Energy efficient construction

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Abstract. Contemporary energy demand, ecological principles concept, and new understandings of the rational use of resources have led to a situation where humanity and every state must use energy in a rational manner. Therefore, several standards for buildings that use almost zero external energy (NZEB) have been adopted. They imply approaches in the process of designing the cladding of the structures with the greatest impact on the building quality in terms of its energy efficiency. Practice shows that for the implementation of these standards, in addition to an unquestionable quality, practically feasible legal framework, and quality engineers - designers, auditors, and contractors - having a competent and motivated workforce, appropriate equipment, and good communication and cooperation among all participants in the construction is required.

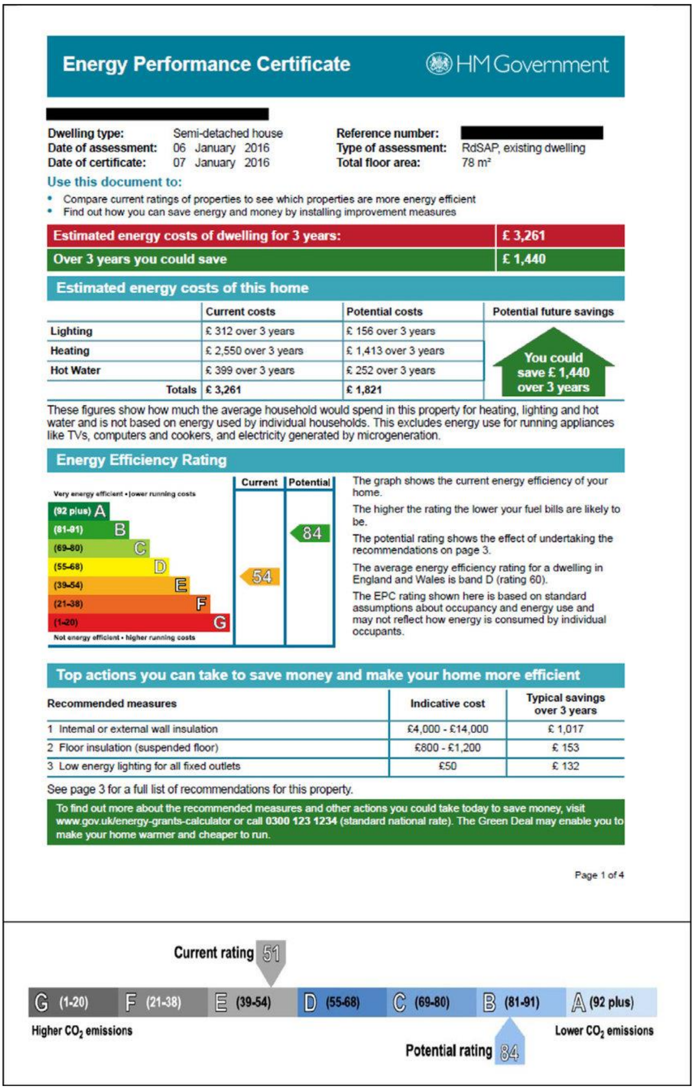
Keywords:

Energy Efficiency, Nearly Zero Energy buildings, Passive House, sustainable development

1. Introduction

Humanity is facing a time of intensive development that implies a huge energy deficit. At the same time, energy needs are constantly growing, and many experts [1,2] predict that the problem will only worsen. Therefore, the primary task is the rational and proper use of existing energy resources. The energy efficiency topic is neither new nor contemporary. This concern has existed throughout history in a latent form, though it caught the attention of scientific research in the 19th century. The following century helped raise global awareness about this topic through mass media, scientific research, economic statistics, standardisations, and regulations. It is important to note that this task unifies economic, social, and political aspects of environmental protection. The sustainable development concept raises awareness of the need to strike a balance between human needs and environmental protection in favour of future generations. Many international conferences have addressed this issue by adopting numerous policies and declarations. These include strategic policies introducing the green economy, established by the European Environment Agency (EEA) through the EEA Report No2/2014 [3]. The green economy has three objectives: resource efficiency improvement, ensuring ecosystem resilience, and social equality. The green economy implies efficient use of resources, providing income and employment through different investment ventures.

The last two decades have been dedicated to the issue of improving the energy efficiency of buildings, reducing carbon emissions, and mitigating the impact of climate change. Thus, the EU Directive [4] adopted in 2002, and amended on 19 May 2010 as *The Energy Performance of Buildings Directive* (EPBD) (Directive 2002/91/EC), addressed the above-mentioned mission by setting out several measures. Some of the main points of the Directive include: larger public buildings are required to display a *Display Energy Certificate* (DEC) Fig.1; when buildings are advertised for rent or sale, energy performance certificates have to be presented; all new buildings have to be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018). As described by Praunseis [5], an energy performance certificate is a document showing the energy efficiency of a building. Energy efficiency is calculated in the energy certificate (annual energy required for heating, annual energy supplied for the building operation, the annual need



Energy Performance Certificate

HM Government

[redacted]

Dwelling type:	Semi-detached house	**Reference number:**	[redacted]
Date of assessment:	06 January 2016	**Type of assessment:**	RdSAP, existing dwelling
Date of certificate:	07 January 2016	**Total floor area:**	78 m²

Use this document to:

- Compare current ratings of properties to see which properties are more energy efficient
- Find out how you can save energy and money by installing improvement measures

Estimated energy costs of dwelling for 3 years:	**£ 3,261**
Over 3 years you could save	**£ 1,440**

Estimated energy costs of this home

	Current costs	Potential costs	Potential future savings
Lighting	£ 312 over 3 years	£ 156 over 3 years	You could save £ 1,440 over 3 years
Heating	£ 2,550 over 3 years	£ 1,413 over 3 years	
Hot Water	£ 399 over 3 years	£ 252 over 3 years	
Totals	£ 3,261	£ 1,821	

These figures show how much the average household would spend in this property for heating, lighting and hot water and is not based on energy used by individual households. This excludes energy use for running appliances like TVs, computers and cookers, and electricity generated by microgeneration.

Energy Efficiency Rating

The graph shows the current energy efficiency of your home.

The higher the rating the lower your fuel bills are likely to be.

The potential rating shows the effect of undertaking the recommendations on page 3.

The average energy efficiency rating for a dwelling in England and Wales is band D (rating 60).

The EPC rating shown here is based on standard assumptions about occupancy and energy use and may not reflect how energy is consumed by individual occupants.

Top actions you can take to save money and make your home more efficient

Recommended measures	Indicative cost	Typical savings over 3 years
1 Internal or external wall insulation	£4,000 - £14,000	£ 1,017
2 Floor insulation (suspended floor)	£800 - £1,200	£ 153
3 Low energy lighting for all fixed outlets	£50	£ 132

See page 3 for a full list of recommendations for this property.

To find out more about the recommended measures and other actions you could take today to save money, visit www.gov.uk/energy-grants-calculator or call 0300 123 1234 (standard national rate). The Green Deal may enable you to make your home warmer and cheaper to run.

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Fig.1 Example Energy Performance Certificate (EPC) [7].

for primary consumption and CO2 indicator), transmission heat losses coefficient, and many other calculated parameters describing energy consumption or the needs of individual buildings. It must be obtained during the construction of a new building or when an existing one is sold or leased. These certificates include comparative values (e.g., categories according to the standard). Recommendations for economically justified energy efficiency improvements are also expected to be attached. Displaying these certificates in a visible place of public buildings with a usable area of more than 1000 sqm is mandatory. Many researchers [6] believe that energy certifications can show many of the realities of structures, improve the efficiency of existing buildings and endow residential sector planning with a more realistic vision. The certification system would contribute not only to reducing the energy consumption of buildings but also serves as a good platform for addressing climate change [7]. This forms an unbreakable bond with the economic aspect of the real estate market in terms of regulation of price range lists according to the certification process values.

2. Zero Energy Building Definitions

The introduction of strict environmental standards—both governmental and voluntary—to address pressing environmental challenges, including climate change, the preservation of natural resources, pollution, ecology, and population—has led to the emergence of ZEBs. In concept, Zero Energy Building is a building with significantly reduced energy needs and demands with efficient gain loads such that the balance of those needs can be supplied from renewable resources. The design process is crucial to set goals for achieving high-performance Zero Energy Building; thus, a combination of applicable efficiency measures, renewable supply options, and selection is relevant. The role of Zero Energy Building (ZEB) has established itself as the standard reference for the target achievements in terms of balance between needs and self-sufficiency for a building under service conditions. The leading institutions worldwide have supported and promoted ZEBs. European and American plans for future developments of cities and energy saving promote and support the construction of an increasing number of ZEBs. According to the Concerted Action (CA) EPBD report, [16] about 40% of Member States (MSs) do not have a detailed definition of nearly zero-energy buildings (NZEB) yet. About 60% of Member States have laid out their detailed definition of nearly zero-energy buildings (NZEB) in a legal document, but several Member States emphasised the draft status of the definition or that the definition might be updated later on. It is important to acknowledge that the term ZEB does not mean an energy-free building. Moreover, these buildings are still energy consumers, though the consumption with a low environmental impact. ZEB definitions range from those that compare the net energy inputs to outputs to those that compare the financial costs of energy consumption with the costs connected with the equipment used in the structure for energy production—from photovoltaics (solar cells) and wind turbines, for example—combined with the advantages connected with exporting energy generated by the structure [17]. Different opinions exist on the relative significance of energy production and energy conservation in attaining a net energy balance, and there are several ways to evaluate the energy in a structure (for example, cost, energy, or carbon emissions). Berardi [17] claims that since the widespread adoption of distributed energy generation systems necessitates infrastructural capacity and flexibility, the interactions between high-performance buildings, Renewable Energy Technologies (RET) available for the building needs, and the supply grid are becoming more and more crucial. When considering how buildings interact with energy grids Fig.2 [19], it is important to consider each place's unique circumstances and the many obstacles that each energy infrastructure or set of building features presents. Therefore, local adjustments of the ZEB and nZEB definitions are required to account for unique site characteristics. Several researchers (Napolitano et al.) [19] and studies have examined potential ZEB definitions over the past ten years. In the case of ZEB, a building is distinguished by some form of energy generation in addition to a specific load Fig.2. The load comprises technical installation efficiency in addition to net energy consumption. Losses from storage and conversion are also included in the generating process. Regardless of the balance between load and generation, a building is considered to be in a stable state throughout the year with no net build-up of energy inside the system boundary. Locally accessible renewable energy sources are utilized both actively (such as ground source heat pumps) and passively (such as solar gains via windows) to meet a portion of the building's load. Depending on the temporal alignment between generation and demand and the available storage options, these on-site renewables are also employed to create energy carriers (such as electricity) that partially cover the load, and parts are supplied back into the grid. The overall term "energy grids," or simply "grids," is used to refer to these numerous supply networks to which a building may be linked. Grids and structures exchange energy in the form of natural resource-derived energy carriers. The term "delivered energy" refers to the energy that networks supply to buildings, whereas the term "feed-in energy" refers to the energy that buildings supply to grids.

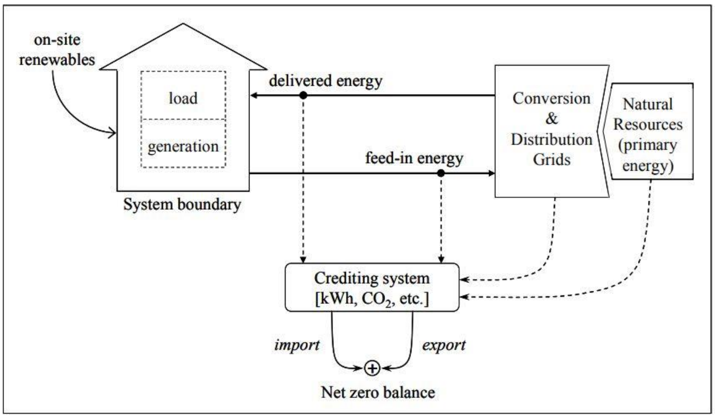

Fig.2 Relationship between building and energy grid. [19].

The key to defining Net ZEBs is the idea of balance between the energy delivered and the fed-in energy, as well as any type of interaction with the grids. However, these two values are typically not directly evaluated in their physical units but through some crediting system. In order to assess the impact of the complete energy chain, including the characteristics of the natural sources, the conversion processes, and the distribution grids, a crediting system translates the physical units into other metrics, such as primary energy or equivalent carbon emission. It is also feasible to use measures other than those given, which will be discussed later. In order to represent the import and export depicted in Fig. 2, we may say:

$$import = \Sigma \mathbf{i}\ \text{delivered}_{\text{energy(i)}} \times \text{credits(i)} \tag{1}$$

$$export = \Sigma \mathbf{i}\ \text{feed} - \text{in\_energy(i)} \times \text{credits(i)}, \tag{2}$$

where i = energy carriers

A Net ZEB requires that the balance of imports and exports over a given period be zero or even positive, meaning that embodied energy or emissions in materials must also be balanced off. Therefore, the following balance imbalance is a prerequisite for a Net ZEB:

$$|\,export\,| - |\,import\,| \geq 0 \tag{3}$$

The central component of a Net ZEB definition is the balance of Eq. (3). However, in order for it to be relevant and useful, several factors must be considered, and certain explicit decisions must be taken, such as the metrics used for crediting. Additionally, it may be useful to use indications other than the simple balance over time to provide qualified information about the overall "quality of design" of a Net ZEB. Taking into consideration above mentioned, the Zero Energy Building is a complicated idea, and several strategies highlight various ZEB components. Additionally, it is not simple to calculate the energy balance of a building that has on-site and/or off-site renewable energy generating equipment, interacts with the utility grid, and strives to achieve the "zero" target. Moreover, there is no obvious, standardised support for the "zero" calculation approach. As stated by Marszsal et al. [20], if ZEB is considered a future goal for buildings, it is crucial to provide a physically compelling, reliable, and understandable calculation technique that embodies the idea and makes it easier for architects and engineers to construct Zero Energy Buildings. Torcellini et al. [21] show that the project objectives, investor intents, concerns related to the environment and greenhouse gas emissions, energy cost, and the unit used in the ZEB definition may all have an impact. The four ZEB definitions they provide are, respectively: site ZEB, source ZEB, emissions ZEB, and cost ZEB. For instance, energy costs are frequently a concern for building owners. Organisations like the Department of Energy (DOE[3]) are interested in primary or source energy and are concerned with national energy statistics. Site energy consumption may be of relevance to a building designer due to energy code requirements. Finally, lowering emissions may be of interest to individuals who are worried about pollution from power plants and the use of fossil fuels. The principal site energy method is utilised in the majority of European nations' ZEB definitions, although in certain nations (such as the United Kingdom, Norway, and Spain), carbon emissions are employed as the primary indication or as a supplementary indicator to primary energy consumption (e.g., in Austria and Romania). Each European Member State would have to specify what it means to achieve a primary energy level of almost 0 kWh/(m^2a) by the spirit of the EPBD recast. Further aspects, factors, and options of ZEB will be presented in the doctoral thesis that will follow up on this research. Three key components make up the design process for reaching ZEB status: energy-efficient (passive) building design, active system energy efficiency optimisation to reduce building energy demand, and on-site renewable energy generation to meet any residual energy requirements.

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