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Near zero energy homes – What do users think?

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HIGHLIGHTS

- The policy concept of zero energy homes is examined from the user perspective.
- Evidence is collected from a near net zero energy housing estate.
- Results show that the homes are highly comfortable and valued by households.
- Seasonal differences in the delivery of thermal comfort are found.
- Significant design problems and technology reliability issues are identified.

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ABSTRACT

With policy directions firmly moving towards net zero energy homes, what do we know about the perceptions and experiences of households who already live in homes at or near that standard? The research sets out to determine whether householders believe these buildings are thermally comfortable, and if they feel confident operating the smart technologies that help achieve the net zero energy outcome? Combining interviews from 25 households and monitored energy data from over 50 near zero energy homes, this paper examines the validity of this policy goal from the building user perspective. The evidence shows households attain high levels of thermal comfort, enjoy lower energy bills, and believe their behaviour has been influenced by the building and its energy systems. Yet many remain concerned that the building industry is unable to produce homes that maintain thermal comfort in all spaces and all seasons. The residents have also identified significant issues in the reliability and usability of the energy technologies. Whilst the policy appears valid from the end-user perspective, the case study highlights the substantial task ahead for policy makers to establish suitable commissioning and compliance processes, and develop effective energy rating tools on the path to zero energy homes.

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1. Introduction

Passive solar design strategies combined with energy efficient devices and renewable energy technologies have been applied in buildings to improve thermal comfort and reduce energy end-use for many years (Butti and Perlin, 1980). Case studies demonstrating the potential for extremely low energy homes have appeared in many countries, and recently the International Energy Agency's 'Towards Net Zero Energy Solar Buildings' project mapped almost 300 net zero energy and energy-plus buildings worldwide (Research for Energy Optimized Building, 2013).

Building energy policy is also moving rapidly towards regulatory levels approximating net zero energy or net zero carbon (Lovell, 2009; Kapsalaki and Leal, 2011). In the United Kingdom the regulatory target is set at net zero carbon for new dwellings by 2016 (Department of Communities and Local Government, 2006); in Europe the EU Directive on the Energy Performance of Buildings (European Commission, 2010) specifies that by the end of 2020 all new buildings shall be 'nearly zero energy buildings' (Sartori, Napolitano and Voss, 2012); and other nations such as the USA, Korea and Australia have developed policy options suggesting a path to net zero energy buildings by the 2020s (Department of Climate Change and Energy Efficiency, 2010; Sartori et al., 2012).

While the policy debate has focussed on energy savings, or emission reductions or economic efficiencies, the policy has rarely been examined from the end-user perspective. Missing from the debate has been a discussion of whether households actually enjoy living in net zero energy homes and feel comfortable interacting with the types of technologies and systems required to achieve that net zero energy balance. With thermal comfort being one of the key drivers of household energy use, it is important to understand whether near net zero energy homes provide the level of thermal comfort expected by building users.

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This paper explores the available evidence from a near net zero energy residential estate to test the validity of the policy by asking the research question: do households feel comfortable and use less energy in homes designed to reach that standard? By addressing this key gap in the literature, this paper will help policy makers understand the benefits and risks associated with the application of net zero or near net zero energy housing standards.

1.1. Energy use in near zero energy homes

Numerous studies attest to the reduction of net delivered energy use through the application of passive solar design, appliance efficiency and local renewable energy supply technologies (Heinze and Voss, 2009; Hodge and Haltrecht, 2009; Parker, 2009; Musall et al., 2010; Gill et al., 2011; Kapsalaki and Leal, 2011). For example Kapsalaki and Leal (2011) examined so called net zero energy homes in USA, Canada, Germany, Austria and the United Kingdom to document the design strategies which achieved significant energy reductions for residential buildings. Not only did many of the buildings reach their intended net zero energy performance target, but Kapsalaki and Leal (2011, p158) concluded that '… reaching a null or even positive net yearly energy balance is not technically difficult and could be reached by combining standard building design with enough integration of on-site renewables.'

Net zero energy homes are increasingly becoming a practical proposition in many countries. Musall et al. (2010) identified over 280 mostly residential net zero energy buildings across USA, Canada, Europe and the United Kingdom, determining the key strategies for energy use reduction as passive solar architecture, very good levels of insulation, power saving appliances, combined with solar thermal systems, heat pumps and photovoltaics.

Studies have demonstrated that the performance of low energy-use buildings can be maintained over time (Hodge and Haltrecht, 2009; Summerfield et al., 2010). Hodge and Haltrecht (2009) found BedZED maintained a high level of energy savings after five years. Summerfield et al. (2010) examined the performance of 36 low-energy homes in the United Kingdom 17 years after a study of the same dwellings to find that energy saving strategies were enduring.

End user experiences for near zero energy homes have been reported in heating dominated climates (Isaksson and Karlsson, 2006; Mlecnik et al., 2012), with investigations covering indoor conditions and general user satisfaction, but there is scant empirical evidence describing the resident's perceptions of thermal comfort, ease of operation and overall energy performance in very low energy-use buildings in climates where cooling demand is also significant.

In Australia, a few studies have documented the energy performance or user perceptions of very low-energy homes in warm temperate and hot humid climates (Oliphant, 2004; Saman et al., 2011b; Miller and Buys, 2012; Milleret al., 2012), although the value of these studies is limited by the sample size, atypical construction materials or floor area, or the atypical demographic profile of the occupants.

The literature provides significant empirical evidence from many countries and climates demonstrating that the combination of passive solar design, high levels of insulation, energy efficient lighting and appliances, and the application of renewable energy technologies can greatly reduce the energy and carbon impact of homes. And in some cases they can be a net contributor to the local energy grid. But the absence of empirical evidence documenting the resident's perceptions of these low-energy homes, particularly in warm temperate and hot humid climates, means that although it is technically possible to create net zero energy homes, little is understood about whether residents enjoy living in them.

1.2. The benefits of thermal comfort

Household energy-use savings, or the associated greenhouse gas emission reductions, may be reasonable policy goals in their own right, but such policies are unlikely to be supported in the long-term if requisite improvements in human thermal comfort are not also sustained. Human thermal comfort is defined as the 'condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation' (ASHRAE, 2010). Human perception of thermal comfort takes into account air temperature, air speed, mean radiant temperature, relative humidity, occupant activity and clothing (Havenithet al., 2002). Humans play an active role in maintaining their own comfort, through changing their clothing, changing their level of activity, changing the natural conditions in that space (i.e. opening windows or doors), or by using technology to return the indoor conditions to that which matches their perceived needs (Nicol and Humphreys, 2002).

Early concepts of human thermal comfort based on Fanger's predicted mean vote model (Fanger, 1970) prescribed a narrow band of temperature to be applied uniformly through space and time, considering building users as passive recipients of thermal stimuli driven by the need to maintain their body's thermal balance with its immediate environment (de Dear and Brager, 1998). Recently a variable temperature model (adaptive thermal comfort) has linked desired indoor conditions to the climatic context of the building which accounts for past thermal experiences and current thermal expectations of the building users (de Dear and Brager 1998, 2001; Nicol and Humphreys, 2002). Thermal comfort is also a social construct reflecting the beliefs, values, expectations and aspirations of households, with demand for comfort increasing dramatically over the past few decades (Chappells and Shove, 2005).

Satisfying the desire for thermal comfort is one of the key drivers of household energy use. Studies investigating operational energy use in Australian homes since 1990 show the amount of energy used for heating and cooling is not only the largest single end-use, but relative demand for each end-use changes over time (Australian Greenhouse Office, 1999; Department of the Environment Water Heritage and the Arts, 2008). Whilst total energy use and thermal comfort energy use per household has remained stable since 1990, the amount of energy used for thermal comfort has trended down for heating but up for cooling (Department of the Environment Water Heritage and the Arts, 2008). This change is probably due to technological trends such as increased building regulatory standards (Department of the Environment Water Heritage and the Arts, 2008); the proliferation of air-conditioning units (Wilkenfeld, 2004); and increased consumer expectations of thermal comfort (Chappells and Shove, 2005).

But energy use in thermally efficient homes, such as expected for net zero energy homes, presents a different picture. Compared to the Australian average stock figures, the relative proportion of energy used for space heating and cooling in near net zero energy homes is noticeably lower, but still a relatively important energy end-use (Berry et al., 2013). Berry et al. (2013) also found that the total amount of energy used for all energy services in near net zero energy homes is also significantly lower when compared with the Australian stock figures, averaging 28.3 GJ per household (2010–13) against the expected average of 47.5 GJ in 2012 (Department of the Environment Water Heritage and the Arts, 2008), with much of that energy-use balanced by on-site electricity generation.

The benefits of thermally comfortable buildings extend beyond lower energy bills. The literature shows that building thermal comfort has a strong relationship with human health both in hotter climates such as found in Australian or Mediterranean conditions, and colder climates such as experienced in North

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