main ways of achieving community engagement is i.e. through involvement of the neighbours and citizens in the decision making processes: taking into account citizens opinion in relevant issues for them.

Neighbour engagement:

Example of indicators:

- Number (or percentage) of inhabitants or neighbours involved in the decision making process (e.g. planning and design phases of AZEB)

II. Diversity and inclusion (PROCESS / DESIGN/ QUAN / OBJ):

Objective: Non-discrimination, including indicators on diversity, such as composition of employees on all levels according to gender, age group, disabled, part-time workers and other measures of diversity.

Gender equality:

Example of indicators:

- % of women contracted for the nZEB design and/or construction

Disabled equality:

Example of indicators:

- % of disabled people contracted for the nZEB design and/or construction

III. Environmental protection (PROCESS / DESIGN/ QUAN / OBJ):

Objective: take advantage of nZEB construction methodologies and technologies to foster the environmental protection and environmental social awareness.

Energy Performance Guarantee:
Good practice: public bodies' ESCOs for social housing buildings, could share the benefits obtained from the exploitation of the energy facilities with the users. This would allow the users (usually low income inhabitants or tenants) to save money through a lower energy bill while contributing to avoid global warming achieving this way a double social impact.

Example of indicators:

- % of benefits shared with users or
- Amount of money saved per user and year

IV. Ethics (PROCESS / DESIGN/ QUAN / OBJ):
Objective: Ethical behaviour, following a system of moral principles, is often measured by the degree of trustworthiness and integrity with which companies conduct business. Ethics in the industry may include Honesty, Fairness, Integrity and Transparency among some of the most remarkable values. This values can be expressed through certain actions that have social impact.

Green financial products: include "energy efficient" aspects on financial products as a method to promote new and fair ways of helping constructors and users/tenants to face nZEB design and construction projects and dwelling rent/aquisition respectively.

Good practice: some banking groups (mainly from the ethical banking sector) are starting to offer Green or "Energy efficient" mortgages where they offer better borrowing rates in return for purchasing more energy efficient homes or committing to implement energy efficient upgrades to current home or a new one. The result is a more environmentally friendly living space that uses fewer resources for heating and cooling and has lower utility costs. The types of things that are covered include upgrades like double paned windows, tankless water heaters, modern HVAC systems, and new insulation. It could also ensure that banks are able to recognise "energy efficient" assets in their risk profiling, which would begin to help the market to price-in the added value of energy efficient real estate.

Example of indicators:

- % of dwellings aquired or rented with green financial products (Green Mortages)

Socialy responsible Value Chain: the construction Value Chain involves a multitude of actors and stakeholders, including building material manufacturers, building and construction companies, small and medium-sized enterprises (above all those engaged in trade), unions, planners, environmental NGOs, users, governmental institutions, financial institutions and research institutes. Value Chain integrating approaches are widely seen as a promising way to use on an equal basis the expertise and experience of all those involved and affected and see how this community can help to get better social conditions of workers.

Example of indicator:

- Average salary of the workers [€]
- Working hours per year [h/year]

V. Health, Safety and Security (PROCESS / DESIGN/ QUAN / OBJ):
Objective: one of the aspects of maintaining a productive workplace is making sure that there are effective health, safety and security procedures in place. Effective procedures protect employees, customers, users and facilities from harm and damage.

Promoters strong subcontracting control to minimize accidents.
Good practice: by enabling a strong control over the subcontracting companies and their performance, construction companies and/or Faculty Management of the Works can significantlly reduce the number and serverity of the accidents happened during the construction works of its nZEB promotions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754174

Example of indicators:

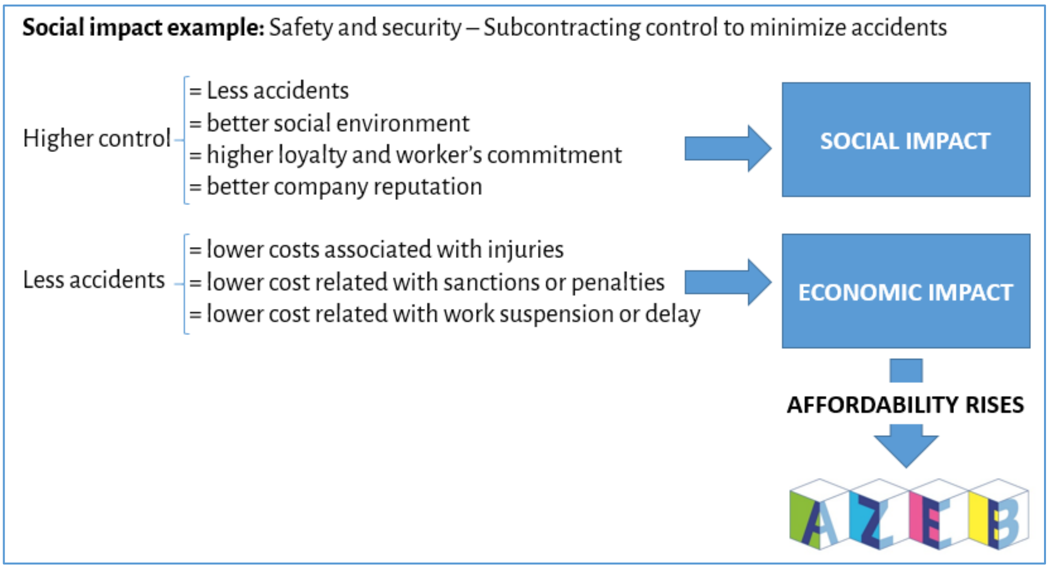
- Nº of lethal accidents during construction works
- Nº of non – lethal accidents during construction works

Workers training: well trained workers are usually more satisfied with their jobs and avoid accidents.

Example of indicators:

- % of workers trained in nZEB related security and safety issues

Figure 23: Social impact example.



5.2.3 Social indicators at USER level

User's characterization (USER / DESIGN/ QUAN / OBJ):

Objective**:** Get general information about the user/tenant. This should be done in the inception or design phase to ensure the maximum matching among user expectations and nZEB designed features.

Example of indicators:

- Dwelling area per person [m^2/person]
- Tenant/user age
- Number of (family) members living on the dwelling
- Number of toddlers, teenagers and adult persons in the dewelling
- Number of adult members working
- Number of adult members working at home
- Aproximated net income: [0 – 5.000€], [5.000 – 15.000€],[15.000 – 20.000€], [+20.000]
- Frecuency of heating use during the winter: never / occasionally / daily

User's opinion (USER / USE/ QUAL / SUBJ):

Objective**:** Evaluate final user or tenant opinion. Does the user feel confortable in his/her dwelling? Does the user feel his/her housing necessities or expectations fullfilled? What is the user's level of satisfaction? Does the user feel fairly treated by the public housing company or construction company?

Example of indicators:

- Perceived quality of the building (1 low to 10 high)
- General comfort of the dwelling (1 low to 10 high)
- General fullfilment of personal necessities (1 low to 10 high)
- General perception of satisfaction with the dwelling (1 low to 10 high)

- General perception of treatment received by the Housing Company (1 low to 10 high)

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5.2.4 *Proposal for classification of additional social indicators*

This set of proposed indicators which are additional to the existing building level indicators, can be classified as follows:

Figure 24: Proposal of indicators classification.

	Indicators (I)					
	Conceptual focus	**Objective**	**Indicator(s)**	**Phase**	**Objective / Subjective**	**Qualitative / Quantitative**
Product	Safe construction materials use	Include in construction processes safe materials and/or products	% of materials used in the nZEB project that have a certificate (SGSS, TÜV or others)	Construction	OBJ	QUAN
			Occupational Exposure Limits (OELs)	Construction	OBJ	QUAN
Process	Socially responsible public procurement	Community involvement	Number (or %) of users and neighbours involved in the decision process	Construction	OBJ	QUAN
		Diversity and inclusion	% of women contracted for the nZEB design and/or construction	Construction	OBJ	QUAN
			% of disabled people contracted for the nZEB design and/or construction	Construction	OBJ	QUAN
		Reducing energy poverty	Energy Performance Guarantee: % of benefits shared with users	Use	OBJ	QUAN
			Energy cost per user and year	Use	OBJ	QUAN
		Ethics	% of dwellings aquired or rented with green financial products (Green Mortages)	Use	OBJ	QUAN
			Average salary	Construction	OBJ	QUAN
			Working hours per year	Construction	OBJ	QUAN
		Health and safety; and Safety and security	Nº of lethal accidents during construction works	Construction	OBJ	QUAN
			Nº of non – lethal accidents during construction works	Construction	OBJ	QUAN
			% of workers trained in nZEB related security and safety issues	Construction	OBJ	QUAN

Affordable Zero Energy Buildings

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Indicators (II)

	Conceptual focus	Objective	Indicator(s)	Phase	Objective / Subjective	Qualitative / Quantitative
User	User's characterization	Get general information about the user	Area of dwelling / office per person	Design	OBJ	QUAN
			Tenant age	Design	OBJ	QUAN
			Number of (family) members living on the dwelling	Design	OBJ	QUAN
			Number of toddlers, teenagers and adult persons in the dewelling	Design	OBJ	QUAN
			Number of adult members working	Design	OBJ	QUAN
			Number of adult members working at home	Design	OBJ	QUAN
			Aproximated net income	Design	OBJ	QUAN
			Frecuency of heating use during the winter	Design	OBJ	QUAN
	User's opinion	How does the user value the quality of his/her dwelling?	Perceived quality of the building	Use	SUB	QUAL
		Does the user feel confortable in his/her dwelling?	Value general confortability of the dwelling (1 low to 10 high)	Use	SUB	QUAL
		Does the user feel his/her housing necessities / expectations fullfilled?	Value general fullfilment of personal necessities (1 low to 10 high)	Use	SUB	QUAL
		What is the user's level of satisfaction?	Value general perception of satisfaction with the dwelling (1 low to 10 high)	Use	SUB	QUAL
		Does the user feel fairly treated by the public housing company?	Value general perception of treatment received by the Housing Company (1 low to 10 high)	Use	SUB	QUAL

5.3 Recommendations and proposal for further research areas

Social impact is rarely structurally assessed in building projects. The former paragraphs show that there are many opportunities already to change this situation and select good indicators to include social factors in the decision making process during the building project. Especially when aiming for cost reductions, implementation of social indicators may be key to ensure that cost reductions do not cause any unwanted effects for the users of the building.

In the process of carring out this set of social indicators for nZEB design, construction and use, there have also arisen some interesting points that could be discussed in further research works with the aim of eventually define useful indicators in these areas. Some of this researching areas could be the following:

Product level

Product usability

Objective: A product or a technology with low usability can have a remarkable impact in user's experience. If the nZEB technologies or products that should be managed by the users are too complex, there is a higher probability of bad use or failure, especially if these technologies or products are going to be used by disabled, handicapped or elderly people. The best balance between functionabillity and usability should be pursued.

Good practice: In the Netherlands there is a non-governmental organization that takes the Housing Plans of a designed building and make a thorough review of it to detect eventual difficulties for the future user of the building. The review is done by volunteers/users who are trained in detecting difficulties for future use. For example: complex heating system user's interface, low accesibility of certain parts of the flat, ventilation systems in houses that no-one understands, cultural habits like hanging out the bedding in the window, just where the solar panels are, which reduces the output of the panels, etc.

Socially responsible construction materials: Are the construction materiales used in the building socially responsible? Have they been manufactured in fair conditions with the workers? Are they promoting the local job creation? Do they contribute to social integration of vulnerable groups? Is the business model of the supplier socially responsible? Socially responsible products have an ethical ideology or obligation to benefit society at large. Socially responsible products help support worth social causes through socially responsible business models.
Even in the construction sector, social actors who were passive receivers of services and products in the past will become active co-producers and co-designers. Do the designers have taken into account user's prespective? Once again, the new approach breaks the barrier between the producer and the user of a product or service. Rather, it changes the role of the customers from consumers to co-producers. Customers are no longer actors external to the value chain, but instead part of value-creation.

Good practice: In the tendering documents for a specific project there was included the requirement of using, when needed, sustainably produced wood valuating both FSC (Forest Stewardship Council), PEFC (Association for Spanish Forest Certificate) or similar forest certification, as well as the implementation of measures to minimize the impact associated with the transport of the wood. This kind of mesures are very much appreciated by the future users.

Process level

Socially responsible public procurement: When facing the tendering process for a nZEB some questions should be answered: Would the tender include sustainability requirements in its products? As sustainability has an important associated social share, does the tender include sustainable products, materials or components?

Good practice: Some public bodies started 10 years ago to request in the tenders ECODESIGN certificate to the architects and designers companies. Not only asked for the certificate for the company, for the products as well. Public bodies can act as spearhead in many items like this one, and could do the same with socially responsible materials. This type of companies should keep on adapting to new challenges and assuming a leader role in innovative public tendering for construction sector.

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6 Comfort

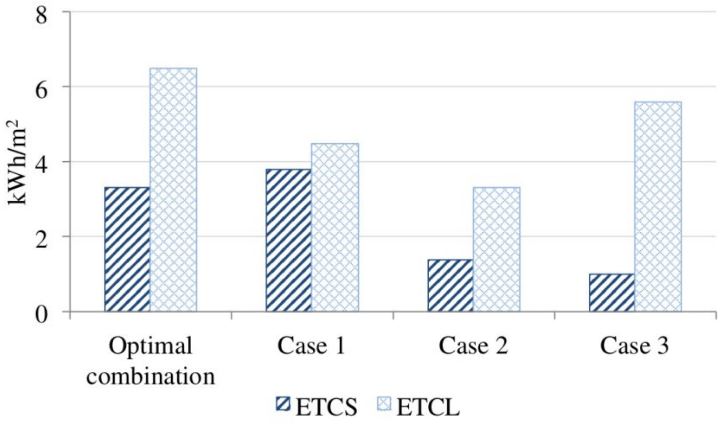
6.1 Comfort models and their implications for the design of nZEBs

The energy consumption of a building strongly depends on the criteria set for the indoor environment; the same level of comfort, as measured e.g. via the index PMV, can be achieved via various combinations of physical parameters, each with different energy need levels (Table 21 and Figure 25, Dama et al. 2014).

Table 21 Comfort set points (Dama et al., 2014).

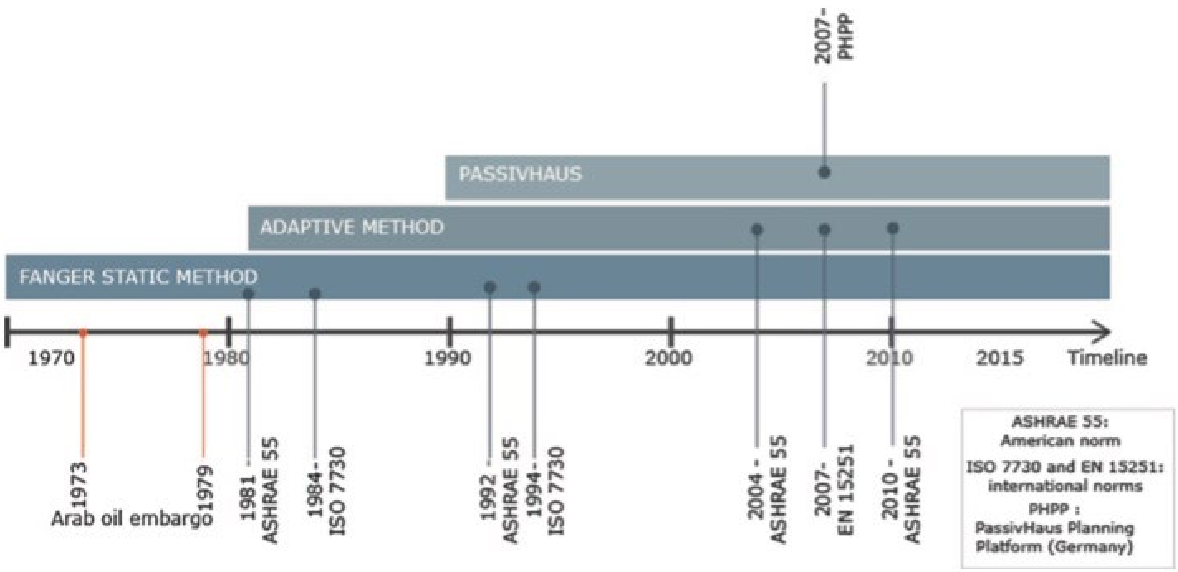
SIM.	T_{op}	R.U.	v	PMV	clo	met
	°C	%	m/s	-	-	-
Optimal combination	26	60	0.01	0.5	0.5	1.2
Case 1	25.7	70	0.01	0.5	0.5	1.2
Case 2	27.3	70	0.5	0.5	0.5	1.2
Case 3	27.6	60	0.5	0.5	0.5	1.2

Figure 25 Influence of comfort set point [Dama et al. 2014].



Recent revisions of international standards have updated the definitions of comfort and ways to use them in designing and evaluating buildings. ASHRAE Standard 55:2017 [1] and EN 15251:2007 [2] have introduced the Adaptive model to be used in naturally ventilated buildings and ISO 7730:2005 [3] and EN 15251 have introduced the concept of comfort categories based on different ranges of Predicted Mean Vote (PMV) or operative temperature around the neutral conditions. There are differences in the approach taken by those standards that have relevant implications on the design of low energy buildings and Net ZEBs.

Figure 26 Evolution of thermal comfort standards in the last 50 years.



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ASHRAE Standard 55 and EN 15251 both propose that acceptable temperature ranges actually depend on the type of system used to provide summer comfort. EN 15251 distinguishes two types of buildings, those with mechanical cooling and those without it, and for the analysis of the latter in summer both Fanger and adaptive models are allowed. In the definition section of the standard, "buildings without mechanical cooling" are defined as "buildings that do not have any mechanical cooling and rely on other techniques to reduce high indoor temperature during the warm season like moderately-sized windows, adequate sun shielding, use of building mass, natural ventilation, night time ventilation etc. for preventing overheating". Mechanical cooling is defined as "cooling of the indoor environment by mechanical means used to provide cooling of supply air, fan coil units, cooled surfaces, etc." The description of situations where it is appropriate to use the adaptive model is further detailed in the section A.2 of the same standard, where the emphasis is on the fact that "there shall be no mechanical cooling in operation" hence allowing for the use of the adaptive model even if a mechanical cooling system is installed: "In order for this optional method to apply, the spaces in question shall be equipped with operable windows which open to the outdoors and which can be readily opened and adjusted by the occupants of the spaces. There shall be no mechanical cooling in operation in the space. Mechanical ventilation with unconditioned air (in summer) may be utilized, but opening and closing of windows shall be of primary importance as a means of regulating thermal conditions in the space. There may in addition be other low-energy methods of personally controlling the indoor environment such as fans, shutters, night ventilation etc."

ASHRAE Standard 55:2017 makes a similar distinction but not exactly with the same wording, allowing the application of an adaptive model (based on outdoor monthly average temperatures), in "occupant-controlled naturally conditioned spaces" defined as "those spaces where the thermal conditions of the space are regulated primarily by occupant-controlled openings in the envelope".

Fanger and adaptive comfort models

Based on a steady-state approach, the model developed by Fanger in the 1970s aims at predicting the mean thermal sensation of a group of people and their respective percentage of dissatisfaction with the thermal environments, through the PMV and Predicted Percentage Dissatisfied (PPD) indexes.

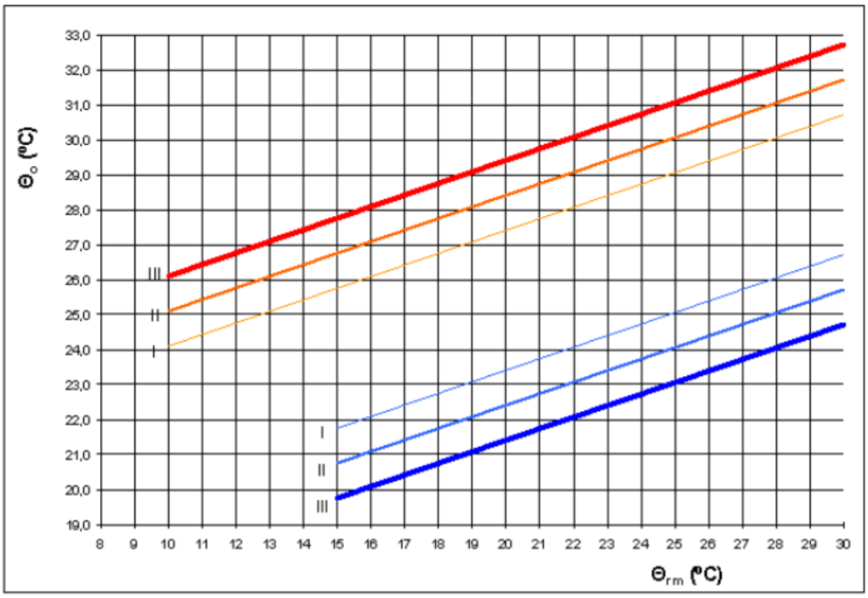
In the Standards, comfort "here and now" is classified in 4 categories (A, B, C, D in ASHRAE and I, II, III, IV in EN standards). Every category is associated to a specific comfort range, written through PMV, PPD or operative temperature, and buildings can be evaluated with long-term comfort indexes which take into account the cumulative departure of conditions in the building from the chosen comfort category/range. The standard leaves the choice to the designers between two possible procedures. The first one provides the direct calculation of the predicted mean vote (PMV-PPD criteria) and requires the values of 4 environmental parameters as air temperature, mean radiant temperature, air velocity and humidity plus 2 personal parameters as activity and clothing.

The second method does not include any calculation regarding the cited indexes because the design criteria are set through temperature ranges. The standard provides comfort ranges in terms of operative temperature rather than PMV, thanks to the assumption about type of clothing and activity of occupants, and an assumption of 50% relative humidity. The temperature range is specified for each season (winter and summer) and the related different clothing level hypothesis.

The upper values of the comfort range must be used to design the cooling system and to calculate the corresponding energy demand while the lower values are the references for the heating system.
Fundamental critique regards the use of the narrower categories (A or I) as a design criteria for new buildings have been raised by a number of researchers. E.g. (Arens at Al. 2010) conclude “The A class (I category) is found to confer no relative satisfaction benefit to individuals or to realistic building occupancies. In addition, the differences in B and C class satisfaction are small”. On the other side, the energy costs of choosing to design and operate the building in the narrower categories are considerably higher than designing for category B (II) or C (III). See e.g. (Sfakianaki et Al. 2011).

The adaptive model instead is based on the different expectation of the users and the strong link between their adaptation and the outdoor climatic conditions (Olesen 2007); in fact, the acceptable indoor operative temperature is evaluated through the running mean external temperature that is “the exponentially weighted running mean of the daily external air temperature” (EN 15251).
Once the running mean temperature is calculated, it is possible to estimate the indoor comfort range as shown in Figure 27. The comfort boundaries are related to the running mean through a linear equation and are differentiated between the categories.

Figure 27 Comfort temperature ranges for the three acceptance levels. Source: EN 15251.



A number of researchers have observed that some buildings will not fall exactly into the two ensembles and some of the interesting technologies for low energy and passive cooling are among those of uncertain classification both on the ground of the available data in the databases and of the wording of the standards, see for example [Pfafferott et al, 2007]. This has direct implications on design procedures particularly for low energy and Net ZEBs. The standard EN 15251 states that: “The temperature limits presented in A.2 [author note: adaptive comfort range] should be used for the dimensioning of passive means to prevent overheating in summer conditions e.g. dimensions and the orientation of windows, dimensions of solar shading and the thermal capacity of the building’s construction. Where the adaptive temperature limits presented in A.2

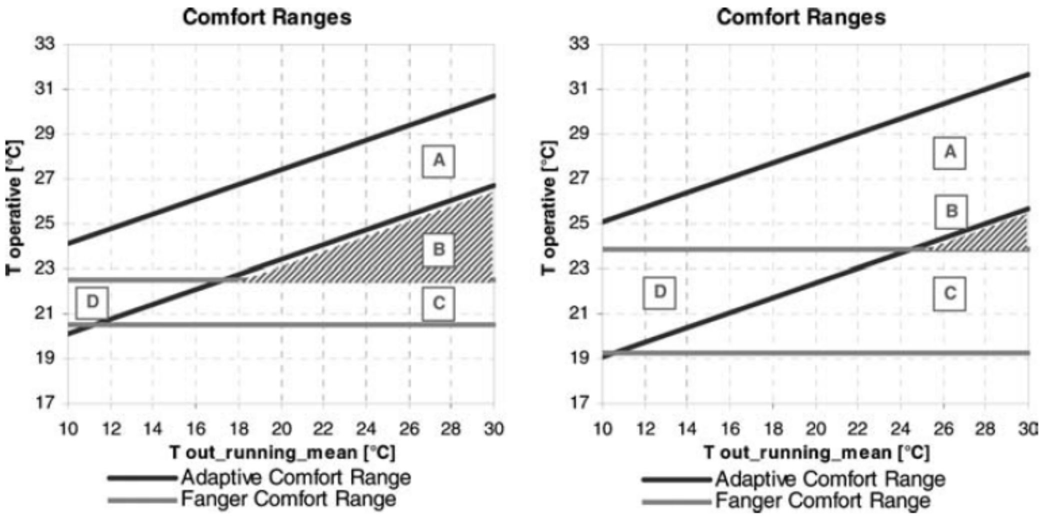
(upper limits) cannot be guaranteed by passive means mechanical cooling is unavoidable. In such cases the design criteria for buildings WITH mechanical cooling should be used."

Therefore, a procedure could be devised to vary building envelope parameters in order to minimise an "adaptive discomfort index". If the adaptive temperature limits cannot be guaranteed, a "Fanger discomfort index" can be used instead as the target to be minimised. These indexes can be selected among the ones proposed in EN 15251 [Annex F (Informative): Long term evaluation of the general comfort conditions]. Reducing the discomfort indexes by choice of passive means also implies a reduction of the energy needed for heating and/or cooling of the building and hence of the energy consumed by active means used to reduce the discomfort (if still needed). In [Pagliano 2010] it is shown that using some of the indexes proposed by EN 15251 (i.e. method A: percentage outside the range) and their intended use (start with its adaptive variant and, if comfort conditions for the chosen category cannot be met, switch to Fanger variant) implies the presence of discontinuities in the procedure. The discontinuity is due to the different response of the two models in the same temperature range that is clearly visible through a direct comparison.

The different comfort ranges for the two models are shown in Figure 28, where PMV is calculated assuming standard condition [Pagliano 2010]. Four significant regions are highlighted:
- The Field D represent a comfort condition for both models.
- The Field A is inside comfort range for the adaptive method while it is above it for the Fanger model.
- The Field C is inside the comfort range for the Fanger model while is below it for the adaptive one.
- In the Field B the operative temperature is below comfort range in the adaptive model while it is above the range for the Fanger model.

The different response is shown clearly in the field B, where there is overheating problem for the Fanger model and overcooling problem for the adaptive one; this situation is mainly due to the diverse assumptions on which the two models are built.

Figure 28 Comfort temperature ranges for adaptive and Fanger model, related to cateory I (left) and II (right) (Pagliano 2010).



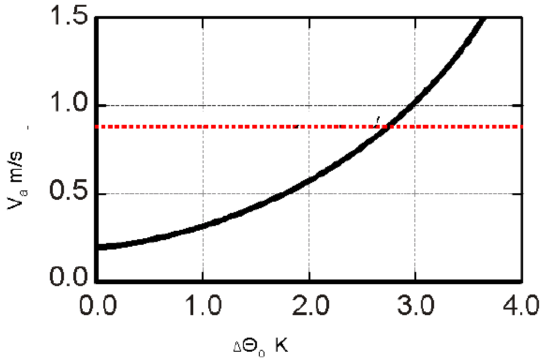
Even with these limitations, these indexes can be useful as objective functions in an optimization procedure to guide design, particularly for the building envelope and passive features. In passive buildings, the use of these indexes (in their adaptive variant) would be useful, for example, to control the operation of motorised openings for night ventilation in summer. In fact, since the comfort operative temperature to be reached depends on the recent history of external temperatures, the temperature set point (for operative or mean radiant temperature) at which night ventilation should be reduced/stopped cannot be set at the same level for the entire season. Instead, it should be calculated each day based on the previous history and on the building characteristics, which determine its dynamic response. It would also be useful to adapt simulation tools in such a way that they can handle directly such control algorithms and calculate their effect.

Part of the discontinuities between the two variants (Fanger and adaptive) arising in the optimisation procedure with use of the long term indexes may be reduced when considering the large influence that certain variables like clothing (and total) insulation and air velocities have on the calculated values of PMV. Ensuring that clothing insulation is under 0,7 clo (e.g. by appropriate relaxation of explicit or implicit dressing codes) enables the use of the ASHRAE correction (in augmentation of the value calculated via PMV formula) to operative comfort temperature when velocities higher than 0.2 m/s are experienced by the occupants. These two changes have the effect of reducing the ambiguous zone between the two comfort ranges.

The increase in the air velocity can extend by some degrees the upper limit of the temperature comfort range (EN 15251). The cooling perception with improved air movement is due to the rise of the heat leaving human body; the movement of air accelerates the process of sweat evaporation from the skin that requires heat: faster is the process, more is the heat leaving our body. In addition, if the air temperature is lower than 38°C, the air movement improves the heat transfer from the skin trough convection.

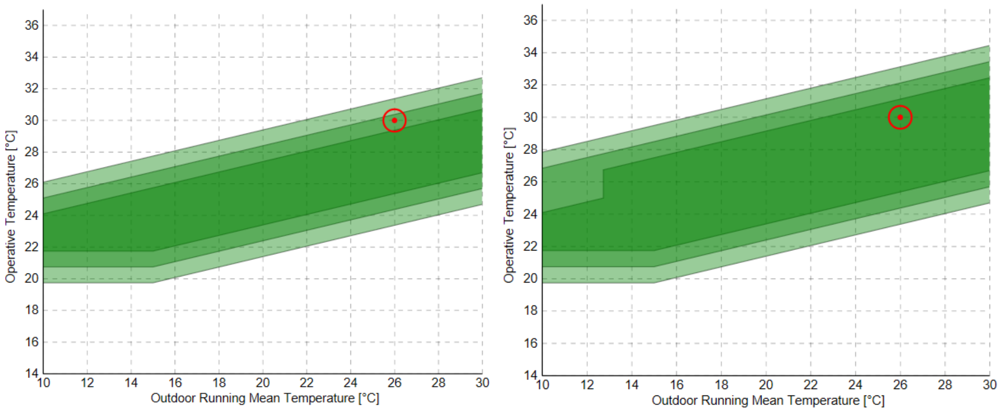
The standard EN 15251 expresses the benefits of air velocity rise with the diagram in Figure 29. The difference of temperature between the standard comfort limit and the increased one (x-axis) is non-linearly proportional to the air velocity (y-axis). For sedentary occupancy the maximum air velocity is set at 0,8 m/s (red line).

Figure 29 Relationship between air velocity and increase in the upper temperature limit (source: EN 15251).



For instance, the adaptive model is considered with a summer condition of 30 °C for operative temperature, 26 °C for outdoor running mean temperature and 0,1 m/s as air velocity (Figure 30 - left). The situation is inside the category II as expectance level, but if the air velocity is increased up to 0,5 m/s (Figure 30 - right) the upper limit has moved, and the point is now in the category I.

Figure 30 Comfort ranges for different air velocities in the adaptive model. Source: Berkeley Tool.



The correction as it is proposed is applicable directly only to temperature, hence only within method A (hours outside range), but not in method B and C which rely on PMV and PPD values that are given in graphic form, hence not directly applicable in simulation or optimization tools. In [Pagliano 2010] a modified version is proposed, where increased air velocities effects are

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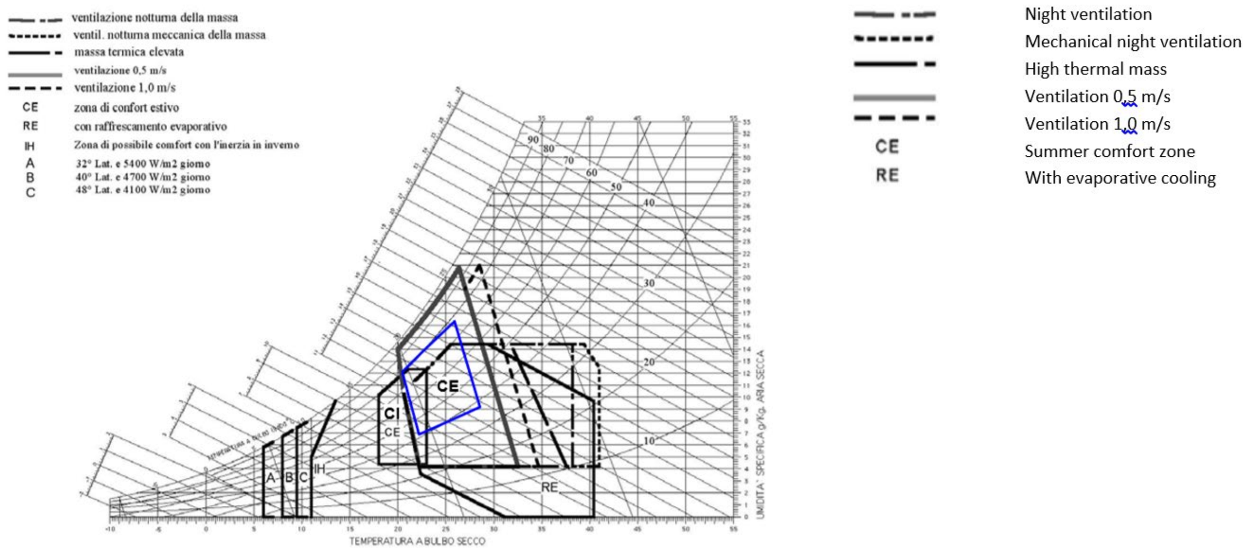
described in terms of PMV in graphic form. Further work is ongoing in order to incorporate it into analytical and numeric procedures for optimization.

Alternatively, the Givoni psychrometric-bioclimatic chart [Givoni 1998] can be considered as an easy to use and pedagogical tool. The method is based on the comfort zones defined in ASHRAE Standard 55, but it also graphically represents the effect of passive measures, hence helping designers to reduce or avoid the need for air-conditioning [Figure 31]. Starting from the areas CI and CE, that embrace the standard comfort conditions, the graph represents the extension of the comfort zone through daily and night ventilation, high thermal mass and evaporative cooling. See [Lenoir 2009] for an example of the Givoni's chart applied in the design of a Net ZEB in tropical climate.

Figure 31 Givoni chart. Source: Peron & Ambientale, 2010.



6.2 Recommendations on comfort

After the choice of the comfort level it is important to formulate different scenarios based on the various combinations of the physical parameters. This analysis allows to identify the most convenient option, in terms of reduction of energy and facilities' cost.

The adaptive comfort is an alternative to be explicitly considered since it could enable the reduction of the costs, focusing the project on the optimization of all the passive elements.

The adaptive model is strenghtened by the two official ASHRAE databases; the second one (Földváry et al.2018) has just been published and contains worldwide data from comfort surveys in real buildings.

6.3 Literature

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7 Decision Making and Optimisation

As may be concluded from the previous chapters many indicators (should) play a role in the decision making during the design process for an AZEB. Many of these indicators have interdependencies. One of the complicating factors for good decision making in this field is the fact that there is not just one possible solution to each design challenge: more than one solution may offer value to the client and/or other stakeholders. The decision making process for an AZEB is characterized by a context with multiple stakeholders and a technical challenge encompassing multiple disciplines. How can one then determine what a good decision is?

In the science of decision making a model has been developed to facilitate this type of decision making. This model contains six crucial elements for a decision to have high quality. The reasoning is that if one of these elements is below the minimum required quality, the decision will not be of high enough quality. These are the elements of the model:

Figure 32 A model for high quality decisions (derived from the theory described in the book Decision Analysis for the professional, see references).

1. *Appropriate frame*

This means that it needs to be very clear what the purpose of the decision is and which problem or challenge it will solve. To gain this information and make sure it is right and complete, it is very important to have the right stakeholders involved in the right way.

2. *Creative and Doable Alternatives*

To make a good decision there need to be enough and the right sort of options to choose from. This means a creative stretch must have been made to include enough relevant options. These options need to significantly differ from each other. Also these options need to be truly doable. In addition the options need to be comprehensive: they need to solve the complete problem or challenge. And finally the options need to be compelling: the decision maker and/or executing parties need to be able to embrace the chosen option for implementation after the decision making.

3. *Clear values and trade-offs*

To make a good decision, there must be explicit decision criteria stated. These criteria should be a clear reflection or practical translation of the value the decision maker is aspiring for. When these criteria are explicit, a clear trade-off method should be chosen to consistently and transparantly compare the different alternatives on the chosen criteria. This element of decision making ensures there is a clear line of sight between the practical solution chosen and the value that this option will (and will not) deliver to the stakeholders.

4. Meaningful and Reliable Information

The information used in the decision making should be appropriate for the problem or challenge at hand. Not more, not less and the right kind. The information should be based on appropriate data and judgments. Any uncertainties in the information should be made explicit. The information should not just reflect the past, but be forward looking, for example taking into account future scenario's of context (economy, society, technical advances,et cetera).

5. Logically correct reasoning

The human mind functions with many biases and shortcuts when it comes to decision making. These biases and shortcuts often prevent us from reaching high quality decisions. Examples of these are automatic associations, habits related to the personality, social influences, relative thinking and faulty reasoning in light of uncertainty and complexity. These biases and shortcuts are mostly unconscious. By bringing the possibility of the main traps into the conscious and applying action to counter these traps, decisions may improve. Examples are: Make your assumptions explicit and test them in reality to prevent confirmation bias. Attain distance before deciding to prevent acting on short-term emotion. Mentally prepare to be wrong to prevent overconfidence. Widen your options to prevent acting on a narrow frame which excludes better options. Also several analytical tools are available to rationally aid in reasoning (e.g. optimisation, value engineering, trade off instruments).

6. Commitment to action

A high quality decision ensures that the stakeholders who need to implement the decision are ready for execution of the decision. They need to be mentally prepared and willing to execute the decision and they need to be facilitated with the proper resources (time, money, skills) to implement the decision. This does not necessarily mean that they agree that the chosen option is the best. They might still differ of opinion. This commitment to action however is built during the decision making process because they have been involved enough to add their input and feel heard. They understand explicitly what problem was addressed and with which purpose, what information has been used, how this information has been interpreted, what criteria were chosen, which options were considered and how the trade-offs were made.

This decision quality model can be used as a checklist when a decision is being made: have we addressed each element sufficiently? Or, in addition, it may be used as an agenda to shape the decision making process right from the start.

The indicators described in the previous chapters can be considereed as input for shaping the element of “clear values” and also for “using meaningful and reliable information” and sometimes for “logically correct reasoning”. The next few paragraphs show some specific methods for doing trade-offs in order to optimize the design. The above explanation of the complete set of necessary elements for achieving a high quality decision should emphasize that the methods discussed in the next paragraphs only function to truly optimise a design, when all other crucial elements have sufficient quality also. The saying of: “Garbage in is garbage out” applies as much in this context as in many others.

7.1 Multicriteria optimisation (cost and energy/environment) based upon simulation

Dealing with numerous indicators is complicated in a design process. Optimising a building project considering many criteria, design possibilities and constraints is presently not possible in practice. Discussing priorities with the decision maker may lead to a simplified optimisation problem that is manageable. This § presents example approaches.

A first example corresponds to the design of a single family house in France, including two steps: architectural sketch, and detailed design (Recht, 2016). The client's brief includes a zero energy objective, a site and an affordability criteria (around 100 m2 living area and reasonnable construction cost). The investment cost is in France the main barrier against ZEB. The decision makers are the contractor and the architect.
In the first step, the objective is to propose improvement of the architect's sketch [Figure 33].

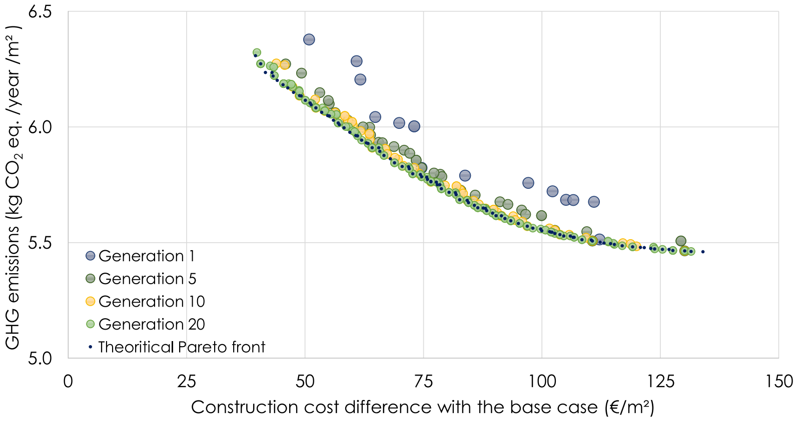
Figure 33 Example of a single family house, initial design proposed by the architect.

The contractor defines a global technical choice corresponding to his practice (e.g. choosing a timber frame or concrete blocks). The architect defines some constraints (e.g. minimum and maximum % of glazing in the facades according to the site, view, daylighting performance etc.). Possible design parameters to be optimised are the % of glazing in the different facades.

The second step corresponds to the detailed design. The optimisation addresses parameters like insulation thickness (in walls, floor and roof), type of glazing (double or triple), ventilation (with or without heat recovery) and area of photoltaic modules, leading to more than 4 million possibilities. Genetic algoriths allow approaching the results of a complete assessment while reducing the number of simulations (8,000 in this example).

The following figure gives an example of optimisation results regarding the minimization of CO2 emissions and construction cost.

Figure 34 Example optimisation result, Pareto front.



The Pareto front corresponds to "non dominated solutions", i.e. emitting the least amount of CO_2 for a given construction cost, or the cheapest for a given CO_2 emission threshold. After 20 generations, the genetic algorithm provides solutions approaching the reference Pareto Front obtained by evaluating the 4 million solutions.

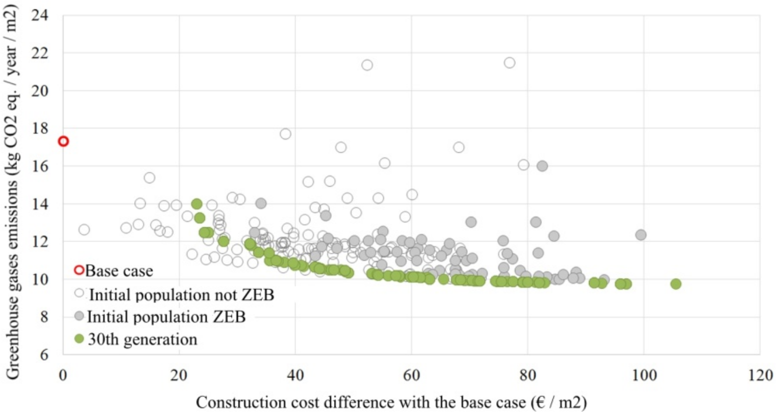
Reducing CO_2 emissions requires increasing investment cost. Beyond 100 €/m^2 overcost, the impact reduction is small. Each solution can be identified, e.g. in this case performing solutions include triple glazing, heat recovery on ventilation and between 25 and 28 m^2 PV modules.

Another example corresponds to the design of a multi-family residential building (34 apartments, 2,350 m^2), see next figure.

Figure 35 Example of an apartment building.

An 80 years life span is considered in the life cycle assessment. The initial design didn't allow reaching the zero energy objective: at least 20 €/m^2 increase of construction cost was needed. CO_2 emissions can be further decreased, but with a higher investment as shown in the next figure.

Figure 36 Example optimisation result for the apartment building.



In this example, all non dominated solutions include heat recovery on ventilation, only half include triple glazing and the area of PV modules adapts to match the zero energy objective.

7.2 Using Value Engineering as a process to optimize AZEB design

Value Engineering (VE) is a systemized method for evaluating and optimizing the value of a product or service. It originates in the United States and has been a formal field of study and application since the fifties of the 20th century. Value Engineering as a method has many applications. It may be used to choose the best design alternative, to reduce costs of a product or service, to improve quality or performance of a product or service, to improve client satisfaction et cetera.The method of Value Engineering is being used in many professional fields and industries. However the building sector until now seems to rarely apply it in its processes. The AZEB project, which has the core purpose to increase the value of (nearly) zero energy buildings by reducing costs, finds the method of Value Engineering specifically useful for this purpose and therefore wishes to use and promote it in some case studies and the trainings developed within the project. In this paragraph we shortly explain the method and show an example from application in a Dutch case study. For more detailed information we refer to the international association for Value Engineering: DACE.

7.2.1 What is value?

Value may be defined as the functionality of a product or service devided by the (lifecycle) cost. A product or service has value when it has appropriate functionality at an appropriate cost. This description implies the fact that value is subjective and even changes in time. Value is always increased when you reduce costs while maintaining the same level of functionality. It might be increased when you improve functionality; but this only works when the customer needs it, wishes for it ánd is willing to pay for it. In practice one could say that the value of a product, for example an AZEB, is good, when it offers a somewhat better ratio than competitors between costs and functionality.

7.2.2 The value engineering process

Value engineering is done with a multi-disciplinary team, representing the different life phases of the product or service, representing the different fields of expertise related to the product or service and representing all stakeholders of the product. The process takes place in a limited time and in a controlled environment with clear steps to be taken. It is somewhat like a pressure-cooker for a project. In this process a lifecycle perspective is always adopted. The effect of the sessions may be that costs are reduced, are relocated or even added, based on a functional analysis of the product or service and the creativity of the team. Value Engineering focusses its efforts on functionalities with high costs (instead of objects or elements with high costs). In addition it is critical towards functionalities that bear costs but are not a necessity.

Value Engineering has seven main phases or steps. For each of these steps several tools and methods are available to guide the team effort and reach the desired results, for example analytical instruments, creative techniques, morphological design process and calculation tools. A value engineer or other facilitator guards the process to make sure the team works efficiently and effectively. The carefully designed boundaries of time and scope as well as the carefully selected tools and processes, tailormade to fit the purpose of each specific project, ensure a maximum result can be achieved within relatively short time.

The consecutive phases are explained now:

Phase 1: The informational phase
- The team is chosen
- General projectinformation is collected
- Problem analysis and critical issues identified
- Cost analysis performed, cost tree made
- Value definition created, exit points for VE study defined

Phase 2: Functional analysis phase
- Describe core needs
- Gain insight in current design choices
- Do a functional analysis
- Assign costs to functions
- Set performance criteria
- Measure the baseline performance
- Select functions for the creative phase.

Phase 3: Creative phase
- Generate as many ideas as possible, also “out of the box”
- No judgment – no boundaries

Phase 4: Evaluation phase
- Select the best, most promising ideas
- Prioritize ideas
- Cluster ideas

Phase 5: Development phase
- Work out ideas
- Estimate effect on (preferably lifecycle) costs
- Test for feasibility and impact on performance criteria
- Make explicit trade-offs
- Make an implementation plan

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Phase 6: Presentation phase

- Prepare and perform a presentation to facilitate decision making

Phase 7: Implementation and reporting phase

- Implement the decision made
- Monitor the realized impact on performance criteria
- Report on the results
- Evaluate for future applications of VE.

The attentive reader may notice that the different phases of Value Engineering, in combination with the multidisciplinary approach and lifecycle perspective, have a strong resemblance with the elements of high quality decision making that were discussed in the first paragraph. In other words, value engineering offers a formalized, highly structured and richly tooled way to achieve high quality decisions and to cost optimize (AZEB) designs.

7.2.3 A case study in The Netherlands: Value Engineering in a light version

Ideally, to facilitate maximum quality decision making, a Value Engineering study is performed as complete as possible. However, in practice there might be many reasons why this is not feasible, for example lack of money or time. The good thing is that the principles of value engineering may even have a strong effect when applied in a "light" version. This may be shown in this Dutch Case study of "The house with the red stairs".

Figure 37 3D representation of the design for the "house with the red stairs".

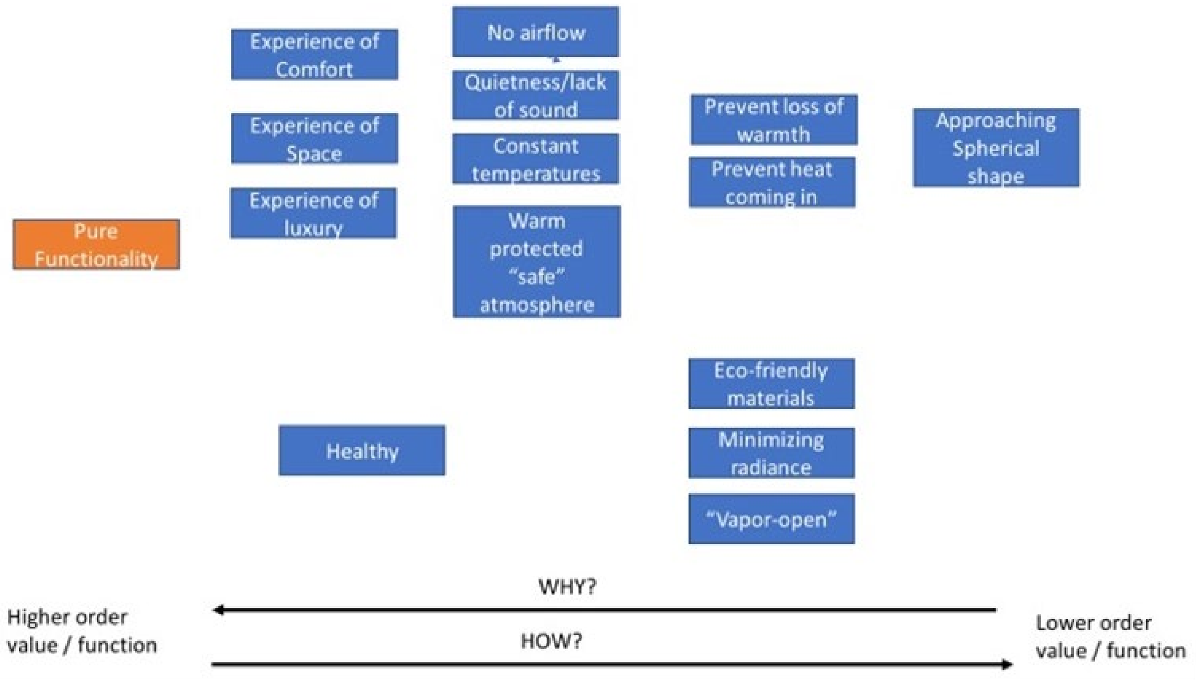
Because of the context changing much in the period between the year of the design (around 2011) and the year of actual start of the building (2018), the design proved to be around €40.000 over budget for the owners. In other words: to make their project feasible, they needed to reduce costs. Having designed the house by themselves however, the owners were very attached to the value and performance the design promised. Also they had already made quite an effort to reduce costs. Being in a tight spot, because they had already acquired the land from the municipality and interest costs were now incurring, they needed a pressure cooker to get their project moving forward again. The Dutch AZEB team offered to facilitate a "quick and dirty" value engineering study, to try and force a breakthrough in their approach.

A date was set for a 4 hours value engineering workshop with the owners, the selected contractor, the architect involved to optimize the design, and several experts to bring extra creativity to the process.

In preparation of this session the owners were interviewed lengthy on their ambitions, wishes, needs, and the design decisions that were made until now. This resulted in a basic functional analysis, clearly showing the main values of these owners, translated to some main functions and design choices of the building. Their five core values were pure functionality, social binding, pure esthetics, caring for the earth and connections through time and place. Each of these values was roughly peeled off via functions towards the actual elements that were chosen to perform these functions or address these values.

Below is an overview of one part of this simple functional analysis. The functional analysis by the start of the workshop was by far not complete yet, but it gave a good indication for all participants on the different design choices that were made:

Figure 38 Example of some functions derived in the preparation of the Value Engineering session.



Also in the preparation of the workshop, an analysis of the project costs was done and the three apparently most costly details were selected for the workshop as topics to start with: first the profiles and setting-work around the window frames and the white edge, second the façade covering with Platowood and slats, third the window frames and glazing and fourth the total package of energy services (installations).

In the workshop, after clearly setting the stage on the purpose and scope of this study, each consecutive detail was first analyzed for its complete set of functions: what does it do for the performance of the building. This was analyzed to make sure that when we would consider less costly alternatives no vital functions would accidently be lost. After the functional analysis, a small creative session was done with the participants: what alternatives are there to fulfill these functions and reduce costs? Finally for the most promising alternatives an estimation was done on the effects on cost and performance. Then homework was given to the builder and architect to work out the chosen alternatives and specify their effect on cost and performance (on functions).

One example: The profiles and setting of the window frames and white edge was analyzed to have the following functions: protecting the wood fiberboard against moisture, maintaining the vapor-open function of the façade, maintaining moisture drainage and capillary function when raining, controlling the risk of damage of the insulation materials by rodents and the estaesthetical function of accentuating the windows/"holes"in roof and façade.
In the following creative session these alternatives were thought of to reduce costs: leaving out the setting of the wndow frames at the head ends of the building, carrying out the white edge with wood instead of settings, adding a ventilated cam instead of setting the plate. In this case the ventilated cam was initially chosen as the best alternative, because it was neutral on costs but greatly improved the design in relation to building physics because they had corrugated iron in their design as the roof cover. However, after working out all details after the VE session, they discovered that the corrugated iron was not

possible to use because of their ambition of building vapor open. Detailling became to complex. They have now chosen fiber cement slates as an alternative.

During the creative and evaluative processes the functional analysis that was made proved very useful, even though it was still rough and incomplete. It quickly pointed out dependencies between elements that might otherwise have stayed unnoticed and could have led to performance issues later in the project.

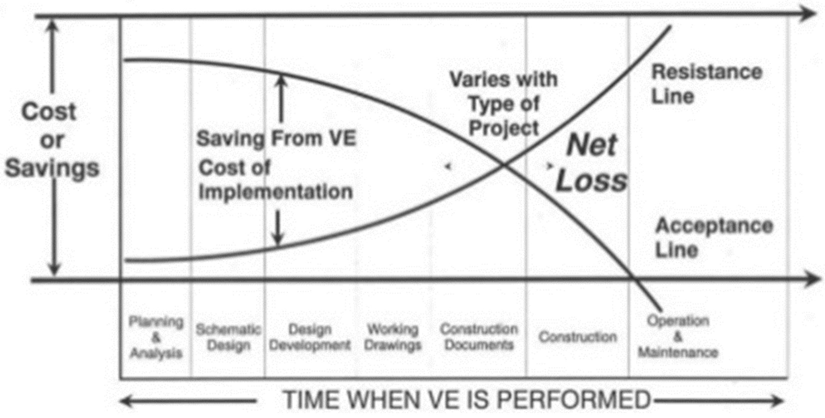
Even though the cost reduction possibilities proved to be minor (only a few thousand euro's was saved in the end), the owners judged the value engineering process as very valuable for two other reasons:
They achieved higher functionality in the design: their values were now even better served with the design.
They got confirmation that the decisions they made are well founded.
We think that one of the reasons that only a minor cost reduction was achieved is the fact that the value engineering was done so late in the process: they were ready to start building. Even during the value engineering session some quetions were raised on choices in their design that were too fundamental to change in this phase of the project.
The good news is that their financing institute after the adaptations agreed to give them an extra loan to cover the difference in their budget. They have now, oktober 2018, started building their dream house.

This case study shows that even applying the main steps of value engineering in a light version can improve decision making and increase the value of a design.

7.3 Applying Value Engineering in the building of n(ZEB)s

The AZEB project team would like to show in the case studies that the Value Engineering approach is a very promising method to improve value and reduce costs of (nearly) zero energy buildings. A method that may be applied in all settings and project types, either in a light version or in the full traditional version. The method of Value Engineering can be applied in several stages of the project, but we strongly advice to start early, because most value is to be gained at the initiative and design phases. In these early phases it is relatively cheap to make changes and the changes might be quite impactful. In later phases it is more costly to implement changes, not all changes are feasible anymore and the resistance from the project team and stakeholders to make changes will be considerably higher. The following figure shows these effects visually:

Figure 39 This figure explains why Value Engineering can add most value in the early phases of a project.



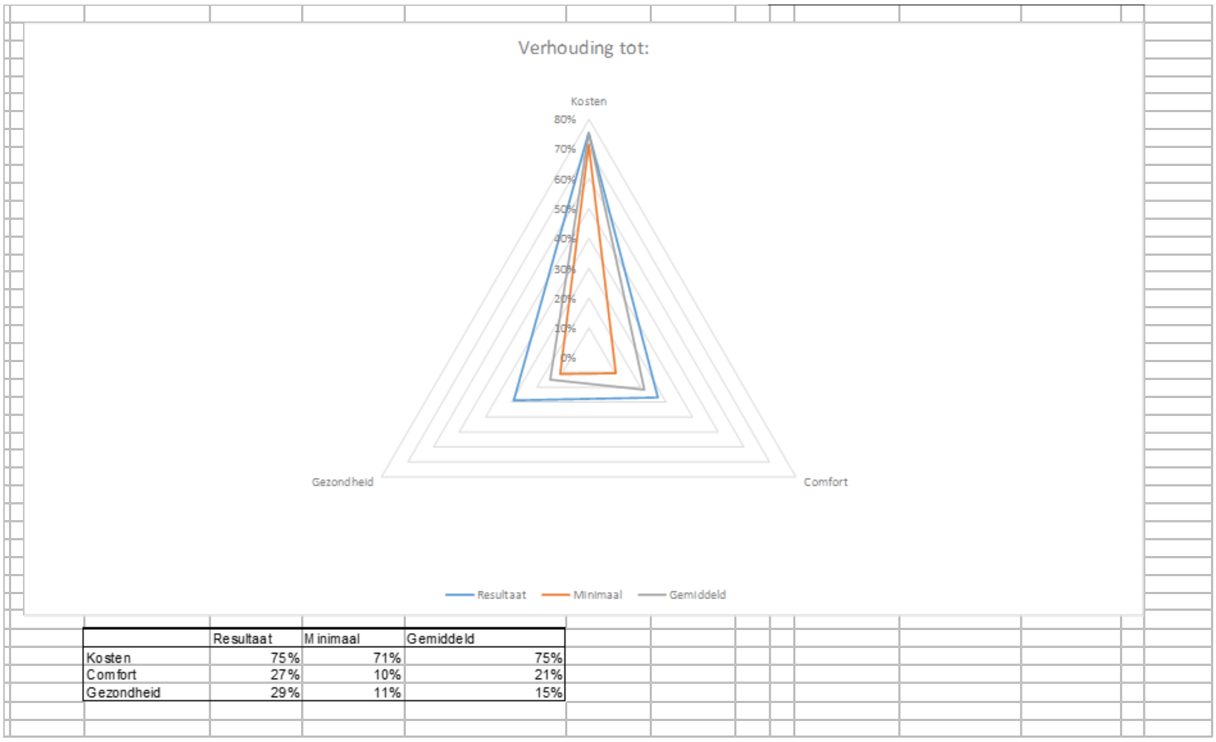
7.4 Using a TCO trade-off instrument to indicate per alternative the trade-off between costs and performance

Within the Dutch team of the AZEB project a decision supporting tool has been developed which in the same program calculates the total cost of ownership, abbreviated as TCO, as well as the performance gains the project is aiming for on user requirements such as energy performance, comfort and health. The tool is developed to facilitate better decision making for AZEBs and specifically aims to give the user and the climate goals a central position in the decision making process. When unilaterally trying to reduce costs, for example by shortening the design phase, applying cheaper materials or implementing quicker setting techniques, there is always a risk that user values like health, safety, value of the building et cetera are violated. For example because moisture and mould problems arise, because the floor plan is suboptimal for use or because a nasty draught[8] arises. Therefore, when attempting to optimize a design, it should never be only for cost. When making decisions to reduce costs, the decision maker should always have a clear view on the trade-off involved. This tool intends to visualize this trade-off for each alternative that is considered and this way help the decision maker make better and more balanced decisions, from a lifecycle perspective.

7.4.1 Contents, look and feel of the AZEB TCO trade off tool

The TCO trade-off instrument is an extensive excel file with multiple tabs, each connected to each other. For each design alternative the project is considering, the tabs can be filled with the corresponding data. Depending on the phase the project is in, these data can be either real or an estimation. Some of the data, like costs, are in principle objective. Some other data, like scores for comfort or health, might be based on expert judgement and more subjective or relative. The results coming from this instrument, as with all tools, are as good and reliable as the input of data is. The main result is shown in a graph that shows the relative performance of the instrument on the factors Cost, Health and Comfort. However, for good interpretation of this graph and to let it support decision making in the right way, it is important for the professional using this tool in its process with the decision making client, to explain the principles and assumptions behind the graph. An example of the final graph is shown in the picture below. The orange line shows the minimum result required (by law in the concerning country), the grey shows the average scores for the calculated alternatives of this project (or even of a database of projects). The blue line is the result for this specific alternative.

Figure 40 Picture of the main graph produced by the AZEB TCO trade-off tool.



	Resultaat	Minimaal	Gemiddeld
Kosten	75%	71%	75%
Comfort	27%	10%	21%
Gezondheid	29%	11%	15%

Below a tab from a Dutch project is shown as another example of how the tool looks to the user. It shows among others the price for electricity, different taxes for energy and storage of sustainable energy, VAT, costs for the net and tax deductions for sustainable energy generation. These are specific for a country and often even for different regions in a country.

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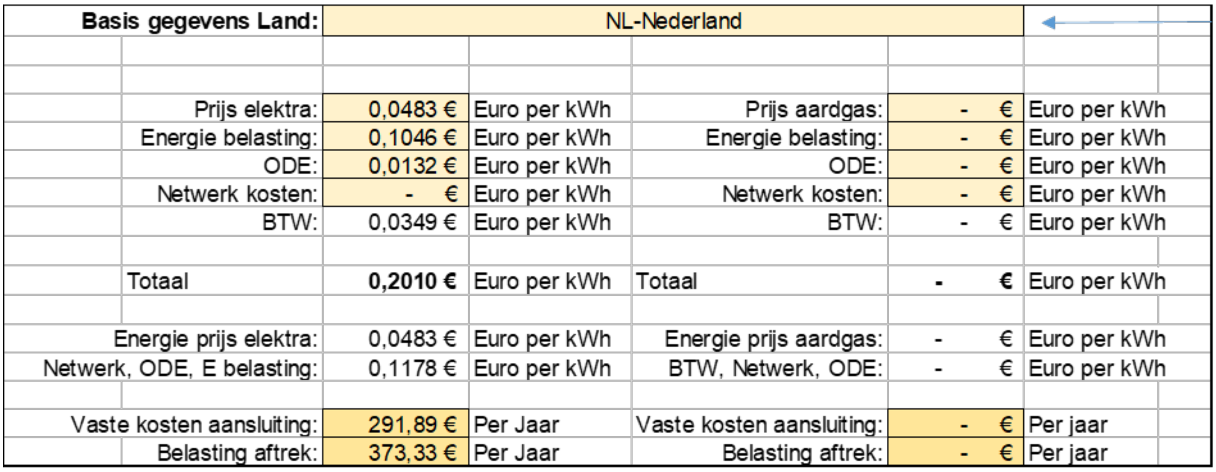
[8] according to the user's view, but an expert could think the cause may rather be related to thermal bridges and lack of ventilation.

Figure 41 Example of a tab that needs to be filled in the AZEB TCO trade-off tool: this tab is on energy costs.



Basis gegevens Land:	NL-Nederland				
Prijs elektra:	0,0483 €	Euro per kWh	Prijs aardgas:	- €	Euro per kWh
Energie belasting:	0,1046 €	Euro per kWh	Energie belasting:	- €	Euro per kWh
ODE:	0,0132 €	Euro per kWh	ODE:	- €	Euro per kWh
Netwerk kosten:	- €	Euro per kWh	Netwerk kosten:	- €	Euro per kWh
BTW:	0,0349 €	Euro per kWh	BTW:	- €	Euro per kWh
Totaal	**0,2010 €**	Euro per kWh	Totaal	**- €**	Euro per kWh
Energie prijs elektra:	0,0483 €	Euro per kWh	Energie prijs aardgas:	- €	Euro per kWh
Netwerk, ODE, E belasting:	0,1178 €	Euro per kWh	BTW, Netwerk, ODE:	- €	Euro per kWh
Vaste kosten aansluiting:	291,89 €	Per Jaar	Vaste kosten aansluiting:	- €	Per jaar
Belasting aftrek:	373,33 €	Per Jaar	Belasting aftrek:	- €	Per jaar

Another example is the tab in the picture below. This tab shows many different measured social performance indicators, their priority as stated by the decision maker and how the expert judges their contribution to the final comfort and health scores of this instrument. This expert judgement should be substantiated explicitly in an accompanying document. The AQSI tool that was described in chapter 4 may be used for this.

Figure 42 Example of a tab that needs to be filled in the AZEB TCO trade-off tool: this tab is on performance on social indicators.

	Prioriteit	Comfort		Gezondheid		Richtlijnen en uitvoering norm
		1 tot 3		1 tot 3		
Gezondheid en Comfort						**Beschrijving normen / wetgeving / richtlijnen**
Thermisch comfort	Nice to have	3	Punten	3	Punten	Catogorie 3 volgens EN 15251
Binnenlucht kwaliteit	Must	3	Punten	3	Punten	Catogorie 3 volgens EN 15251
Akoestische kwaliteit	Want	3	Punten	3	Punten	Catogorie 3 volgens EN 15251
Visueel comfort			Punten		Punten	EN 16309
Ruimtelijke eigenschappen			Punten		Punten	
			Punten		Punten	
Toegankelijkheid						
Gebruikersgebieden	Nice to have	1	Punten	2	Punten	EN 16309
Installaties			Punten		Punten	
			Punten		Punten	
Aanpasbaarheid						
Individueel gebruiker			Punten		Punten	
Verandering van gebruik			Punten		Punten	
Technische wijzigingen			Punten		Punten	
Functiewijziging	Want	1	Punten		Punten	EN 16309
			Punten		Punten	
Invloed op de omgeving						
Trillinghinder			Punten		Punten	
Verblinden schaduw			Punten		Punten	
Emissies			Punten		Punten	
Geluidhinder			Punten		Punten	
			Punten		Punten	
Onderhoud						
Pers. Veiligheid			Punten		Punten	
Brandveiligheid			Punten		Punten	
Gezondheid en comfort	Must	3	Punten	3	Punten	EN 16309
			Punten		Punten	
Veiligheid						
Uitval nutsvoorzieningen			Punten		Punten	
Pers. Veiligheid			Punten		Punten	
Ongevallen brandveiligheid			Punten		Punten	
			Punten		Punten	
			Punten		Punten	
Overige						
Geen CMR stoffen (kankerverwekkend)	Must		Punten	3	Punten	EN 15804
25 m2 per bewoner	Nice to have	1	Punten	1	Punten	NEN 2580 / VVO
			Punten		Punten	
			Punten		Punten	
			Punten		Punten	
			Punten		Punten	
			Punten		Punten	

7.4.2 Different applications of the AZEB TCO trade off tool

The AZEB TCO trade-off tool may be used to support decision making in all phases of the project. Its greatest added value is in the initiative and design phases. Early in the project it can use estimations to select the most promising alternatives. Later in the design, as the available designs and data become more detailed, the tool can be updated and becomes more reliable in its predicting value concerning the trade-offs. In the engineering phase it can serve as substantiation for the design choices made.

When used in several projects, the tool can facilitate comparisons, even across country borders. Since it explicitly incorporates and specifies country-bound indicators (like norms and calculation methods), economic and societal differences are calculated for and interesting analyses might be made.

The AZEB TCO trade-off tool also incorporates the specifics of national or regional financial and real estate markets. This makes it possible to show the impact of this factor on cost and may provide interesting implications for financing models and real estate value.

This instrument may be used stand-alone, but can become even more powerful when combined with other instruments like the PHPP or AQSI or when embedded in integrative processes such as value engineering.

7.4.3 Applications of the AZEB TCO trade off tool in the AZEB case studies of WP3

The existing beta-version of this decision supporting tool will be tested in at least 2 case studies within WP3, each in another country. This way we can explore the full potential of a tool such as this, ranging from the benefits of using this tool for a single AZEB project to the benefits of using this tool for comparing projects between countries and possible implications for the impact of policy making and on real estate value. In WP4, training material will be created to help users apply the tool.

7.5 **Discussion and recommendations**

The tools and methods described in the previous paragraphs are optimization tools to further improve the quality of the decision making throughout the project. These tools have the highest impact during the initiative and design phase, when there is still plenty of opportunity to change the course of the project without significant extra costs. They can be used for validation and verification of certain decisions, in other words: To prove that one has made the right choices. Alternatively, they may aid in actually optimizing decisions. In the case studies which will we performed within the AZEB project, we will demonstrate some instances of how these methods can be used in an actual project to improve results.

7.6 **Literature**

Decision Analysis for the Professional, 2001-2008, Peter McNamee and John Celona, book available by download from: https://smartorg.com/wp-content/uploads/2011/08/Decision-Analysis-for-the-Professional.pdf

Information and informative video’s on value engineering may be found at: https://www.value-eng.org/

Recht T., Schalbart P., and Peuportier B., Ecodesign of a "plus energy" house using stochastic occupancy model, life cycle assessment and multi-objective optimisation, Hamza N and Underwood C. (Ed), Building Simulation & Optimization 2016, Newcastle, September 2016

8 Proposed indicators for the AZEB case studies

The table below shows the proposed set of indicators to be tested in the case studies. The relevant ones will be selected according to the context of each case study. Some further recommendations will be derived and integrated in the final version of the AZEB methodology.

Energy, Quality of the building fabric	Per unit of heated or conditioned floor area
Energy needs for heating (kWh/y/m^2)	
Energy needs for cooling (kWh/y/m^2)	
Optional: *Energy use for lighting* (kWh/y/m^2)	
Optional: air tightness (Ach at 50 Pa difference or equivalent)	
Energy, users' behaviour and appliances	Per unit of heated or conditioned floor area
Energy needs for Sanitary Hot water (kWh/y/m^2)	
Total *internal gains* (kWh/y/m^2)	From lighting, appliances, IT equipment, people
Total primary Energy**, (Building fabric + systems)**	Per unit of heated or conditioned floor area On Hourly, monthly and yearly base
Total Primary energy use (kWh/y/m^2)	
Provide values for present national *primary energy factors* – PEF (3 values for each flow of delivered energy: total, renewable, non renewable) For renewable PEF distinguish between energy imported from the grid, self consumed or exported to the grid	natural gas, heat from district heating, electricity from the grid , PV, other renewables,…
Renewable energy on-site generation , export and import	Per unit of heated or conditioned floor area On Hourly, monthly and yearly base
Renewable Primary energy generated on-site (kWh/y/m^2) *Renewable Primary energy* generated on-site and Self consumed (kWh/y/m^2) *Renewable Primary energy* exported to the grid (kWh/y/m^2)	
Non Renewable Primary Energy**, or Global *primary energy* balance**	Per unit of heated or conditioned floor area On Hourly, monthly and yearly base
Non Renewable Primary energy use without compensation for exported energy (kWh/y/m^2)	
Non Renewable Primary energy use with 100% compensation for exported energy (consumption minus on-site generation in kWh/y/m^2)	

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Renewable Primary energy use considering the 100% renewable scenario (kWh/y/m^2). In this case it coincides with *Total Primary energy use*	
Ratio of *renewable primary energy* over the *total primary energy* use (with and without compensation) (%)	
Calculation time step	Please specify whether the calculation time step is an hour, a month or a year
Costs	Per unit of heated or conditioned floor area
Construction cost (€/m^2)	
Life cycle cost (€/m^2)	
Operational energy and energy related maintenance costs (€/m^2 y)	
LCA	Per unit of heated or conditioned floor area
Greenhouse gases emissions (kg $CO_2/m^2/y$)	Precising including or excluding biogenic CO_2
Primary energy use (kWh/y/m^2)	Precising if total or non renewable
Reference study period (years)	
Optional: other impacts	
Comfort	(EN 1525) (Carlucci and Pagliano 2012)
Percentage outside the range	the percentage of hours of occupation when the — actual or simulated — PMV or indoor operative temperature are outside the specified comfort range of comfort category II
Degree-hours criterion	Sum over occupied hours, each I weighted by a factor, wf, which depends on the module of the dif- ference between operative temperature, at a certain hour, and the lower or upper limit, of the comfort range of comfort category II
Social indicators	Based on EN16309
All: Health and comfort 1) Acoustic comfort 2) Indoor Air Quality 3) Thermal comfort (as per previous row) *Optional*: all other categories from EN16309: • Accessibility • Adaptability • Maintenance and Maintainability • Safety and Security • Impact on the neighbourhood • Materials and services sources • Involvement of stakeholders	

9 Annex: indicators in national regulations

This annex provides example indicators from national regulations.

Spain

This questionnaire has been completed using the following documents as a reference:

- RD 1027/2007 – Regulation for thermal installations in buidings
- CTE DB HE 2018 – Draft building regulations with energy requirements for buildings, expected for publication in summer/autumn 2018, replacing CTE DB HE 2013

Comfort objectives of the design	
Which comfort standard is used as a reference ?	ISO 7730:2005
The comfort objectives of the design are based on the PMV model?	x_ yes _ no (it is based actually on PPD)
The comfort objectives of the design are based on the Adaptive Comfort model?	_ yes x_ no
Which comfort categories is prescribed? (EN 15251 suggests category II for new buildings)	_I; _II, _ III No category explicitly required. An example shown on how to calculate set point temperatures is based on PPDs between 10-15%, which corresponds to category III
Which long term comfort indices from EN 15251 (or other legislation/literature) are chosen/suggested in your national legislation?	Specify Not considered
Quality of the envelope	
Energy needs for heating	_ yes x_ no
Energy needs for cooling	_ yes x_ no
Energy needs for domestic hot water	_ yes x_ no
Energy use for lighting	_ yes x_ no
Is there a global energy need indicator (including two or more services) in your country, and for which services/end-uses? If yes, which are the weighting factors?	_ yes x_ no _ heating _ cooling _ domestic hot water _ lighting If yes, provide values of the weighting factors
Reference area used in calculating indicators /m2 y	_ total floor area _ net floor area _x thermally conditioned space area _ other, please specify:
Other indicators (e.g. air tightness)	please specify: ____Air tightness for windows and doors, corresponding to Class 2 and 3 from EN 12207:2017 (depending on the climate zone)____
Quality of Envelope+systems	
Total primary energy (use)	_x yes _ no
If yes, reference area	_ total floor area _ net floor area x_ thermally conditioned space area _ other, please specify:
Provide values for primary energy factors (fill he table at the bottom providing for each carrier or energy source:	_x electricity from the grid _x natural gas _on-site PV x_biomass _ other, please specify:

Non renewable primary energy factor **f**$_{P,NREN}$ Renewable primary energy factor **f**$_{P,REN}$ Total primary energy factor **f**$_{P,TOT}$	
Accounting for renewable energy production	
Non-renewable primary energy If yes, indicate which is the reference area used in your country	_x yes _ no total floor area _ net floor area x_ thermally conditioned space area _ other, please specify:
Global primary energy balance	
Does the legislation in your country make use of the concept of "global *non-renewable primary energy balance*", equal to "*total* global *primary energy use*" minus "*self consumed primary energy* from *on-site* RES" minus "exported *primary energy* from *on-site* RES " (this latter being possibly accounted only partially or as zero in some countries)? Equivalent to the term *Numerical indicator of non-renewable primary energy use with compensation* in ISO 52000.	_ yes x_ no
If, yes, provide in the table below the values of the primary energy factors for exported electricity (which is in relation with the factor kexp)	Provide values in the table below
If yes, indicate the reference area used in your country using the term in your national language and the corresponding ISO term.	_ total floor area _ net floor area _ thermally conditioned space area _ other, please specify:
If yes, indicate the calculation time step under which it is possible to consider that expoted renewable energy compensates for energy use (e.g. in Italy compensation is possible only within eah calendar month, and excluded between different calendar months).	_ hourly _ monthly _ yearly

Table with adopted National values of *primary energy factors* (non-renewable, renewable, total)

Energy carrier	**f**$_{P,NREN}$	**f**$_{P,REN}$	**f**$_{P,TOT}$
Natural gas	1,190	0,005	1,195
GPL	1,201	0,003	1,204
Fuel oil	1,179	0,003	1,182
Coal	1,082	0,002	1,084
Solid biomass	0,034	1,003	1,037
Liquid and gaseous biomass			
Electric energy from the grid	2,007	0,396	2,403
District heating			
Municipal solid waste			
District cooling			
Thermal energy from solar collectors			

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Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumed)			
Electric energy produced by photovoltaic, small scale wind/hydro electricity (exported to the grid)			
Thermal energy from the external environment - Free cooling			
Thermal energy from the external environment - Heat pump			
Solid biomass (pellets)	0.085	1,028	1,113

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France

The French regulation RE2020 is still being discussed, so that no finalized document exists but some preliminary information has been used to derive the table hereunder (see http://www.batiment-energiecarbone.fr/niveaux-de-performance-et-label/niveaux-de-performance/9).

Comfort objectives of the design	
Which comfort standard is used as a reference?	
The comfort objectives of the design are based on the *PMV* model?	_ yes X no
The comfort objectives of the design are based on the *Adaptive* Comfort model?	X yes _ no
Which *comfort categories* is prescribed? (EN 15251 suggests category II for new buildings)	_I; X II, _ III
Which *long term comfort indices* from EN 15251 (or other legislation/literature) are chosen/suggested in your national legislation?	A specific French indicator (degree-days of discomfort)
Quality of the envelope	
Energy needs for heating	Xyes _ no
Energy needs for cooling	X yes _ no
Energy needs for domestic hot water	_ yes X no
Energy use for lighting	X yes _ no
Is there a *global energy need* indicator (including two or more services) in your country, and for which *services/end-uses*? If yes, which are the weighting factors?	X yes _ no X heating X cooling _ domestic hot water X lighting If yes, provide values of the weighting factors 1 for heating and cooling, 2.5 for lighting
Reference area used in calculating indicators /m^2 y	_ *total floor area* X *net floor area* _ *thermally conditioned space* area _ other, please specify:
Other indicators (e.g. air tightness)	please specify: ____
Quality of Envelope+systems	
Total primary energy (use) (in fact "primary energy use, including non renewable and limited renewable (e.g. wood, hydro-electricity)"	X yes _ no
If yes, reference area	_ *total floor area* X *net floor area* _ *thermally conditioned space* area _ other, please specify:
Provide values for *primary energy factors* (fill he table at the bottom providing for each carrier or energy source: *Non renewable primary energy factor* $\mathbf{f}_{P,NREN}$ *Renewable primary energy factor* $\mathbf{f}_{P,REN}$ *Total primary energy factor* $\mathbf{f}_{P,TOT}$	2.58 electricity from the grid 1natural gas 2.58 *on-site* PV 1 biomass _ other, please specify:

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9 accessed 26/10/2018

Accounting for *renewable energy* production	
Non-renewable primary energy If yes, indicate which is the reference area used in your country	X yes _ no *total floor area* X *net floor area* _ *thermally conditioned space* area _ other, please specify:
Global *primary energy* balance	
Does the legislation in your country make use of the concept of "global *non-renewable primary energy balance*", equal to "*total* global *primary energy use*" minus "*self consumed primary energy* from *on-site* RES" minus "exported *primary energy* from *on-site* RES " (this latter being possibly accounted only partially or as zero in some countries)? Equivalent to the term *Numerical indicator of non-renewable primary energy use with compensation* in ISO 52000. If, yes, provide in the table below the values of the *primary energy factors* for **exported** electricity (which is in relation with the factor k_{exp} of EN ISO 52000) If yes, indicate the reference area used in your country using the term in your national language and the corresponding ISO term. If yes, indicate the calculation time step under which it is possible to consider that exported renewable energy compensates for energy use (e.g. in Italy compensation is possible only within each calendar month, and excluded between different calendar months).	X yes _ no Provide values in the table below _ *total floor area* X *net floor area* _ *thermally conditioned space* area _ other, please specify: X hourly _ monthly _ yearly

Table with adopted National values of *primary energy factors* (non-renewable, renewable, total)

Energy carrier	$f_{P,NREN}$*	$f_{P,REN}$*	$f_{P,TOT}$*
Natural gas	1	0	1
GPL	1	0	1
Fuel oil	1	0	1
Coal	1	0	1
Solid biomass	0	1	1
Liquid and gaseous biomass	0	1	1
Electric energy from the grid	2.58	0	2.58
District heating	1	0	1
Municipal solid waste	1	0	1
District cooling	1	0	1
Thermal energy from solar collectors	0	1	1

Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumed)	0	2.58	2.58
Electric energy produced by photovoltaic, small scale wind/hydro electricity (exported to the grid)	0	1	1
Thermal energy from the external environment - Free cooling	0	1	1
Thermal energy from the external environment - Heat pump	0	1	1
Solid biomass (pellets)	0	1	1

* the distinction between renewable and non renewable does not make sense because e.g. using wood in a building reduces the wood resource, which is limited, for other buildings though wood is renewable. The same is true when using hydro-electricity. On the other hand, using electricity produced by PV modules on the roof of a building does not reduce the resource for other buildings.

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Italy

This questionnaire has been completed using the following documents as a reference: (please indicate the reference national legislation and standards on which your responses are based)

- CAM (Criteri Ambientali Minimi) 6/11/2017
- UNI EN 13788 Decree 26 giugno 2015
- DM 26 June 2015 - annex 1
- Legislative Decree 3 March 2011 - annex 3
- Decree 8 March 2017 “Disposizioni in merito alla disciplina per l’efficienza energetica degli edifici ed al relativo attestato di prestazione energetica”

Comfort objectives of the design	
Which comfort standard is used as a reference?	PMV/PPD (Fanger comfort model) as defined in ISO 7730:2005
The comfort objectives of the design are based on the PMV model?	_x yes _ no
The comfort objectives of the design are based on the Adaptive Comfort model?	_ yes x no
Which comfort categories is prescribed? (EN 15251 suggests category II for new buildings)	_I; _II, _ III Category B according to ISO 7730 (which corresponds to II category of EN 15251)
Which long term comfort indices from EN 15251 (or other legislation/literature) are chosen/suggested in your national legislation?	Specify Not specified
Quality of the envelope	
Energy needs for heating	_ x yes _ no
Energy needs for cooling	_ x yes _ no
Energy needs for domestic hot water	_ yes _ x no
Energy use for lighting	_ yes _ x no
Is there a global energy need indicator (including two or more services) in your country, and for which services/end-uses? If yes, which are the weighting factors?	_ yes _ x no _ heating _ cooling _ domestic hot water _ lighting If yes, provide values of the weighting factors
Reference area used in calculating indicators /m2 y	_ total floor area _ net floor area _ thermally conditioned space area other, please specify: the net floor area which is conditioned “area della superficie utile dell’edificio”, according to Decree 8 March 2017
Other indicators (e.g. air tightness)	please specify: • Transmission heat transfer coefficient per unit of *thermal envelope area* [W/m²K] • Equivalent summer solar area per unit of *useful floor area [-]*
Quality of Envelope+systems	
Total primary energy (use)	_ x yes _ no
If yes, reference area	_ total floor area _ net floor area _ thermally conditioned space area _ other, please specify: the net floor area which is conditioned “area della superficie utile dell’edificio”, according to Decree 8 March 2017

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Provide values for primary energy factors (fill he table at the bottom providing for each carrier or energy source: Non renewable primary energy factor $\mathbf{f}_{P,NREN}$ Renewable primary energy factor $\mathbf{f}_{P,REN}$ Total primary energy factor $\mathbf{f}_{P,TOT}$	_ electricity from the grid _ natural gas _on-site PV _biomass _ other, please specify:
Accounting for renewable energy production	
Non-renewable primary energy If yes, indicate which is the reference area used in your country	_ yes _x no total floor area _ net floor area _ thermally conditioned space area _ other, please specify: the systems producing thermal energy must be sized and realized to guarantee the contemporary fulfillement of two requests: a) to cover 50 % of the expected *primary energy* for domestic hot water (DHW) and b) 50 % of the sum of the expected *primary energy* for DHW, heating and cooling, using energy produced from Renewable Energy Sources (RES) plants. Moreover, c) the power of the electrical renewable energy systems installed has to be greater o equal to P= (1/K)*S, where S is the footprint surface of the building at ground level (in m2) and K = 50 m2/kW. For public buildings, these obligations are increased by 10%.
Global *primary energy* balance	
Does the legislation in your country make use of the concept of "global *non-renewable primary energy balance*", equal to "*total* global *primary energy use*" minus "*self consumed primary energy* from *on-site* RES" minus "exported *primary energy* from *on-site* RES " (this latter being possibly accounted only partially or as zero in some countries)?	_ yes x no In Italian regulation nZEB are defined using the *total primary energy* and not the *non-renewable primary energy*. In the calculation of *total primary energy* if a building generates on site electric energy from PV, this is weighted with a *total primary energy factor* equal to 1, while electric energy imported from the grid is weighted 2.42. There is hence incentives to generate locally and self-consume in order to lower the *total primary energy* index. The calculation is only approximate: since the calculation is done on monthly steps all the RES energy generated in one month is considered self-consumed if it exceeds the energy use in that month; if the calculation would be on hourly based part of that RES would be not self-consumed but sold to the grid and hence will not appear in the calculation.
Equivalent to the term Numerical indicator of non-renewable primary energy use with compensation in ISO 52000.	
If, yes, provide in the table below the values of the primary energy factors for exported electricity (which is in relation with the factor kexp of EN ISO 52000)	
If yes, indicate the reference area used in your country using the term in your national language and the corresponding ISO term.	Provide values in the table below
If yes, indicate the calculation time step under which it is possible to consider that exported renewable energy compensates for energy use (e.g. in Italy compensation is possible only within each calendar month, and excluded between different calendar months).	_ total floor area _ net floor area _ thermally conditioned space area _ other, please specify: _ hourly _ monthly _ yearly

Table with adopted National values of *primary energy factors* (non-renewable, renewable, total)

Energy carrier	$f_{P,NREN}$	$f_{P,REN}$	$f_{P,TOT}$
Natural gas	1.05	0	1.05
GPL	1.05	0	1.05
Fuel oil	1.07	0	1.07
Coal	1.1	0	1.1
Solid biomass	0.2	0.8	1
Liquid and gaseous biomass	0.4	0.6	1
Electric energy **from** the grid	1.95	0.47	2.42
District heating	1.5	0	1.5
Municipal solid waste	0.2	0.2	0.4
District cooling	0.5	0	0.5
Thermal energy from solar collectors	0	1	1
Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumption)	0	1	1
Electric energy produced by photovoltaic, small scale wind/hydro electricity (export **to** the grid).	0	1 (only to counterbalance consumption in the same month, NOT in the entire year)	1 (only to counterbalance consumption in the same month, NOT in the entire year)
Thermal energy from the external environment - Free cooling	0	1	1
Thermal energy from the external environment - Heat pump	0	1	1

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Germany

Preliminary remarks: The national implementation of the NZEB in Germany has not yet been finalized. There was a draft for this, but it was withdrawn.

The following information assumes that the currently valid calculation methods are also used in the NZEB specifications.

Comfort objectives of the design	(Information on current national calculation method)
Which comfort standard is used as a reference?	The room temperature requirements of the national energy balance method are specified in the standards [DIN V 18599] or [DIN 4108-6] / [DIN 4701-10] and are differentiated according to use: Room set point temperature for the heating case: Residential building: - 20°C (according to [DIN V 18599], 19°C (according to [DIN 4108-6]) Office building: - 21°C (according to [DIN V 18599], 19°C (according to [DIN 4108-6]) Room set point temperature for cooling (if the building is equipped with an active cooling system): Residential building: 25°C according to [DIN V 18599], Office building: 24°C according to [DIN V 18599] Assessment of summer comfort in buildings without active cooling according to [DIN 4108-2]: Requirement value of overheating degree hours 1200Kh / a in residential construction and 500Kh / a in non-domestic buildings at given internal boundary temperatures. Reference values of the internal temperature for three climatic regions in Germany: A) 25°C B) 26°C C) 27°C Calculation method for Passive Houses [PHPP]: Room set point temperature for the heating case: 20 ° C Room set point temperature for cooling (if the building is equipped with an active cooling system): 25 ° C Assessment of summer comfort in buildings without active cooling according to [PHPP]: Requirement value of the over-temperature frequency at a reference internal temperature of 25 ° C: ≤ 10%
The comfort objectives of the design are based on the PMV model?	- see above
The comfort objectives of the design are based on the Adaptive Comfort model?	- see above

Which *comfort categories* is prescribed? (EN 15251 suggests category II for new buildings)	- see above
Which *long term comfort indices* from EN 15251 (or other legislation/literature) are chosen/suggested in your national legislation?	Specify
Quality of the envelope	(Information on current national calculation method)
Energy needs for heating	- No. But requirement for specific on the building envelope related transmission heat loss.
Energy needs for cooling	- No. But requirement for summer case according to [DIN 4108-2].
Energy needs for domestic hot water	- No. But request for thermal insulation of domestic hot water distribution lines.
Energy use for lighting	- No
Is there a *global energy need* indicator (including two or more services) in your country, and for which services/end-uses? If yes, which are the weighting factors?	- No If yes, provide values of the weighting factors
Reference area used in calculating indicators $/m^2$ y	_ total floor area _ net floor area _ thermally conditioned space area _ other, please specify:
Other indicators (e.g. air tightness)	air tightness Building with ventilation system - n50 ≤ 1.5 1/h Building without ventilation system - n50 ≤ 3.0 1/h
Quality of Envelope + systems	(Information on current national calculation method)
Total primary energy (use)	Yes. The maximum permitted annual energy demand is established using the so-called reference building method. Here the reference building corresponds to the building to be verified in terms of geometry and orientation, but constructed with building components and technical systems for the reference building specified in the currently applicable ordinance EnEV.
If yes, reference area	The national process uses the following energy reference areas: Residential building: - "usable area" = building volume x 0.32 m-1 Non-residential building: - net floor area
Provide values for *primary energy factors* (fill he table at the bottom providing for each carrier or energy source: Non renewable primary energy factor $\mathbf{f}_{P,NREN}$ *Renewable primary energy factor* $\mathbf{f}_{P,REN}$ *Total primary energy factor* $\mathbf{f}_{P,TOT}$	_ electricity from the grid _ natural gas _on-site PV _biomass _ other, please specify:

Accounting for renewable energy production	(Information on current national calculation method)
Non-renewable primary energy If yes, indicate which is the reference area used in your country	- Yes. As below “Total primary energy”
Global primary energy balance	(Information on current national calculation method)
Does the legislation in your country make use of the concept of "global *non-renewable primary energy balance*", equal to "*total* global *primary energy use*" minus "*self consumed primary energy* from *on-site* RES" minus "exported *primary energy* from *on-site* RES " (this latter being possibly accounted only partially or as zero in some countries)? Equivalent to the term Numerical indicator of non-renewable primary energy use with compensation in ISO 52000.	- Yes
If, yes, provide in the table below the values of the primary energy factors for exported electricity (which is in relation with the factor kexp of EN ISO 52000)	Provide values in the table below
If yes, indicate the reference area used in your country using the term in your national language and the corresponding ISO term.	- reference area: As described above in “Total primary energy”
If yes, indicate the calculation time step under which it is possible to consider that exported renewable energy compensates for energy use (e.g. in Italy compensation is possible only within each calendar month, and excluded between different calendar months).	- monthly

Table with adopted National values of *primary energy factors* (non-renewable, renewable, total)

Energy carrier	$f_{P,NREN}$	$f_{P,REN}$	$f_{P,TOT}$
Natural gas	1.1		1.1
GPL			
Fuel oil	1.1		1.1
Coal (stone coal)	1.1		1.1
Solid biomass	0.2		1.2
Liquid and gaseous biomass	1.1		1.5
Electric energy from the grid	1.8		
District heating CHP (Share of CHP of 70%), fossil fuel	0.7		0.7
District heating heating station (no CHP), fossil fuel	1.3		1.3

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Municipal solid waste			
District cooling			
Thermal energy from solar collectors	0.0		1.0
Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumed)			
Electric energy produced by photovoltaic, small scale wind/hydro electricity (exported to the grid)			
Electric energy produced by combined heat and power CHP (exported to the grid)	2.8		
Thermal energy from the external environment - Free cooling	0.0		1.0
Thermal energy from the external environment - Heat pump	0.0		1.0
Solid biomass (pellets)	0.2		1.2

The Netherlands

Comfort objectives of the design	
Which comfort standard is used as a reference?	NEN-EN-ISO 7730:2005- Climate conditions - Analytical determination and interpretation of thermal comfort by calculations of PMV and PPD values and local thermal comfort NEN-EN 15251: 2007 - Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings – Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics. ISS0 74:2004: Thermal comfort - requirements for indoor temperature in office buildings and similar utility buildings
The comfort objectives of the design are based on the *PMV* model?	_x yes _no
The comfort objectives of the design are based on the *Adaptive* Comfort model?	_x yes _no (NEN-EN 15251 and ISSO 74)
Which *comfort categories* is prescribed? (EN 15251 suggests category II for new buildings)	No regulation. Recommended: For buildings for vulnerable people or special circumstances: Category A (I) For standard buildings for healthy people: Category B (II) For temporary or existing buildings: Category C(III) according to ISO 7730 (which corresponds to resp. categories I, II, III of EN 15251)
Which *long term comfort indices* from EN 15251 (or other legislation/literature) are chosen/suggested in your national legislation?	Not specified in legislation
Quality of the envelope	
Energy needs for heating	_ yes _ x no
Energy needs for cooling	_ yes _ x no
Energy needs for domestic hot water	_ yes _ x no Not regulated directly (EPG) From 2020: Indicator 2 (BENG) includes *primary energy* use for domestic hot water
Energy use for lighting	_ yes _ x no Not regulated directly (EPG) From 2020: Indicator 1 (BENG) includes energy need for lightning in case of utility buildings, also the *primary energy* use for lighting will be part of BENG indicator 2.
Is there a *global energy need* indicator (including two or more services) in your country, and for which *services/end-uses*? If yes, which are the weighting factors?	_ yes _ x no Not regulated directly (EPG) From 2020: Indicator 1 (BENG) includes energy needs for heating and cooling and for lightning (in case of utility buildings) all together
Reference area used in calculating indicators /m^2 y	_ net floor area other, please specify: the net floor area according to NEN 2580:2007
Other indicators (e.g. air tightness)	please specify: Airtightness qv;10 in dm^3/s Volumetric air flow in dm^3/s Setpoint temperatures in °C

	Ect.
Quality of Envelope+systems	
Total primary energy (use)	_ x yes _ no
If yes, reference area	_ *total floor area* _ x *net floor area* _ *thermally conditioned space* area _ other, please specify: the net floor area according to NEN 2580:2007
Provide values for *primary energy factors* (fill the table at the bottom providing for each carrier or energy source: *Non renewable primary energy factor* $f_{P,NREN}$ *Renewable primary energy factor* $f_{P,REN}$ *Total primary energy factor* $f_{P,TOT}$	_ electricity from the grid _ natural gas _*on-site* PV _biomass _ other, please specify:
Accounting for *renewable energy* production	
Non-renewable primary energy If yes, indicate which is the reference area used in your country	_ x yes _no _*total floor area* _*x net floor area* _ *thermally conditioned space* area _ other, please specify:
Global *primary energy* balance	
Does the legislation in your country make use of the concept of "global *non-renewable primary energy balance*", equal to "*total* global *primary energy use*" minus "*self consumed primary energy* from *on-site* RES" minus "exported *primary energy* from *on-site* RES " (this latter being possibly accounted only partially or as zero in some countries)? Equivalent to the term *Numerical indicator of non-renewable primary energy use with compensation* in ISO 52000. If, yes, provide in the table below the values of the *primary energy factors* for **exported** electricity (which is in relation with the factor k_{exp} of EN ISO 52000) If yes, indicate the reference area used in your country using the term in your national language and the corresponding ISO term. If yes, indicate the calculation time step under which it is possible to consider that exported renewable energy compensates for energy use (e.g. in Italy compensation is possible only within each calendar month, and excluded between different calendar months).	q _ yes _ x no (EPG) from 2020 on: _x yes _no (BENG) Provide values in the table below _ *total floor area* _ *x net floor area* _ *thermally conditioned space* area _ other, please specify: _ hourly _ monthly _ x yearly

Table with dutch values of *primary energy factors* (non-renewable, renewable, total) (EPG/NEN 7120):

Energy carrier	$f_{P,NREN}$	$f_{P,REN}$	$f_{P,TOT}$
Natural gas	-	-	1
GPL	-	-	-
Fuel oil	-	-	1
Coal (stone coal)	-	-	-
Solid biomass	-	-	0/0.5/1
Liquid and gaseous biomass	-	-	0/0.5/1
Electric energy from the grid	-	-	2,56
District heating CHP (Share of CHP of 70%), fossil fuel	-	-	NEN 7125
District heating heating station (no CHP), fossil fuel	-	-	NEN 7125
Municipal solid waste	-	-	NEN 7125
District cooling	-	-	NEN 7125
Thermal energy from solar collectors	-	-	-
Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumed)	-	-	2,56
Electric energy produced by photovoltaic, small scale wind/hydro electricity (exported to the grid)	-	-	2
Electric energy produced by combined heat and power CHP (exported to the grid)	-	-	2
Thermal energy from the external environment - Free cooling	-	-	1.0
Thermal energy from the external environment - Heat pump	-	-	1.0
Solid biomass (pellets)	-	-	0/0.5/1

Bulgary

This questionnaire has been completed using the following documents as a reference:

- Regulation Nr. RD-16-1058/10.12.09 – regulation for the energy consumption parameters and energy characteristics of buildings
- Regulation Nr 16-1594/13.11.13 – regulation for investigation of energy efficiency, certification and assessment of energy savings of buildings
- Regulation Nr 7 – regulation for energy efficiency, warmth savings and reduction of energy consumption in buildings

Comfort objectives of the design	
Which comfort standard is used as a reference?	There are no comfort requirements or objectives in the design
The comfort objectives of the design are based on the *PMV* model?	N/A
The comfort objectives of the design are based on the *Adaptive* Comfort model?	N/A
Which *comfort categories* is prescribed? (EN 15251 suggests category II for new buildings)	N/A
Which *long term comfort indices* from EN 15251 (or other legislation/literature) are chosen/suggested in your national legislation?	N/A
Quality of the envelope	
Energy needs for heating	yes
Energy needs for cooling	yes
Energy needs for domestic hot water	yes
Energy use for lighting	yes
Is there a *global energy need* indicator (including two or more services) in your country, and for which *services/end-uses*? If yes, which are the weighting factors?	no
Reference area used in calculating indicators /m^2 y	*thermally conditioned space* area
Other indicators (e.g. air tightness)	please specify: U value for the construction elements in the envelope (walls, windows, etc.)
Quality of Envelope+systems	
Total primary energy (use)	no
If yes, reference area	N/A
Provide values for *primary energy factors* (fill he table at the bottom providing for each carrier or energy source: *Non renewable primary energy factor* $\mathbf{f_{P,NREN}}$ *Renewable primary energy factor* $\mathbf{f_{P,REN}}$ *Total primary energy factor* $\mathbf{f_{P,TOT}}$	There is just one coefficient accounting for the energy losses during production and transport, called “e_p”. For some renewable energy sources like solar radiation and wind there are no factors and the value assumed to be 0, which is an obvious mistake.
Accounting for *renewable energy* production	
Non-renewable primary energy If yes, indicate which is the reference area used in your country	No
Global *primary energy* balance	
Does the legislation in your country make use of the concept of	

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"global *non-renewable primary energy balance*", equal to "*total* global *primary energy use*" minus "*self consumed primary energy* from *on-site* RES" minus "exported *primary energy* from *on-site* RES " (this latter being possibly accounted only partially or as zero in some countries)? Equivalent to the term *Numerical indicator of non-renewable primary energy use with compensation* in ISO 52000. If, yes, provide in the table below the values of the *primary energy factors* for **exported** electricity (which is in relation with the factor k_{exp} of EN ISO 52000) If yes, indicate the reference area used in your country using the term in your national language and the corresponding ISO term. If yes, indicate the calculation time step under which it is possible to consider that exported renewable energy compensates for energy use (e.g. in Italy compensation is possible only within each calendar month, and excluded between different calendar months).	no

Table with adopted National values of *primary energy factors* (non-renewable, renewable, total)

Energy carrier	**e_p**
Natural gas	1,1
GPL	1,1
Fuel oil	1,1
Coal	1,2
Solid biomass	-
Liquid and gaseous biomass	-
Electric energy from the grid	3,0
District heating	-
Municipal solid waste	-
District cooling	-
Thermal energy from solar collectors	-
Electric energy produced by photovoltaic, small scale wind/hydro electricity (self-consumed)	-
Electric energy produced by photovoltaic, small scale wind/hydro electricity (exported to the grid)	-
Thermal energy from the external environment - Free cooling	-
Thermal energy from the external environment - Heat pump	-
Standard pellets	1,25
Heat from centralized heating system	1,30
Solid biomass (wooden pellets)	1,05

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