NEARLY ZERO ENERGY BUILDINGS AND OFF-SITE RENEWABLES

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SUMMARY

The energy performance of buildings is key for reaching the European Union's very ambitious climate targets. "Nearly zero energy building (nZEB)" is the term for a building standard that complies with this ambition. Living in 2013 we have 8 years to go until every single Member State will have to build every single new building as a nearly zero energy building, and even only 6 years to go for nearly zero energy public buildings. A reality check on European construction sites reveals the challenge linked to these targets.

A clear idea on potential configurations for today's and future nZEBs is needed. The starting point is the European Performance of Buildings Directive's (EPBD) definition: *[A nearly Zero-Energy Building is a] "building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby."* A large share of the discussion on how to fill this broad definition with life circles around the terms "on-site" and "nearby". However, this focus distracts from the potential role of "off-site" electricity in the nZEB concept. This is surprising, as electricity consumption in buildings is expected to rise due to increased uptake of heat pumps and, as electricity supply is on a path toward decarbonisation, making off-site renewable electricity for buildings a logical option to consider.

The facts and thoughts presented in this position paper reveal the complexity but also the potential organisational, financial and environmental benefits of integrating off-site electricity into the nearly-zero energy building concept. A thorough analysis of the EPBD's definition, existing concepts for nZEBs, aspects that influence the share of renewable energy and key issues around off-site renewables in nZEBs like energy cost, the advent of grid parity, metering schemes, ownership schemes of electricity generation, standardisation, monitoring, verification and enforcement has been done as a first contribution for starting a broader discussion around this topic.

Utmost energy efficiency alone will not suffice to reach the European Union's very ambitious climate targets for buildings by 2050. Renewable energy is the second pillar for constructing nZEBs. This asks for a clear set of rules on how to determine the renewable share and also for suitable metering schemes and tariff design. Here the balancing period plays a major role. Following from the preliminary analysis in this study, today balancing intervals like weeks or months seem to be most reasonable.

Although nearly-zero energy building standards will be mandatory only for new buildings by 2020, the next and even more important question is how to transform the building stock to that level by 2050. The sheer magnitude of this challenge requires that in principle every building owner must be given a sufficient set of options to have a fair and equal chance to transform his property to nearly-zero energy standard. Thus electricity from on-site, nearby *and* off-site sources must be a natural part of the set of options.

The implicit target to be reached by nearly-zero energy buildings is nearly-*zero greenhouse gas emissions* buildings which are needed for a climate neutral building stock. Therefore, the current key indicator "primary energy" should be at least complemented and maybe replaced by "greenhouse gas emissions" in the long run.

Finally nZEB must lead to *additional* environmental relief. Therefore European climate policy needs to explicitly integrate the share of renewable energy in nearly zero energy buildings into the overall picture of renewable energy targets for reaching real additional positive environmental impact rather than a bookkeeping exercise.

A lot of research still needs to be done for developing a consistent European approach for nZEBs. This paper aims to make a contribution to getting the answers in time.

INTRODUCTION

Extremely ambitious targets for reducing carbon emissions from the building sector - approximately 90% by 2050 - have been set by the European Union.

The European energy performance of buildings directive (EPBD) is the major regulatory instrument to make this happen. The recast of the EPBD published in 2010 introduced "nearly Zero-Energy Buildings" (nZEB). This standard will be mandatory for new public buildings from 2019 on and all other new buildings from 2021 on. *[A nearly Zero-Energy Building is a] "building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby."*

A lot of discussion is going on about the ambition level nZEBs should have, their cost and options for supplying them with renewable energy. Probably due to the EPBD's emphasis on renewable energy produced "on-site" or "nearby" surprisingly little discussion is going on about renewable energy produced "off-site". As nearly zero energy buildings will be mandatory for every new building, every building owner under most variable circumstances should then have a fair chance to fulfil the EPBD's requirement. The chance to do so will increase with the number of available options. There will be many cases where on-site or nearby options either won't be available or financially viable. Thus restricting nZEBs to these options will increase overall compliance cost to building owners and endanger reaching the long-term climate targets.

Therefore the major focus of this paper will be in analysing options on how to fulfil the EPBD's requirement to cover a very significant extent of the energy required by an nZEB from off-site renewable sources. More specifically we will address electricity from off-site renewable sources.

First of all we will give an overview about the EPBD and the definition for nearly-zero energy buildings. After that we will focus on different aspects having a major influence on the share of renewable energy and subsequently the energy performance of a building.

The major part of the paper will discuss key issues around the use of off-site renewable energy in nearly-zero energy buildings. It will turn out that we enter a highly complex topic where we will discuss and highlight the variety of aspects to consider, the role of future changes, major challenges to solve until the implementation of nearly zero energy buildings and also give some hints for solutions.

We will end the paper with conclusions and recommendations also pointing out further need for research.

Nearly Zero Energy Buildings (nZEBs)

The European Energy Performance of Buildings Directive's request for nZEBs

The recast EPBD was published in the Official Journal in June 2010, replacing its predecessor Directive 2002/91/EC. The recast of the EPBD introduced, in Article 9, "nearly Zero-Energy Buildings" (nZEB) as a future requirement. For new buildings occupied and owned by public authorities the requirement becomes effective by 31 December 2018 while the date for all other new buildings is 31 December 2020. The EPBD defines a nearly Zero-Energy Building as follows: *[A nearly Zero-Energy Building is a] "building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby.*" The Directive provides a comprehensive and integrated approach towards improving the efficient use of energy in both new and existing buildings, residential as well as commercial.

Although "energy" is obviously a keyword within the definition, the EPBD is not utterly clear whether energy need, energy use, delivered energy or primary energy is meant in this context. It will be one of the major tasks of the ongoing revision of EPBD related CEN standards to clarify the meaning of "energy" within the EPBD's definition for nearly zero energy buildings.

Energy efficiency obtains the top priority in the EPBD's nearly zero energy building concept. For this fact several indications can be found within the EPBD itself and its accompanying documents. A very high energy performance is mentioned first in the definition while energy from renewable sources is mentioned second and *should* to a very significant extent cover the nearly zero or very low amount of energy. Recital 15, EPBD stipulates the *"principle of first ensuring that energy needs for heating and cooling are reduced to cost optimal levels."* Finally the cost optimal guidelines accompanying the EPBD mention the "*overall spirit of the EPBD … reduce energy use first*".

Nevertheless considering the extremely ambitious EU targets for reducing carbon emissions from the building sector, by approximately 90% by 2050, (BPIE, 2011), suggest maximum carbon emissions of 3 kg/m^{2}a for the building *stock* by 2050. It is estimated that three quarters of 2050s building stock have already been built today. Due to the limited capabilities to reach such reductions in the building stock, new buildings in fact not only need to be nearly zero energy but also (nearly) zero *carbon* emissions buildings. This will only be possible by accepting the "very significant extent of energy from renewable sources" generally to be a "must" and not a "should" within the nZEB concept. Therefore a nZEB typically would be characterised by a high level of passive measures, e.g. in moderate and cold climates high insulation, very energy efficient windows, a high level of air tightness and natural/ mechanical ventilation with very efficient heat recovery in order to achieve a "nearly zero or very low amount of energy" for heating, domestic hot water, cooling, ventilation, lighting (commercial buildings) and auxiliary energy which is needed to provide these services. These are the services explicitly to be included according to the EPBD. These services generally need to be covered by renewable energy in an nZEB.

While in the building stock these services in fact cause the bulk of energy costs and environmental impact the situation is different in nZEBs. Looking at total running costs and total environmental impact of current concepts which may be considered to be equivalent with the nZEB concept, like Passive House, plug loads of home and office appliances as well as electricity for other building services (e.g. fire protection, elevators) and are typically equivalent or even higher than for the services mentioned in the EPBD. Keeping in mind the ultimate goal of minimising building-related CO_2 emissions (BPIE, 2011), household electricity or electricity for appliances should be included in a future version of the EPBD (BPIE, 2011) as well.

In this context it also has to be noted that more and more integration takes place of the formerly quite separate markets for heat and electricity - recent developments call for an integrated approach for nearly zero energy buildings with high level energy efficiency, renewable heat and cold and also with renewable electricity as main ingredients:

- Heat pumps getting more and more attractive,
- decreasing thermal loads and unchanged or even increasing electricity demand in nZEBs,
- the discovery of the load management potential of buildings,
- small-scale CHP plants ("electricity generating heating systems"),
- the storage capacity of gas and district heating networks for electricity overproduction from renewables (“power to gas”, “power to district heat”),
- carbon emissions for electricity gradually moving towards the level of gas.

As a result there must be an increasing focus on electricity consumption and supply in nZEBs.

One way to follow is to increase the efficiency of electricity use. The simultaneous track to follow is to increase the share of electricity from renewable sources in nZEBs. We will therefore elaborate the discussion on renewable electricity supply options in relation to nZEBs and provide an outline for how electricity infrastructures are affected by renewable electricity used and/or produced in nZEBs.

The role of Renewable Energy in the EPBD’s nZEB concept

Renewable energy sources are a necessity for achieving nZEBs and beyond. Therefore, it is extremely important that renewable energy applications are considered accurately in the national calculation methods or requirements in order to provide a sound basis for comparison, evaluation and monitoring.

There are different opinions among stakeholders, experts and policy makers on which renewable energy supply options may be included in the EPBD’s nZEB definition. In their study, BPIE (2011) emphasise that the EPBD text appears to be clear in saying that “*the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including [but not saying: “being” or “limited to”] energy from renewable sources produced on-site or nearby*”.

Thus, this paper analyses on-site *and* off-site renewable options mapping the technical and economic potential and the legal aspects of their application to depict their respective benefits and barriers for the building owners. The essential parameters of nZEBs with regards to renewable energy supply options and the room that the EPBD allows for the choice to be made by the building owners are discussed.

Article 2.5 of the EPBD explicitly defines “energy from renewable sources” as “*energy from renewable non-fossil sources, namely wind, solar, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases*”. Most of these options could not be used by narrowing the space around the nZEB down to on-site or nearby.

In terms of electricity, the building owner has the choice among different renewable electricity sources to fulfil the nZEB requirements. REN21 report (2012) mentions that “in power sector wind and solar photovoltaics (PV) accounted for almost 40% and 30% of new renewable capacity, respectively, followed by hydropower (nearly 25%)”. We believe that analyses of configurations where these technologies are part of nZEB concepts are fundamental for getting a complete set of potential ways towards nZEB. The possibilities for integration of electricity from on-site, nearby and off-site renewable sources are presented in Table 1. These possibilities relate to different economic aspects and market segments which consequently affect the end-user choices.

Table 1 Typical size and market segments for renewable energy applications and relevance to nZEB boundary definitions

RE generation options	On-site and nearby	Off-site
Wind		
Small scale (<2.5kW)	x	-
Community scale (<20MW)	x	x
Utility scale(>20MW)	-	x
Solar PV		
Residential systems (<10kW)	x	-
Commercial buildings (10-100kW)	x	-
Industrial plants (100 kW-1 MW)	x	x
Utility scale plants (>1MW)	-	x

Note: (1) Source for typical Solar PV sizes and market segments (EPIA-Greenpeace, 2011)

Being a future European goal, it is worthwhile looking at barriers and opportunities imposed by different renewable energy options. The determination of renewable energy options that a building owner has will depend on the project economics, technical feasibility and availability of renewable sources. Climatic conditions and constraints of a building are related to the previous aspects and also have a strong influence. Additionally, different levels of renewable energy supply options such as on-site and off-site go beyond mere physical descriptions but essentially define the level of interaction between the building and the energy infrastructure. Therefore national definitions of nZEBs might consider country and even regional conditions, potentials, economic and legal aspects of each renewable energy option, as they are an integral part of the nZEB concept. These issues are elaborated later in this paper.

DEFINITIONS OF RENEWABLE ENERGY SUPPLY FOR NZEBS

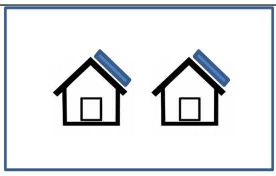
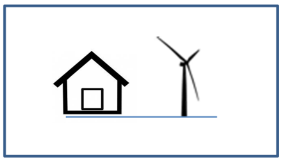
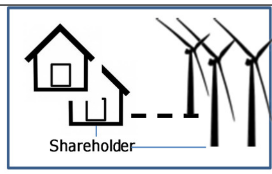
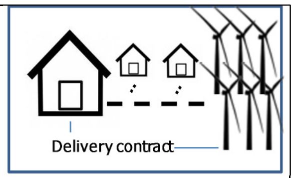
The nZEB projects emphasise the joint effort for energy efficiency in buildings and utilisation of renewable energy with the ultimate aims of achieving a balance between demand and (renewable) supply within a specified time interval. Despite the clear goals, a common internationally or at least European acknowledged definition is not available yet. As discussed previously, nZEB definitions should be broad enough regarding the choices for achieving a "significant extent" of supply from renewable energy. A sufficient number of these choices should be realistically available for every building owner even after having eliminated all non-available options that result from very different site specific conditions. In this section we provide a systematic overview and brief discussion of relevant renewable energy aspects being related to the definition. These aspects impact the multitude of renewable options for the nZEB concept. Economic, technical and legal aspects as well as the key issue of how these discussions are reflected in the concurrent EPBD related CEN standardisation will be discussed later.

INFLUENCE OF THE PHYSICAL BOUNDARY

Various studies formulate the nZEB definitions based on the physical boundaries of supply options for renewable energy. Despite the differences in structuring methods, the majority of the studies base their discussion on the physical hierarchical relation between the building and the renewable energy generation. One of the first attempts in categorising the possible supply options is given by Torcellini et al. (2006). They have defined renewable energy supply side options emphasising "on-site" (i.e. being located on the building plot) and within the "building footprint" which obviously is a subset of "on site". Furthermore they introduce the term "off-site" as the use of "renewable energy from sources outside the boundaries of the building site". A graphical overview of the options is presented by Marszal et al. (2010) and providing the basis of current approaches to define the nZEBs. Our summary focusing on electricity supply options is presented in **Table 2**.

As mentioned above, according to the EPBD's definition "… *the nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby.*" Thus it is emphasised that renewable energy produced on-site or nearby is included but at the same time it does not mean that renewable energy production for nZEB is restricted to renewable energy produced on-site or nearby. Taking Torcellini's definition, the EPBD term "nearby" logically belongs to "off-site". We will get back to this item when discussing the EPBD related CEN standardisation.

Table 2 Supply options for renewable electricity in nZEBs

			
Supply Option 1:	**Supply Option 2**	**Supply Option 3**	**Supply Option 4**
Buildings footprint	On-site	Off-site (incl. nearby), ownership	Off-site, purchase
Energy generation on immediate building surface e.g. PV systems installed on building roof-top or vertical façade	Energy generated on the building cadastre boundaries including open territory areas and parking space	The energy generation is (partially) financed by the nZEB owner e.g owner invests in shares from wind farms, remote wind turbine, solar farms	Energy generated off-site supplied to nZEB with a delivery contract, includes purchase of electricity from grid, trading of renewable energy certificates

Going from option 1, via 2 and 3 to 4 there is an increasing probability for technical availability or feasibility respectively. Often, high energy use buildings such as hospitals, laboratories, and grocery stores lack the required renewable electricity generation capacity within the building footprints or within the site boundaries (Pless & Torcellini, 2010). Moreover, building geometries where the building façade surface is limited compared to the energy demand e.g. apartment buildings or buildings in densely populated city centres may not provide sufficient electricity generation options for on-site or even (narrowly defined) nearby renewables. An example provided by Torcellini et al. (2006) shows that nZEB standard is not feasible for an exemplary two-story building within its footprint unless its load is reduced to a minute portion. Thus we discuss the aspects of off-site electricity generation options, or a combination of options presented in **Table 2** to cover the significantly reduced but still required energy demand for nZEBs. This is also done with a view to the next step of buildings which would be true zero energy buildings or even plus energy buildings balancing all EPBD categories (heating, cooling, ventilation, DHW, auxiliary energy) plus appliances.

Discussing "plus energy" buildings in an EPBD context is relevant because it is linked to a high share of renewable energy and also because the nZEB definition should enable stepping up to plus energy without the need for modification. Plus energy is achieved when more energy is exported across the system boundary than imported. Here again energy could mean "primary energy" or "delivered energy". Widely known is a definition based on delivered energy where more kWh electricity from onsite renewable generation (PV) is exported than kWh "imported" from the grid. Although easy to balance, this approach ignores the environmental quality of the delivered energy (which might be in a range between 100% fossil and 100% renewable) as well as the environmental quality of the electricity which is replaced by the exported energy. This means that "delivered plus energy" might not necessarily perform well in terms of primary energy or CO_2 emissions, i.e. real share of renewable energy.

Moreover, the allocation of the system boundary is decisive for whether a high share of energy from renewable sources is possible at all or not. Restricting the system boundary to option 1 (building footprint) or 2 (building plot) will obviously decrease the options and probability to achieve a high share of energy from renewable sources. These options also tend to promote small scale units which cannot benefit from economies of scale effects of larger systems. Extending the areal system boundary from onsite to off-site (incl. nearby) will usually result in more than just one building within the system boundary. Thus physically, the share of energy from renewable sources would have to be determined for a group of buildings. Additional thought is needed when it is about a high share of energy from renewable sources for a single building using off-site (renewable) supply. Then we have to simultaneously deal with two different physical system boundaries: onsite (the building) and off-site (supply system).

There is no easy solution to define a common system boundary for the building and off-site supply solutions where energy import and export may be balanced. While this approach focuses on physical boundaries another focus could be on the legal boundaries of a system. As an example the building owner (the “legal system”) can easily have shares in off-site renewable generation or simply buy “green” electricity. Using this approach a high-share of energy from renewable sources would be possible without on-site renewables. De facto the energy flow across the system border (from the building to beyond the boundary) is replaced by a monetary flow. Even “plus energy” would be possible by “over-offsetting” the imported energy.

Every building owner should have a fair and equal chance to meet the nZEB requirement from 2020 on. As building owners are facing very different conditions, the nZEB definition should provide enough flexibility for achieving a high share of renewable energy. Building owners should not be limited to (possibly non-available) physical (on-site) options but until then should be given “legal” options for achieving a high share of energy from renewable sources, too. Nevertheless, utmost care has to be taken in order to achieve *real* additional energy from renewable sources in the energy system which is the ultimate background of the nZEB definition. This issue will be discussed later in this paper.

INFLUENCE OF THE METRIC OF THE BALANCE

The influence of the metric of the energy balance stems from the need for a suitable “numerical indicator” that can be used in energy calculations for nZEB. Comparisons with benchmarks and between buildings require a common indicator or denominator for energy performance. Different fuels with different primary energy factors may be used within one building, and also different buildings will have different fuel-mixes for supplying heating, cooling, ventilation, domestic hot water, etc. Therefore clarity about the metric to be used for calculation of the energy balance is needed. The EPBD related standard EN 15603 mentions energy need, energy use, delivered energy and primary energy - all of them being related to different system boundaries.

Article 9.3a EPBD requires national definitions of nZEB to include “[…]a numerical indicator of *primary energy* use expressed in kWh/m²y. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values […]”.(Baake et al, 2012) estimate primary energy factors (and CO2-factors) for electricity generation in Europe to drop from 2.5 (400 g/kWh) today, to 2.05 (300 g/kWh) by 2020, 1.65 (175 g/kWh) by 2030 and 1.2 (40 g/kWh) by 2050 due to more energy from renewable sources. This will lead to increasing (environmental) competitiveness of electricity based supply options for nZEB until 2020 and beyond. Primary energy demand (or consumption) is the EPBD’s primary measure of energy performance. Primary energy is derived from delivered energy and their respective primary energy factors (PEF). For a reasonable benchmarking and comparison there should be a uniform methodology for the determination of PEF in all EU 27 Member States. Nevertheless a recent study by (Ecofys, 2012) revealed a significant lack of transparency and/or very different approaches in determining PEF amongst EU Member States. Sometimes PEF seem to have more a political than a physical background.

Despite the clear indication for using primary energy in the nZEB definition, it is noted that the ultimate intent of the EPBD clearly is to achieve (nearly) zero CO_2 emissions through reductions in energy use and the use of energy from renewable sources. As there is a strong relation between “nearly Zero-Energy Buildings” (especially when taking the non-renewable share only but with the major exception of nuclear energy) and “nearly zero CO_2 emission buildings” in the long run primary energy might be replaced by CO_2 in order to indicate the compatibility of buildings with the overarching EU targets for reducing CO_2 emissions. Thus, the minimum requirements for the energy performance of the building should use one metric or several metrics that can properly indicate both energy use (indicating the energy performance of the building shell) and CO_2

emissions (indicating the integrated climate performance of building shell and (physically or legally attributed) supply system (BPIE, 2011).

Both on-site and off-site options for renewable electricity are relevant options for reaching nZEB and nearly zero CO_2 emission buildings.

INFLUENCE OF THE PERIOD OF THE BALANCE

The definition of zero, within the nZEB concept, does not mean an “absolute” zero consumption, but instead *net* zero over a period of time as a result from balancing energy production that physically or legally belongs to the building (see above) and its use. Hence, the balance period concerns the regulation of the time interval within which a (nearly) zero energy aim should be achieved. Recital (9) EPBD asks for a balance period of one year in order to not just cover heating but also cooling which causes the dominant energy use in warm European regions: “[...] the methodology for calculating energy performance should be based not only on the season in which heating is required, but should cover the annual energy performance of a building […]”). Thus a yearly balance includes all consumptions and (renewable) gains and allows e.g. PV gains in summer or wind in autumn to compensate for higher consumptions during the heating season.

Having a balance period of one year does not forbid dividing the year into smaller sub-intervals and asking for a (nearly) zero energy balance for each of these sub-intervals. Several calculation procedures for the energy performance of buildings are based on monthly intervals which suggest applying a similar approach to the determination of a (nearly) zero energy balance. Obviously it is more ambitious to reach (nearly) zero energy balances for sub-intervals being arbitrarily shorter than one year. Shorter time intervals usually aim at a smaller stress of the (electricity) grid through harmonizing demand and supply. The need to do so is easy to see in the case of PV on the buildings footprint (roof and/or façade) where high net surpluses in summer face high net deficits in winter. These time disparities of energy generation and use cannot be seen annually, but they get more and more pronounced with sub-intervals getting shorter. This relation can be seen in the “load match index”. (Koch et. al 2011) present the following chart with sub-intervals of one year, one month, one day and one hour for a PV powered net zero energy building in an annual balance. The net ZEB can only “live” without importing energy for 25% of a year’s hours; e.g. all nocturnal hours need energy imports.

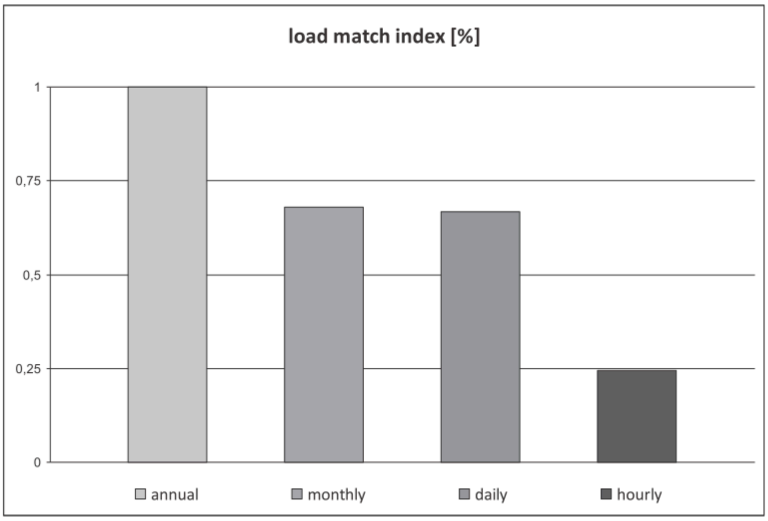


Figure 1 - Load match index for different sub-intervals (source: Koch et al. 2011)

Obviously it is easier to achieve a high load match index the longer the sub-interval is chosen.

The difference between the time of use and the time of generation of “on-site” or “nearby” electricity hinders the possibility to use electricity fully for self-consumption. Grid connection is usually necessary to enable the true physical zero energy balance. Thus, it is assumed that excess electricity generated on-site is sent back to the grid, using the grid as a virtual storage (strictly speaking, electricity grids have very limited physical energy storage capacity). Due to rapid growth of distributed electricity generation the grid may not need this electricity or simply may not be able to receive it within its capacity limits.

Two main possibilities are discussed below for temporal disparities in the energy production and consumption of a building. The topic is particularly important within the discussion of self-consumption and regulation of metering schemes for on-site or nearby renewables as discussed in detail in chapter 0.

Restrictive allowance for disparities

Hourly (on-site) balances for single buildings would mean almost no allowance for disparities. This would impose significant restrictions on the possibilities of utilising the grid as a virtual buffer to offset energy consumption in case of excess on-site production. Local storage technologies or cutting off local over production would be required in this case. Currently on-site storage technologies have limited capacity and low economic feasibility. Thus, limitations on allowances for disparities and restricted technical capability of storage systems would require very careful dimensioning of the energy generation systems. However, this scheme would possibly result in over-sizing the (onsite) electricity generation systems, due to the need for production capacity for the period where maximum electricity consumption occurs (Marszal, et al., 2011), due to (partly unpredictable) small source energy flows (e.g. calm wind, low irradiation in winter) and also because installing over-capacity in generation (which partly would have to be cut off the grid to keep the balance) would still be cheaper than installing sufficient electricity storage.

Full allowance for disparities

Looking at an annual balance (cf. **Figure 1**) would effectively mean full allowance for disparities. This would avoid the limitations mentioned above while keeping the temporal mismatch between local production and consumption, which will raise problems in the energy balance as pointed out before.

BPIE (2011) addresses the issue as a topic for further elaboration. The study points out that “... it seems advisable to follow approaches such as annual or monthly balances. Nevertheless a drawback to increasing the time intervals is that an increasing share of energy from renewable sources produced on-site is in fact not used on-site but off-site because of the decreasing match between demand and supply loads in decreasing time intervals. Therefore the real share of grid power is higher than the annual balance shows and, thus, the real CO_2 balance may as well be worse than the annual balance reveals – except when energy from the grid also stems from renewable sources and may be considered in the nZEB balance. This is another reason for interpreting the EPBD definition so as to include on-site, nearby and off-site energy from renewable sources.” (BPIE 2011, p.36)

In the end this means that an optimal level between the two extremes of annual balancing, which overestimates the renewable share and disguises the grid impact and hourly balancing, which leads to over-investment, needs to be determined. Summarising the discussion above, considering the current technology, balancing intervals like weeks or months turn out to be most reasonable currently.

Examples for application of variations in the definition from member states

In the previous sections we have shown that the EPBD’s nZEB definition has a qualitative nature and leaves quite some room for interpretation which will be used in the concrete national applications of the nZEB definition. Although currently very little evidence exists about these upcoming national applications of the nZEB definition, a large variety of already existing concepts and examples that may be considered sufficiently equivalent to nZEB exist. A summary of available definitions based on the on-site and/or off-site supply options and prevailing approaches in various countries is given in this section.

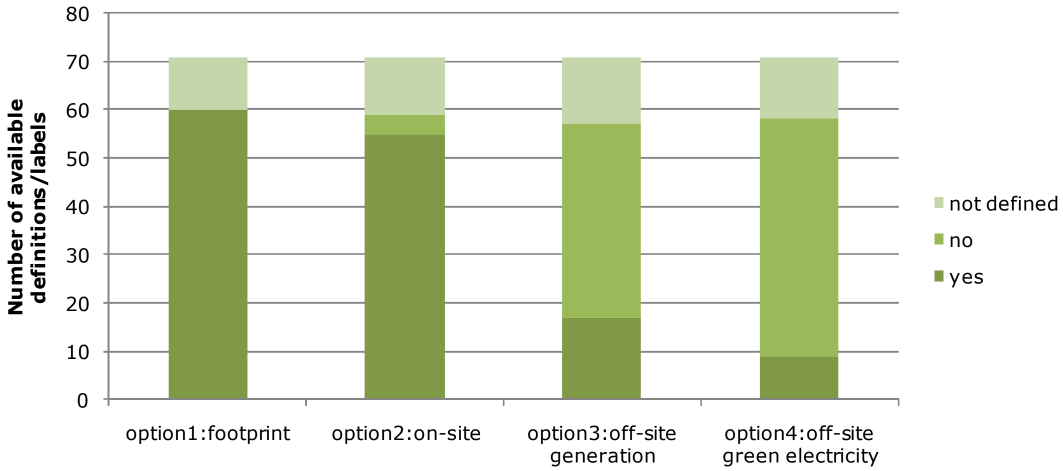


Figure 2 Number of known nZEB definitions/labels/certifications with regards to renewable energy supply options with public/governmental or voluntary/non-governmental background

A recent survey (ECOFYS et al, 2012) for the European Commission identifies 71 partly voluntary certification schemes, definitions, descriptions, calculations methodologies or labels from 17 EU countries and two international definitions for what possibly could be classified as nZEB. 60 definitions explicitly allow the renewable energy source to be on the buildings footprint, 54 to be on-site, 17 to be off-site and 9 to be green electricity. On the other hand almost 50 of those definitions explicitly exclude green electricity while approximately 40 forbid off-site generation and three do not even allow on-site generation. It should be noted that the definitions (in case of option 1 and 2) are not limited to supply of electricity but also include heat and other renewable sources. Off-site generation and green electricity still appear to be an option in a significant amount of the identified definitions although a better understanding for why these options are excluded over-proportionally is needed. It may well be excluded because the explicit mention of 'nearby' in the buildings directive may be interpreted as exclusion of these options from nZEB designs.

Some more details relative to the current applications are provided in **Table 3**. It is important to note that some of the achieved projects utilise combinations of renewable electricity supply instead of being limited to a single option, especially when the available “footprint” or “on-site” area increases such as in apartment and office buildings.

Table 3 Selected nZEB examples

Typology		Project name, year, location	Label /definition	Main features in energy concept	Renewable energy supply
residential	single house	D10, 2011,DE	TripleZero©	all-electric building* fully recyclable big window proportion	PV system on roof surface
	apartment	Kleehäuser,2006,DE	zeroHaus	Passive house concept	PV system Share in wind park
Non-residential	office	NREL - Research Support Facility, US, 2010	Net Zero Site and Net Zero Source Energy	focus on shading and daylight	on-site solar energy (2.5 MW) on the rooftop, parking lot, and parking garage.
	factory	Solvis,DE,2000	zeroHaus, Nullemissionsfabrik	Passive Building concept use of waste heat solar collectors	PV system
	Hotel	Boutique Hotel Stadthalle, AU,2008		rainwater collection recycling drinking water LED lighting solar panels and water pumps	PV system on building facade

KEY ISSUES AROUND OFF-SITE RENEWABLES IN NZEB

In chapters 2 and 3 it was pointed out that due to current technical and physical limitations, it may not always be possible to reach nZEBs with “on-site” or “nearby” renewables. This calls for careful analysis of the options for utilising *off-site* renewables to cover the *“nearly zero or very low amount of energy required … to a very significant extent”*. So far there has not been too much focus on this aspect in the nZEB literature although “on-site” options are especially quite limited in new buildings (the same goes for "nearby" when only district heat is considered which is not at all available everywhere). Options are even more limited when it is about extending the nZEB concept to the building stock. Focusing merely on “on-site” and “nearby” solutions will hamper the implementation of nZEB, at least if these are supposed to rely to a very significant extent on energy from renewable sources. In this chapter, we elaborate on options relative to off-site electricity, their benefits and barriers.

From the building owner’s perspective the decision on which supply option to choose will depend on a number of parameters. Thus, we discuss important parameters such as: cost and price of various renewable electricity supply options and the influence of grid parity; the legal and administrative aspects of possible metering schemes and how they influence the choice of on-site renewables; open issues on the implication of off-site renewables and the practicality of enforcement and verification.

ENERGY COST AND INFLUENCE OF GRID PARITY

In this section we discuss how the cost of renewable energy has developed in recent years and how future cost is forecasted. Fuel prices increase, while renewable energy sources continue to reduce in upfront costs. As a result, widespread grid parity (based on retail price) for wind and solar is generally predicted for the time between 2015 and 2020. Reaching grid parity is considered to be an important point in the development of new sources of power as the variety of energy from renewable sources that is financially viable to utilise will increase.

DEVELOPMENT OF COST OF RENEWABLE ELECTRICITY

The Levelised Cost of Electricity (LCOE) is used as an indicator to compare the cost of electricity from renewable sources with other sources of electricity generation in cost per kilowatt hour (kWh). The LCOE covers all investment and operational costs over the system lifetime, including the fuels consumed and replacement of equipment. This allows for a solid comparison of various technologies.

Wind Energy

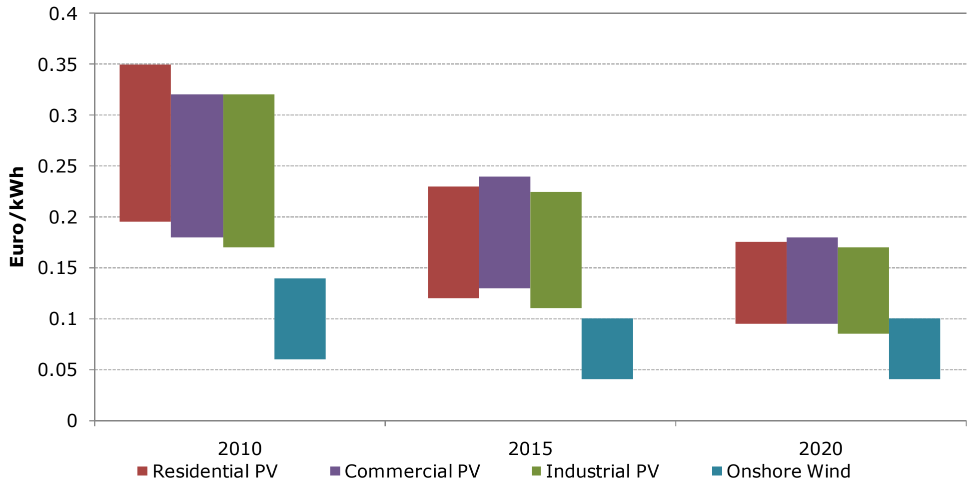
The LCOE from wind varies depending on the wind resource and project costs. The LCOE of typical onshore wind farms was 0.05 - 0.11 €/kWh[1] in 2010. The higher capital costs of offshore wind farms are only partially offset by the higher capacity factors achieved, resulting in LCOE of an offshore wind farm of 0.10 - 0.15 €/kWh[2].

[1] assuming a cost of capital of 10%

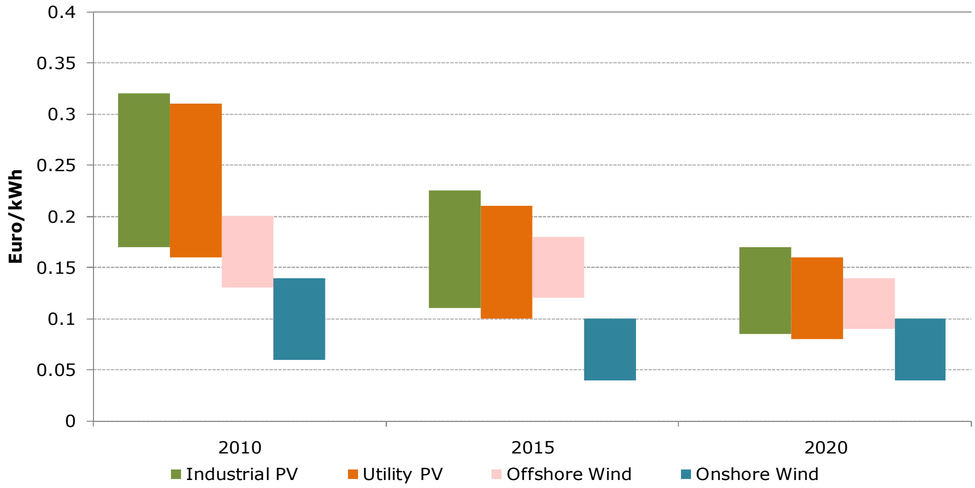
[2] assuming a 10% cost of capital (IRENA,2012, Note €/USD values of (1.3) used for conversion of LCOE

We used electricity cost scenarios from various sources: for LCOE of onshore wind (IRENA, 2012), and for LCOE of offshore wind (Tegen et al.,2012), (The Crown Estate, 2012) to arrive at ranges of cost levels for 2015 and 2020. The LCOE for various market segments and renewable energy supply options is provided in (b) off-site supply of renewable electricity

Figure 3.Error! Reference source not found.



(a) on-site supply of renewable electricity



(b) off-site supply of renewable electricity

Figure 3 European renewable electricity LCOE range projection by segment[3]

Solar PV

The LCOE from solar PV also varies depending on the solar resource and project costs. Moreover, the differences are estimated in the LCOE of PV depending on the market segments: residential, commercial, industrial and utility scale. Expected generation costs for large, ground-mounted, namely off-site, PV systems in 2020 are in the range of 0.07 €/kWh to 0.17 €/kWh across Europe (EPIA, 2011). In the sunniest Sunbelt countries the rate could be as low as 0.04 €/kWh by 2030. EPIA forecasts that prices for residential PV systems on building site and the associated LCOE will also decrease strongly over the next 20 years. However, they will remain more expensive than large ground-mounted systems (EPIA-Greenpeace, 2011).

In **Error! Reference source not found.** we have presented the cost levels for wind and solar PV electricity, but distinguished the market segments that could be relevant for on-site and off-site renewable energy for NZEBs. The cost levels for these technologies and the market segments that could be utilised for on-site and off-site renewable electricity are shown in **Error! Reference source not found.**(a) and **Error! Reference source not found.**(b), respectively. Some overlap can be seen as the industrial PV applications and onshore wind can be utilised both as on-site and off-site options. The applicability and cost of these systems depends significantly on the size of the systems, thus the figure provides general cost levels without differentiating between system sizes. Especially for wind energy, one should consider that the small scale wind turbines which are available for on-site supply (e.g. 2.5 kW systems) yield electricity costs that are significantly higher than medium or large systems (e.g. 5kW->20MW)[4]. This puts the small wind tribunes on the higher end of the cost scale. **Error! Reference source not found.** shows that off-site options would yield economically viable electricity supply for building owners by 2020.

Grid Parity

In addition to the comparisons that are provided in **Error! Reference source not found.**(b) off-site supply of renewable electricity

Figure 3 in terms of costs, investing in energy technologies in various segments could very well represent positive business cases in general, for the building owner in particular. Whether this is the case or not will depend on the price of electricity in the various market segments in combination with stimulation measures that may be in place in Member States.

A common definition of grid parity refers to the level where the electricity production cost of a renewable energy system is equal to the purchased electricity at *retail* price. **Figure 4** shows the variation in retail price of electricity for different market segments by 2020 according to a prediction by EPIA. This would mean that renewable electricity supply options will become increasingly financially attractive in the different market segments by 2020 from the view point of building owners.

[4] ECOFYS in house communication

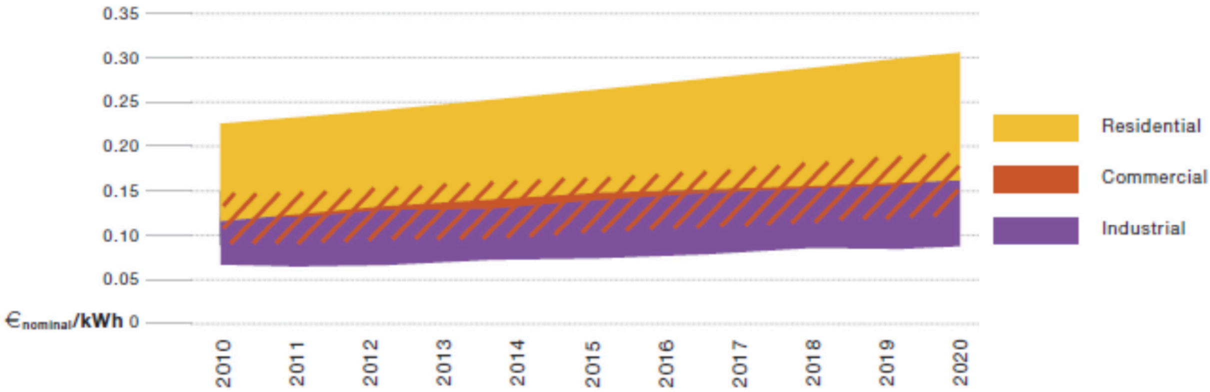


Figure 4 Assumption on the increase of retail electricity prices for different types of consumers (EPIA, 2011)

For the building owner, the discussion above implies that the cost of electricity from on-site renewable electricity may be lower than the cost of electricity from the grid. Based on the current price developments the (retail price) grid parity is close at hand or already reached in the residential segment for several countries in Europe with high electricity prices (e.g. Italy, Germany, the Netherlands). By 2020 it is expected to be reached for many countries in Europe. Recent projections suggest that PV systems will be economic without support for residential consumers in most countries by 2020 and the cost of PV electricity will continue declining (IRENA, 2012).

When it is commercially attractive, it is possible for a building owner to choose solar electricity to offset electricity demand. For example this could already be an option in Italy where solar energy is abundant and sufficient generation is possible for the decreased demand (especially in case of single family homes). Moreover the building owners could even decide to make the system somewhat larger to offset for the remaining electricity demand from appliances as well. A building owner in the countryside in Denmark may decide to put a windmill on its premises. This case is especially attractive when the building owners may benefit from the retail price for not only the electricity they save, but for the electricity they export to the electricity grid. Whether this is the case, or whether it is even allowed, will be discussed later.

In addition to on-site options discussed above, one could argue that the building owner (both residential and non-residential) who has an opportunity to buy shares in an off-site renewable electricity generation option with interesting financial returns may want to use these shares to offset the electricity demand of the nZEB. It is beyond the goal of this paper to discuss in detail the financial attractiveness of such off-site options. However, we do want to point out that there could be an increasing amount of financially interesting options for building owners in this market segment until 2020 when nearly zero energy buildings will be mandatory. A problem often encountered is that small investors are not welcome in large projects because they represent too much overhead, resulting in a much less interesting financial proposition for the small investor. On the other hand, some progress has been made to make renewable energy investments possible for small investors within renewable energy cooperatives (cf. chapter 4.3).

Although uncertainties exist to assess the exact time where different technologies reach grid parity, almost all of the studies mentioned above predict decreasing costs of renewable electricity to a level that will be competitive with retail prices within the next few years (before 2015). Both wind and solar with appropriate system sizes have reached grid parity in areas with abundant renewable energy resources and favourable market conditions. The first point of grid parity is seen as a physiologically important milestone, which will possibly motivate a further increase in renewable electricity consumption (IÖW, 2011).

However, two important limitations of the options as presented before need to be mentioned. First, the previously applied definition of grid parity refers to retail electricity prices, but not to wholesale prices. In this sense, from the perspective of a single user grid parity is only financially attractive, when the average price of avoided electricity purchase (self consumption) and self generated electricity sold to the grid is at least at the level of LCOE. Retail prices include other price components such as network tariffs, taxes and other fees. The current wholesale price of electricity (December 2012) is about 0.05 €/kWh which is substantially below retail price levels shown in Figure 4. If building owners use their own electricity generation to substitute electricity from the grid, the other price components need to be carried by other parties. Hence, in the long run, the effective cost-savings of renewables need to be benchmarked against wholesale prices.

Secondly, the effective substitution of purchased electricity with self-generated electricity is only possible in times where generation and consumptions correlate. In case of PV and households, only about 20% of own generation can be replaced without additional storage systems and/or substantial re-organisation of energy usage patterns. This aspect is discussed further in the next section.

METERING SCHEMES

Having electricity generators on the low voltage grid in addition to consumers (loads) is a relatively new phenomenon. In the 1980s the first grid connected PV-systems went online. Since then, much work has been done to develop standards and to put in place laws that allow and control the connection of distributed electricity generators to the grid. In addition, laws and programmes have been put in place to stimulate distributed generation. In the early 2000s several countries in Europe started to apply feed-in tariffs, which enable consumers to receive a fixed price per kWh of electricity produced. Then feed-in tariffs were generally higher than consumer prices.

Several local and national governments have adopted so-called net metering schemes. They were first implemented in a few states in the USA. Net metering schemes enabled customers to use their excess electricity at certain times to offset their use of electricity from the grid at other times[5]. The 'net' indicates the deduction of electricity exported to the grid from imported electricity into the home, with a balancing period of a billing period, a year, or several years. Very often, constraints are built into the schemes, such as:

- Type of energy technology. Not all types of local electricity generation might be rewarded evenly. Distinctions can be made between e.g. solar panels and (urban) wind turbines and micro CHP (Combined Heat and Power). In this paper we focus the discussion on renewable electricity (wind and solar), and focus our example on PV as it is the most common form of onsite renewable electricity.

- Capacity / energy limits. Very often, capacity or energy limits are imposed on the generator. For example, in the Netherlands utilities are obliged to allow consumers to feed up to 5000 kWh and pay the retail price for it. In Denmark there is a capacity limit of 6 kVA[6].

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[5] EIA (the US Energy Information Administration) website, http://www.eia.gov/todayinenergy/detail.cfm?id=6190.

[6] M. Latour, EPIA, 'Net metering and self-consumption in European countries', presentation at the 27th European PV Solar Energy Conference, Frankfurt, Germany. Strictly speaking these schemes are 'metering schemes' rather than 'net metering schemes', because a limit is built independent of the own consumption.

- Compensation. Very often, compensation of electricity fed into the grid is done using the same retail price that consumers pay (using old meters that can turn backwards this automatically happens). However, this is not automatically the case and with increased penetration of smart meters it will become easier to implement other tariffs for electricity fed into the grid. For example, it is conceivable that grid companies will start to impose charges for exporting electricity to the grid, or that taxes will be deducted from the retail price consumers receive, or that taxes are even imposed.

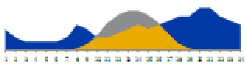
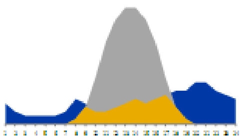
The variations described above may not describe all possibilities for metering schemes that exist or are conceivable. For example, new schemes have been devised awarding a bonus to self-consumed electricity, e.g. in Italy and Germany (Germany until 2011) where Germany has cancelled the scheme after a short period.

For our discussion it is most relevant to realise the effect of varying limits of allowed capacity combined with varying prices for the portion of electricity that is exported to the grid, because both will be influential to the financial viability of on-site renewable energy systems vs. other options. This is illustrated in **Table 4**.

In this table, the financial viability of four possible cases is illustrated with pluses and minuses. It is assumed that grid parity is present. This may be a realistic scenario for the residential sector in many countries in the EU by 2020.

In the columns, a distinction is made between cases where retail prices are received for electricity exported to the grid and cases where the reimbursement is much lower, e.g. wholesale prices. In the rows, a distinction is made between large and small PV-systems, producing more or less than what is consumed in the house. This situation is illustrated with a picture of electricity consumption and PV-production throughout the day, where the area in grey illustrates the amount of electricity fed into the grid, the area in blue consumption in the absence of PV-production and the area in yellow self-consumption of PV-electricity.

Table 4 Illustration of effect of prices received for electricity exported to grid and size of PV-system on financial viability of the system.

	Retail	Wholesale
production < consumption  	++	-/+
production > consumption  	++	--

The system is financially viable if retail prices are received for all electricity exported to the grid. This is indicated with ++ in the ‘retail’ column and independent of system size. If much lower prices are received the financial picture will quickly change unless significant further reductions of investment costs for renewable energy technologies will happen. For a small system it may still be possible as most electricity is self-consumed (indicated with -/+). However, for a larger system that exports a significant amount of electricity to the grid, it will be a challenge to make it financially viable (indicated with --).

It should be noted that the portion of electricity in an NZEB that needs to be generated with renewables according to the EPBD definition should be a very significant portion; the exact amount will certainly be the result of political decisions rather than technical considerations but easily could mean 50% or more (BPIE 2011). Thus smaller PV-systems are possible which increases the share of self-consumption and thus the financial viability in cases where over-production can only be sold below the retail price.

The table also shows that the kind of metering schemes Member States will have in place by 2021 will be very important for the viability of on-site renewable electricity in nZEBs.

Relevance of metering schemes for onsite definition and for the on-site vs. off-site discussion

For the metering schemes it is relevant whether any renewable electricity systems can be put 'behind the meter' as long as they are based on the physical point of feeding in rather than on a virtual system that may be legally assigned to an nZEB. If systems are located on the building footprint (option 1) there will be no issues and the illustration in Table 4 applies. If the generation system is located on-site close to the building, (option 2) the relevance will depend on whether the renewable electricity system is connected 'behind the meter' or not. Following the logic of different system boundaries explained above, the question is on which boundary the meter measures imports and exports. If it is behind the meter, there is no difference as to metering options. If it is not, the situation could be less favourable, for example if the system is connected to a meter without consumption. In that case there is no self-consumption. One could wonder if the electricity produced by this generator shouldn't be considered as self-consumption to some extent. In fact, this argument is also used by cooperatives of private consumers who join together to buy renewable energy generators. Virtually they set a wider areal boundary. This will be discussed in the next paragraph.

Until now, we have focussed the discussion on solar electricity mainly from PV systems, however a windmill could also qualify (option 2, or as part of option 3). We expect such windmills to fall under metering schemes that are different from those meant for rooftop PV-systems, with the main difference of probably not being connected to the low voltage distribution grid. This could hold for larger ground based PV systems as well.

Generation schemes for off-site renewables

In this paragraph we consider the possible ways to deploy off-site renewable energy in an nZEB. The building owner can exploit two possibilities as illustrated in Figure 5.

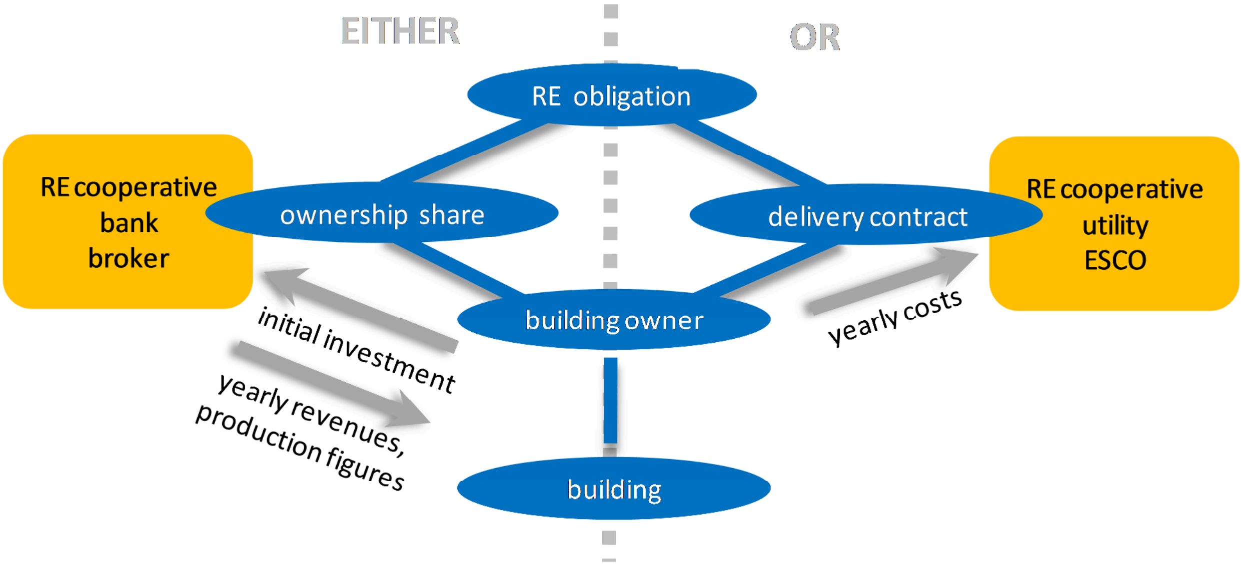


Figure 5 Illustration of how RE obligations in NZEB could be fulfilled by off-site renewable energy.

The left side of the illustration represents the case where the building owner becomes a shareholder in a renewable electricity generation facility (e.g. wind farm). The right side of the illustration represents the case where the building related electricity demand of an nZEB is supplied by establishing a delivery contract for a yearly amount of renewable electricity. These cases refer to "option 3" and option 4", respectively (also see **Table 2**).

Ownership share

Community owned renewable energy models open up an option to electricity customers to own renewable energy generation capacity in a shared facility when there is no means to do so on the building envelope or at a lower cost than using their own roof.

The broadest category involves cooperatives incorporating a group of people, who may or may not be located in a certain geographical boundary, and who become members of a cooperative by buying shares to finance a renewable energy generation project (Walker, 2008). Within cooperatives the customer subscribes to a portion of a shared facility. The power generated results in reductions or credits on the electricity bill. One can also consider the option where such shares are offered by a bank or broker, where available. This scheme sees consumers as becoming more active participants in the energy system as financial investors in infrastructure and as contributors to policy goals considering environment and energy. The community ownership schemes are already widely accepted and have been an important element in the success of wind energy markets. Countries like Denmark, Germany and the Netherlands in particular have experience with such renewable electricity cooperatives.

Historically, the ownership schemes for off-site renewable energy have been linked to physical proximity of the premises of the (partial) owner and the location of the renewable energy system (Walker, 2008) (e.g. residents of a village in a windy area install wind turbines). However, the increased public environmental awareness and economic viability of renewable technology gave way to ownership schemes where a common interest is more important than a physical link between the building and the renewable energy source (e.g. environmentally conscious investors or individuals who see the option as economically attractive investment and throughout a nation raise funds to invest in new wind projects). For example legislation in Denmark refers to the definition of "locality" for ownership of wind farms (Bolinger, 2001). The Danish government has gradually relaxed the ownership restrictions for community wind farms: 1980s investment in a wind partnership was limited to those living within 3 km of the turbine (1980), geographic eligibility expanded to include those living within 10 km (1985), then to neighbouring areas (1992), those who work or own property in a borough but don't live there (1996), all of Denmark (1999), and the entire European Union (2000).

By the community owned renewable energy models the building owner makes an investment in the facility for renewable electricity generation. The financial viability, tax regulations and legislation for such schemes are well developed already in many countries. In Denmark first modern wind turbines were installed by groups of individuals without government support. Following this initiative government has since supported the local ownership of renewable energy through a variety of subsidies. There is an incentive targeted specifically at cooperative ownership: revenues are tax exempt if the investment is up to 50% more than their households' electricity costs. Sweden has employed two ownership models – the real estate commune and the consumer cooperative. The real estate commune is based on the communal ownership of physical resources. This scheme is traditionally seen in rural areas (e.g. people owning a land along a fishing stream). The consumer cooperative does not seek such a community character. The two schemes are structurally not different in terms of shareholding and operation but the distribution of benefits. In both schemes members usually limit their size of investment to their expected consumption level. The generated electricity is sold to the utility grid, receiving an agreed feed-in tariff. As long as a member of the renewable energy ownership has not invested in more kWh/year than he consumes, the investment is taxed as a personal housing investment. If a commune member's investment exceeds his annual kWh consumption, the amount of production in excess of consumption is treated as a business investment, and legal nuances may occur between the two ownership schemes.

About 10-15% of the wind capacity in the Netherlands is operated by cooperatives. Many of the first turbines were installed by cooperatives, where members were willing to accept a below market return or no return at all in order to support the cooperative with a desire to produce clean energy (Gipe, 2004). Germany's primary model is more commercial in nature – a limited partnership with a developer's limited liability company as general partner. The UK, which lacks cooperative laws, has employed a legal structure known as an industrial and provident society, which operates like a cooperative, though is not bound by strict cooperative limits on investment. The UK has also pursued an investment fund structure, which is similar in nature to a mutual fund, though it invests in renewable energy projects and not publicly traded companies (Bolinger, 2001).

Renewable electricity delivery contract

If the building owner decides to arrange a delivery contract rather than shares, supply option 4 applies. In this case electricity may be supplied from a utility company as well as a renewable electricity cooperative.

Worldwide, electricity utilities are investing in large-scale renewable electricity plants or investigating how they can benefit from meeting their customers' interest in renewable electricity, often leading to the development of new business opportunities. In Sweden some utility companies are buying excess electricity from private PV owners at a higher price than the spot prices and selling the electricity to consumers that are willing to pay a little extra for renewable electricity (IEA, 2012). Thus, in this option a building owner buys renewable electricity from a provider whose energy service packages include renewable electricity. In terms of consumer-supplier relations this scheme does not imply substantial changes from the current situation of centralised energy supply.

A noteworthy difference between an ownership share and a delivery contract is that in case of an ownership share, an investment in the share will need to be done at the same time that an investment in the nZEB as a whole needs to be done. For a delivery contract on the other hand, no upfront investment is necessary, but yearly costs are incurred. This may be a decisive point that some building owners may decide for a delivery contract, as their initial investment is lower. For a project developer (as a 'first owner') this may also be preferable, as it will make the price of the building (a little) lower. One could wonder if this will also be a decisive point for a project developer to always choose for off-site renewable supply (option 4), even in cases where on-site renewables may in the end be cheaper for the building owner. The burning question in all cases is how to ensure the persistence of renewable shares or renewable supply in the context of an nZEB, in order to keep the “significant extent of renewable energy” which is part of the nZEB concept without interruptions.

Ongoing nZEB related CEN standardisation

For the original EPBD 31 standards have been developed by the European Committee for Standardisation (CEN) based upon mandate M343 from January 2004. Publication took place in 2007 and 2008. A new mandate M480 was issued by the EC to CEN in December 2010 e.g. having the following objectives:

- The current set of CEN-EPBD standards have to be improved and expanded on the basis of the recast of the EPBD. Other relevant existing national, CEN/CENELEC and ISO standards should be taken into consideration.
- The subsequent CEN/CENELEC proposal shall consist of a systematic, clear and comprehensive package with a modular structure of technical reports and standards that are manageable and user-friendly for all stakeholders relative to buildings addressed by the EPBD.
- The package has to be ready by 2014.

The development of these standards has already started. Although not being mandatory for the calculation of the energy performance of buildings CEN standards traditionally gives strong guidance for national standardization. Above, EPBD Annex I says: *“The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC.”*[7]

EN 15603 is the overarching standard giving a framework for the assessment of a building’s energy performance. A major aspect in the ongoing work prEN15603 (:2013) is the definition of system boundaries for the calculation. CEN TC 371 Program Committee is responsible for updating EN 15603.

As pointed out above, definitions of system boundaries are of overarching importance relative to the share of energy from renewable sources and the available options: on-site and off-site including nearby sources. Therefore it is instructive to see the current status of EN 15603 work (Hogeling, 2012).

The EN 15603 committee has identified the system boundary to be of overarching importance; the system boundary is called “assessment boundary”. The following “geographical perimeters” shall be considered as assessment boundaries for the building energy performance: the conditioned space of the assessed building (or building unit), the building site (on-site), outside the building site – nearby, and outside the building site - distant. This is equivalent to what has been presented above. In the above given explanations, the term “nearby” turned out to be quite vague. EN 15603 now has preliminary specified the terms “nearby” and “distant” which are the two off-site elements.

[7] Note: the Renewable Energy Directive 2009/28/EC requires in Article 13(4): *“Member States shall introduce in their building regulations and codes appropriate measures in order to increase the share of all kinds of energy from renewable sources in the building sector. … By 31 December 2014, Member States shall, in their building regulations and codes or by other means with equivalent effect, where appropriate, require the use of minimum levels of energy from renewable sources in new buildings … “*

- *"'Nearby' is defined as an energy source which can be used only at local or district level and requires specific equipment for the assessed building or building unit to be connected to it (e.g. district heating or cooling).*
- *'Distant' is defined as all the other energy sources not included in the previous definition."*

At the moment within the technical committee there does not seem to be a restriction to only consider on-site or nearby as just defined within the nZEB context. It seems that all boundaries "on-site", "nearby" and "distant" will be looked at. Another positive aspect is the ongoing differentiation between primary factors of exported and imported energy as well as explicit mentioning of the need for solving the questions around plus energy buildings. Up till now, no information is available on how to link "distant" generation to the building. We highlighted in this paper, that this will be one of the main challenges for making available the whole set of renewable options for future nZEB and their owners.

Monitoring, verification and enforcement (MVE)

MVE in the EPBD

Monitoring, verification and enforcement (MVE) is an essential part of successful implementation of nZEBs. For the MVE of regulation in general, the member states are responsible for controlling the grant of Energy Performance Certificates (EPC). At the initial stage of a building project the requirement of certificates would be linked to the building permit or a permit for use. At a later stage the certificates should be available when buying or selling the building.

The EPBD requires that independent control systems are set by member states within a system of MVE. Annex II states "*the independent control system shall make a random selection of at least a statistically significant percentage of all the energy performance certificates issued annually and subject those certificates to verification*". Verification includes control of input data and verification of energy performance and control of correspondence between specifications given in the certificate and the building itself. For an effective implementation, the EPBD (Article 27) also requires that the Member States shall lay down the rules on penalties applicable to non-compliance with the regulation. Member States shall take all measures necessary to ensure that the penalties are implemented.

Once an nZEB is in use, careful monitoring and verification are needed to verify the match between EPC input values and what is realised during the construction, to identify and correct improperly constructed or functioning systems and to secure the validity and persistence of the initially stated energy performance which in the case of nZEB is closely related to a "to a very significant extent" of energy from renewable sources. With respect to renewable electricity use in nZEBs, a clearly, unambiguously defined accounting of energy from renewable sources should be available.

Today there is not a commonly agreed framework for calculating or accounting the share of renewables in an nZEB, but such rules are urgently needed. The ongoing CEN standardisation around the recast EPBD could have as a result a comparative methodology framework for calculating the extent energy from renewable sources used in nZEB. This would be similar to the EPBD's requirement to the EC to set up a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements.

As a starting point for such a framework the focus could be on the share of renewables for services (heating, cooling ventilation, domestic hot water, lighting) explicitly mentioned in the EPBD. In a later stage this should be extended to include appliances, construction and disposal (cf. BPIE, 2011). It should be noted that already today the EPBD does not forbid Member States to extend the EPBD in this respect.

A meaningful monitoring, verification and enforcement is only possible with clear definitions for the key indicators that are to be the subject of MVE.

Verifying the renewable share for on-site and off-site options

Relative to energy from renewable sources, design, application and conditions within a system of MVE differ depending on the renewable energy supply option. Today many uncertainties in regulation and certification are present. The possible ways of resolution of conflicts is discussed under three distinct scenarios:

- On-site generation

The generator of electricity is physically attached to the building structure (e.g rooftop PV units). In theory the PV unit is an integral part of the property and handled as a part of the building itself. Without further regulation, this option has the highest probability of persistence over the building's lifetime. This does not discredit the purchase of renewable power – it simply highlights the motivational and "probability of persistence" advantages of on-site renewable energy generation for those buildings that have this option.

- Off-site generation –community ownership

The ownership of nZEB is coupled with the (partial) ownership in an RE generation unit as a shareholder (e.g. in a windfarm). The shareholder contract should therefore include a clear relationship between the building owner and a certain amount of renewable electricity (in terms of kW or kWh/yr). In addition, requirements on the guarantee of the continuity of the renewable electricity plant should be in place. This continuity requirement may involve yearly statements of production figures. Up until now, banks and brokers do not offer shares with such clear connection; on the other hand it is possible to provide a link through renewable electricity cooperatives.

As pointed out before, switching to off-site renewable supply may be done by a legal connection between the building owner and the off-site generation. Still, as we talk about nearly-zero energy buildings rather than nearly-zero energy building owners, the nZEB itself should have this legal connection too, even if the owner changes. In this case, the cooperative shares should be transferred to the new owner of the nZEB, establishing the continuity of the link between the building and the renewable energy generation facility. This could be arranged through a '*transferable clause*'. Such a provision in the contract would secure that the renewable energy share obligation upon the nZEB owner should also be applied to subsequent owners of the building. Thus the right of nZEB certificate is inseparable from the renewable energy supply obligation.

- Off-site – renewable electricity purchase

Under the monitoring and verification requirement the nZEB owner who purchases electricity will be obliged to provide the evidence that he meets the compliance requirements for renewable electricity and the renewable energy belongs to the building. The evidence of compliance should be provided in terms of a certification scheme[8] that will be linked to the nZEB. Similar certification schemes are already used in Europe in the form of support to electricity generation from renewable energy sources as the renewable energy certificate[9] (REC). REC is a certificate that indicates the generation of one megawatt hour (MWh) of electricity from an eligible source of renewable power.

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[8] The Guarantee of Origin (GO or GoO) is the tracking certificate regulated in the European Directive 2009/28/EC, article 15. The GO is further standardized via the European Energy Certificate System (EECS) provided by the Association of Issuing Bodies (AIB).

[9] Renewable Energy Certificates (RECs), also known as "green tags," "green certificates," tradable renewable energy certificates" and "renewable energy credits,

The building owner can purchase the RECs separately from electricity or bundled together from the electricity provider. In the case that the electricity and RECs are bundled as a single green energy product, the nZEB owner would be largely limited to purchasing energy from renewable projects that are geographically close by[10]. The building owner may choose to purchase the electricity and assurance of renewable generation separately. In this "unbundled" approach, the building owner buys regular electricity from their electricity service provider but purchases the renewable energy certificates from a REC vendor. In such a scenario one can consider to purchase REC from another country (e.g. due to lower REC prices). For example currently Norway and Sweden experience a surplus of RECs due to the existing hydro power and wide use of renewable electricity from other sources. Such an application brings in the question whether nZEB will lead to a saturation of the REC market and create a drive for construction of new renewable generation systems.

Although this scheme certainly brings flexibility to the use of renewable electricity, continuity and connection to the building is important and needs to be warranted, in the delivery contract as well as through a 'transferable clause'. Currently, legal schemes lack in coupling nZEB ownership with renewable electricity certificates and/or ownership of renewable energy generation. Due to non-standardised verification methods it must be ensured that fraud or double counting is avoided related to green energy taken from grids. Risk of non-ensured availability of renewable energy during the life time of a building should be avoided. In setting up the system, special contracts, penalties for non-compliance will need to be devised to avoid and eliminate such risks while at the same time avoiding unnecessarily high administrative burden resulting from MVE of an nZEB's renewable share.

ECOLOGOGICAL ADDITIONALITY

All options discussed in the previous sectors need to be benchmarked against the concept of ecological additionality. Ecological additionality is given when a measure or an instrument has an ecologically positive effect compared to a reference case without this measure. Hence, the question is whether the requirements of the nZEB add an ecological benefit with regard to the share of energy from renewable sources and if these requirements interact with other policy instruments. It has to be ensured, that the requirements defined by the nZEB lead to a supply from additional renewable electricity to be entirely carbon-free.

Politically set renewable energy source (RES-) targets often imply an actual cap as measures and investments will be allocated to exactly meet the target. Any further activities that might lead to an outperformance are neither incentivised nor financially supported anymore. The European Commission's Renewable- Directive (EC, 2009) has set obligatory RES-targets for Europe as well as for each member state individually. The Europe-wide target is 20% renewable energy in the energy consumption till 2020. In addition to this, flexibility mechanisms allow member states to transmit parts of their renewable energy share to other countries that can, thus, raise their renewable energy share. Subsequently, the current European target has to be seen as a cap since countries are likely to transmit or sell any surplus to another country. As a consequence, it is important to what extent renewable energy investments in the context of nZEBs are taken into account when calculating the EU-targets and in how far they benefit from national support schemes for renewables.

The EBPD's requirement of using renewable energy source to a "very significant extent" should certainly mean an increase in the demand for RES when it comes to building nZEB based on electricity by 2020.

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[10] "An issue that is often linked to bundling is "geographic sourcing." When drafting the RES, legislators have to decide whether and to what extent they should limit the geographic area for renewable projects that can comply with their RES" http://www.renewableenergylawinsider.com/2011/03/07/all-recs-are-not-created-equal-part-1-bundling-and-geographic-sourcing/

To cover the demand, new investments in renewable electricity – that would not have been made anyway without the request for nZEB – will need to be made. If no additional investments in renewable electricity are made, the additional demand will be supplied by power from conventional (mostly fossil) generation, as this source is able to adapt to rising electricity demand. This will even take place in a situation, where a certain share of the already existing renewable generation is legally bound to an nZEB. Such a measure would simply reduce the (legal) availability of renewable electricity for other buildings and/or sectors. In fact such an approach would lead to an increase of primary energy factors for everybody who does not explicitly consume renewable energy but just a share of what remains from the overall generation after subtracting the share of renewables that is explicitly dedicated to certain buildings or parties. Obviously the share of conventional electricity generation would increase within in this "remainder". This scenario also highlights the high probability of double counting renewable shares in a system where allocation of renewable production is not fully defined.

The new investments in nZEB must fulfil the requirement of ecological additionality. Hence the question is crucial whether these new investments are taken into account within the EU-targets from 2020 or not and if they receive funds foreseen for support schemes to achieve the EU-targets. If the nZEB-driven investments are taken into account, don't increase the target and receive funding (e.g. for surplus power fed into the grid), the nZEB-driven investments only substitute investments which otherwise would have been made anyway. Hence, they don't provide ecological additionality. The same logic applies if REC certificates are purchased and this transaction does not initiate additional investments but shifts the renewable energy mix between two entities without further consequences.

Consequently, it is important to ensure in nZEB regulations, that the initiated investments fulfil the requirements of ecological additionality, at least from the moment on, where nZEB are mandatory, i.e. 2019 or 2021 respectively.

The EPBD does not yet seem based on a requirement for nZEB to additionally use – for the purpose of nZEB - supplied RE supply. But this could be a compliance criteria introduced by the Member States which also would give the boost to renewable energy which is probably intended by the nZEB definition, but might fail without such obligation. The building owner can evaluate RECs based on a range of factors including, but not limited to, price, the technology (e.g. from which technology is the electricity generated; only wind, wind and hydro, etc.), locality of supply, and regulations.

Potential options to do so for off-site electricity solutions might be funds which are additional to national RE funds or which extend these national funds and which are financed by nZEB owners. Also possible would be solutions where neither for the nZEB related investment in RE nor for the generated RE electricity subsidies (which were meant to achieve a target that did not consider nZEB) are granted. Such a situation obviously becomes more and more realistic the closer we get to grid parity. As nZEBs are due by 2019 or 2021, respectively there is a real chance for such a situation.

CONCLUSIONS AND RECOMMENDATIONS

Energy efficiency and renewable sources are usually mentioned as two sides of the coin "EPBD buildings", with a priority for reducing energy needs for heating and cooling first. Nearly zero energy buildings are a cornerstone for reaching the European Union's very ambitious climate targets for buildings by 2050. Energy efficiency alone will not suffice to reach those targets. This is why the use of renewable energy even in buildings with nearly zero energy demand and in spite of the guideline "efficiency first" is highly relevant. Typically, energy supply from on-site renewable sources is in the focus of the debate. This is why the major purpose of this paper was to shed some light on the role of off-site energy from renewable sources within the nearly zero energy building concepts of the EPBD. Facts, considerations and reflections presented above allow for some conclusions and recommendations.

One of the major standpoints of this paper is, that it will be necessary, for reasons of equality, providing even chances and thus avoiding discrimination, to develop clear definitions, processes and instruments for making energy from off-site renewable sources a viable option to cover the nearly zero amount of energy required.

Article 2.5 EPBD includes all kinds of renewable sources. Nevertheless typically "onsite or nearby" categories are considered , where large scale or community scale production of energy from renewable sources do not fit, although their levelised cost of energy will reach "retail" grid parity till 2020 and wholesale grid parity beyond.

TABLE 5 POTENTIAL BENEFITS AND BARRIERS FOR DIFFERENT OWNERSHIP OF OFF-SITE RENEWABLE ENERGY GENERATION SCHEMES FROM INVESTOR POINT OF VIEW

	onsite RE	offsite -share ownership	offsite - delivery contract (green electricity)
Investment upfront needed?	YES	YES	NO
Sensitive to electricity price or product price increase?	Self consumption part: NO	NO	YES
Sensitive to changes in metering schemes?	YES	NO	NO
Sensitive to local grid capacity and physical limitations	YES	NO	NO
Possibility to exploit most cost-effective RE options	NO	YES	YES
Sensitivity to the match between supply and demand	YES	NO	NO
Sensitive to period of balance?	YES	NO	NO
Ease of monitoring verification and enforcement incl. persistence	+	-/+[11]	-/+
Financial viability for building owner	-/+	-/+	-/+

[11] Difficult at start as mechanisms need to be developed to standardise and facilitate this. Once established, not very difficult, however, will still require more monitoring than on-site.

Table 5 shows potential barriers and benefits of different ways to include renewable energy sources in nearly zero energy buildings. The table clearly shows that there are distinct differences between the options for renewable energy as part of nZEBs. It will be highly dependent on the situation what factors are most influential in the decision of the building owner (or project developer) and what option is to be preferred in each case. It will therefore be of vital importance to the building owner to have all options available and these options being accessible within a system of MVE. In the case of offsite sources, both for forms of ownership and delivery contracts, development work needs to be done to get standardised products on the market that can easily be monitored and verified by the authorities.

As to the EPBD's nZEB definition itself, *[A nearly Zero-Energy Building is a] "building that has a very high energy performance… [ ]. The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby*" all key terms need to be sharpened, probably through a mixture of scientific and political discussions: nearly zero or very low amount; energy (energy *need*? energy *use*? d*elivered* energy? pr*imary* energy?), "should" be covered; nearby.

We see a strong need for development of a commonly agreed set of regulations for calculating the share of energy from renewable sources in a nearly zero energy building; this will build upon a more precise nZEB definition. Today no such framework exists. In this context the questions of allowing for time disparities between demand and supply and suitable time intervals for balancing have to be answered. Following from the preliminary analysis in this study, today balancing intervals like weeks or months seem to be most reasonable.

As to the importance of electricity in nZEB, the environmental impact and cost of electricity (for appliances and other services) is the same order of magnitude or even higher than for heating/cooling in a nZEB, even if electricity is not used for heating or cooling. Therefore, a much stronger focus on electricity in nZEB is needed in order to avoid sub-optimal allocation of investments for further decreasing environmental impact and life-cycle cost. In the long run all energy used during construction, operation and disposal should be considered as well as the CO_2 and other relevant emissions for these life-cycle stages. As the ever increasing role of electricity, increasing the share of renewable energy and decreasing the cost for providing it are major nZEB topics, too. Also for this reason clear rules that allow unbiased comparison of different buildings' energy performance, as well as to the share of renewables and its effect on PE and CO_2, are needed.

Metering schemes turn out to have a large influence on the available options for energy from renewable sources in nZEB. Currently not the same metering schemes are available for on-site, nearby, and off-site electricity. Thorough analysis should be done about if this can be changed as it means a restriction for all options beyond on-site unless other schemes will be developed.

We have major concerns over whether the renewable energy component in nZEB will really lead to *additional* environmental relief; this must be the ambition for nZEB and must be secured for all kinds of renewable sources for nZEB. Current European policy seems to lack harmonisation between different policies, therefore it is unclear, if the renewable energy share in NZEB will be a share in the (beyond) 2020 targets or make them more ambitious respectively; the latter would be necessary in order to not let the nZEB RE share just be a "bookkeeping" exercise without real positive environmental impact. A lot of research for and development of suitable instruments and legal schemes seems to be necessary in order to avoid falling into this trap.

Finally we would like to emphasise that nearly zero energy buildings won't be mandatory from tomorrow on but from 2019 on for new public buildings and from 2021 on for all other new buildings. This means there is still some time left to solve open questions and to develop missing instruments. Nevertheless the horizon is short enough to call for starting the search for answers and developing missing instruments from today.

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