Journal of Building Engineering 6 (2016) 65–74

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Less is more: A review of low energy standards and the urgent need for an international universal zero energy standard

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ARTICLE INFO

Article history:
Received 29 November 2015
Received in revised form
15 February 2016
Accepted 15 February 2016
Available online 17 February 2016

Keywords:
Zero energy buildings
Building codes
Building standards

ABSTRACT

There are in excess of 70 low or zero energy/carbon building definitions/standards in circulation around the world. However there are few zero energy or zero carbon buildings. This suggests that despite, or possibly because of, a continuing debate over definitions, aspiration has not been met by reality. In this paper the most important 35 standards are reviewed and a correlation between activity in standard generation and completed buildings is presented. Combining this with the requirement for an 80% cut in carbon emissions, a consideration of the proportion of humanity that live in countries without any standards and the ratio of new-build activity vs. pre-existing stock, leads to a conclusion that there is an urgent need for a binding international zero (rather than low) energy/carbon standard that can be adopted world-wide. It is argued this is only possible if carbon is ignored in favour of energy, and many lifecycle issues put to one side. In part this is because of changing national carbon intensities within the energy supply chain, but it is also due to unresolved issues in carbon and energy accountancy. It is hence suggested that such issues are left to optional additional local standards.

1. Introduction

The latest IPCC synthesis report [1] notes that since 1970 cumulative CO_2 emissions from global fossil fuel combustion, cement production and flaring have tripled, and that climate change is already having an observable impact on the more vulnerable and exposed parts of the world. This is not only via the occurrence of more extreme weather events but is also from impacts on sensitive natural ecosystems, fishery stocks and the production of crops [1]. Due to the importance of the issue, it has been a longstanding requirement of countries to address their production of greenhouse gasses via the Kyoto and other protocols.

Buildings are a major contributor to world carbon emissions both operationally and during construction, with the energy consumption of buildings being around a third of total energy use worldwide [2]. As world population grows and the level of urbanisation increases, the amount of energy required by buildings is also set to increase. The building industry therefore has a key role in helping to reduce carbon emissions by providing buildings that minimise their energy use and general impact. Governments and others have started to rise to this challenge. For example, in the UK the construction and operation of the current building stock accounts for around 30–40 per cent of the country's total carbon emissions, and so has been a focus within the Government's overall strategy for reducing emissions [3], the policy situation is similar in much of the developed world.

Given the need to cut world carbon emissions by 80% to ensure climate change is limited to a rise of no more than 2–4 °C in mean global temperature [1], all sectors, from transport to electrical generation, to buildings will need to undergo a transformation. Some sectors are likely to find this more difficult than others. With little progress toward non-fossil fuel based aviation having been made, oil still dominating land transport, nuclear power only paying a minor role and the diurnal or seasonal storage of renewable energy proving technologically difficult, several sectors are unlikely to be able to achieve an 80% cut in the required timeframe. Logic therefore dictates that the built environment may well need to offer a greater than 80% cut – quite possibly a 100% reduction to a zero energy/carbon state. By reflecting on the current complexity of the low energy/carbon standards landscape, this paper argues that, to be effective and adopted worldwide, it might be necessary for any zero energy/carbon building standard to be relatively simple.

The concept of buildings that have no energy requirements or are producers of no carbon emissions is therefore an important

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http://dx.doi.org/10.1016/j.jobe.2016.02.007
2352-7102/

Table 1
Summary of zero energy building definitions as presented by Kilbert and Fard [9].

Source	Definition
Esbensen and Korsgaard (1977) [12]	A zero-energy house (ZEH) is considered to be self-sufficient in space heating and hot water supply during normal climate conditions in Denmark.
Gilijamse (1995) [13]	A ZEH is defined as a house where no fossil fuels are consumed, and annual electricity consumption equals annual electricity production. Unlike the autarkic situation, the electricity grid acts as a virtual buffer with annually balanced delivers and returns.
Iqbal (2004) [14]	A ZEH is one that optimally combines commercially available renewable energy technology with the state-of-the-art energy efficiency construction techniques. In a zero-energy home no fossil fuels are consumed and its annual electricity consumption equals annual electricity production. A zero-energy home may or may not be grid-connected. In a zero-energy home annual energy consumption is equal to the annual energy production using one or more of the available renewable energy resources.
Charron (2005) [15]	Homes that utilise solar thermal and solar photovoltaic (PV) technologies to generate as much energy as their yearly load are referred to as net zero energy solar homes (ZESH).
Torcellini et al. (2006) [16]	A zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable energy technology.
EISA (2007) [17]	A net-zero energy (NZE) commercial building is a high-performance commercial building designed, constructed and operated: (1) to require a greatly reduced quantity of energy to operate; (2) to meet the balance of energy needs from sources of energy that do not produce greenhouse gases; (3) to act in a manner that will result in no net emissions of greenhouse gases; and (4) to be economically viable.
Mertz et al. (2007) [18]	A net-zero energy home is a home that, over the course of a year, generates the same amount of energy it consumes. A net-zero energy home could generate energy through PV panels, a wind turbine or a biogas generator.
Rosta et al. (2008) [19]	A ZEH produces as much energy as it consumes in a year
Laustsen (2008) [20]	Zero net energy buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grid. Seen in these terms, they do not need any fossil fuel for heating, cooling, lighting or other energy uses, although they sometimes draw energy from the grid.
Green Building Advisor (2010) [21]	Net zero-energy buildings (nZEB) are those producing as much energy on an annual basis as it consumes on-site, usually with renewable energy sources such as PV or small-scale wind turbines.
European Parliament (2010) [22]	The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
Aelenei et al. (2010) [23]	The nZEB concept can be defined as a building that over a year is neutral meaning that it delivers as much energy to the supply grid as it uses from the grid.
Voss et al. (2011) [24]	The understanding of an nZEB is primarily based on the annual balance between energy demand and energy generation on the building site. An nZEB operates in connection with an energy infrastructure such as the power grid.
Hernandez and Kenny (2010) [8]	A life cycle zero-energy building (LC-ZEB) is one where the primary energy used in the building in operation plus the energy embodied within its constituent materials and systems, including energy generating ones, over the life of the building is equal to or less than the energy produced by its renewable energy systems within the building over their lifetime.
Salom et al. (2011) [25]	A nZEB can be succinctly described as a grid-connected building that generates as much energy as it uses over a year. The 'net zero' balance is attained by applying energy conservation and efficiency measures and by incorporating renewable energy systems.
Sartori et al. (2012) [26]	A nZEB is a building with greatly reduced energy demand that can be balanced by an equivalent on-site generation of electricity, or other energy carriers, from renewable sources.
Lund et al. (2011) [27]	A ZEB combines highly energy-efficient building designs, technical systems and equipment to minimise the heating and electricity demand with on-site renewable energy generation typically including a solar hot water production system and a rooftop PV system. A ZEB can be off or on-grid.

one, however the details of what a building must achieve to be classed as one of these is still debated. The literature has many examples of definitions of zero carbon or energy buildings (Table 1) and defining what is meant by these terms is often seen as complex and challenging [4,5]. Supplementary to these definitions there are in excess of 35 low energy standards in active use across the world. These differ in both their ideology and their methodology, and they use a variety of metrics for verification. Low, rather than zero, energy/carbon buildings have been built in reasonable numbers, however given the need to cut carbon emissions by 80% [1], the size of the historic building stock and the lack of progress on lowering transport emissions [3] it is clear that at least new build needs to be zero energy/carbon.

The future impact of any standard is hard to quantify, as it no doubt depends not only on the standard but also the degree of application it finds. This will vary around the world with the specific demand and levels and nature of construction. For example a large proportion of the building stock in many countries already exists and so for a standard to find wide use in these areas applicability to retrofit is an important consideration. However, from the data presented later, it would seem the impact has been minor, despite a proliferation of suitable standards.

This work first considers existing definitions of low and zero energy buildings as debated in the literature, their applications, and differences. The review goes on to focus on the currently applied standards, both optional and mandated, around the world