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PV in historic dwellings: The potential to reduce domestic CO_2 emissions

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ABSTRACT

Historic (i.e. pre-1919) dwellings in the EU account for around 14% of the total stock (21% in the UK) and must therefore contribute significantly to any long-term energy reduction or carbon saving goal. However, the principle of minimal intervention advocated by heritage conservationists is at odds with the fabric-first approach that energy conservationists propound. It is clear, therefore, that a different approach is needed to ensure significant savings are still delivered by the historic stock whilst balancing the need to maintain our built heritage.

In this paper, we raise the question of whether the price of altering the built historic environment is worth the contribution such measures could make to meet the overarching and serious challenge of climate change. We focus the work on the potential for roof mounted Photo Voltaic (PV) installations, by taking a case study approach. The research examines 5 case studies in and around the UNESCO World Heritage city of Bath in the South West of the UK. The generation pattern of the PV systems is compared to electricity demand in the dwelling to assess the potential for maximising the use of PV electricity and minimising domestic CO_2 emissions.

Results indicate that in ordinary energy use patterns, without additional demand management, an average of 56% of electricity generated from a roof mounted PV system is used within the dwelling, reducing CO_2 emissions by an average of 19%. In contrast, typical *actual* savings from changes to the building fabric, which are difficult to implement and often not realised in practice, are around 9%. Results \ also show that where energy use patterns are arranged to synchronise with PV electricity generation, reductions of up to 23% can be made in CO_2 emissions arising from delivered electricity use.

1. Introduction

Climate change is a key challenge of the 21st Century. Meeting this challenge requires reductions in Greenhouse Gas (GHG) emissions, particularly CO_2, from all sectors of society. The UK's Climate Change Act mandates a reduction in GHG emissions of 80% by 2050. In addition, as part of its European commitments, the UK is bound to source 15% of its energy from renewable sources by 2020.

Buildings in the UK contribute almost 40% of all emissions [1]; this is higher than the overall contribution of buildings to global emissions at 34.2% (2000 data).[1] Within the UK, domestic dwellings accounted for 26% of CO_2 emissions in 2010 [2] as a result of operational energy use. As between 70% and 80% of UK dwellings in 2050 have already been built [3], it is clearly necessary to improve the energy efficiency of the existing built stock if carbon reduction targets are to be met.

Fig. 1 shows the distribution of dwelling stock by age in England for 2008 [4]. It is evident that a significant proportion of these (4.8 million or 21%) were built before 1919. For the purposes of this study, all pre-1919 dwellings are defined as 'historic' dwellings [5].

These historic buildings have significant cultural and heritage value and the overarching aim of reducing CO_2 emissions demands solutions that are specific, suitable and replicable at district scale to deliver enduring energy efficiency savings and emissions reduction while maintaining their heritage value.

Further, taken together with dwellings built between 1919 and 1945 (which also have a heritage value), these buildings account for 37% of all dwellings. Whilst built form and age has little effect on electricity use (most heating is provided by gas/oil), the significance of the higher proportion of older dwellings is apparent if their contribution to our built heritage limits the take up of roof mounted PV on grounds of visual aesthetics. This is of importance as the options to reduce CO_2 emissions arising from electricity use in dwellings are limited.

The challenge of reducing CO_2 emissions in existing dwellings is demonstrated by Jenkins et al. [6] who modelled an extensive list of retrofit adaptations that could only achieve 52% reduction in CO_2 emissions, but with the inclusion of PV this increased to 75%.

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[1] Table 6, p. 17 in [34].

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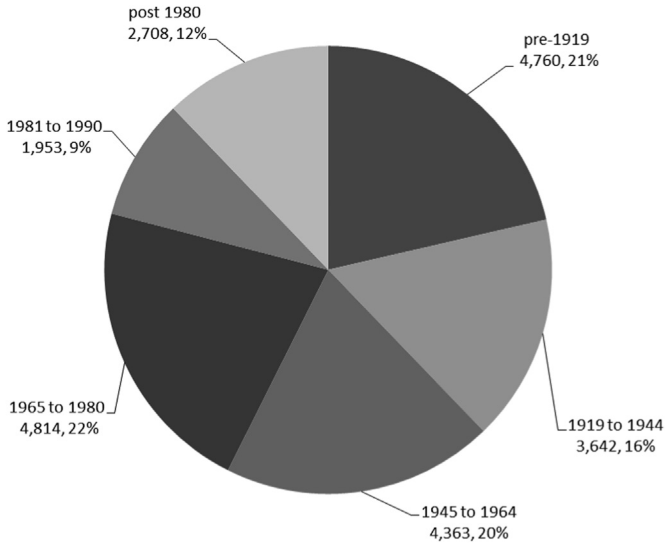

Fig. 1. Number (000s) and percentage of homes by age in 2007. *Source*: English House Condition Survey (EHCS) [4].

This highlights the difficulties in achieving sizeable CO_2 emissions reductions in existing buildings and the potential contribution the adoption of PV systems can make.

In historic buildings achieving such savings is likely to involve fabric and aesthetic alterations. This research aims to evaluate the CO_2 emissions reduction through the adoption of PV arrays in historic buildings under current planning regulations. There is no methodology to balance reduction in emissions against loss of heritage, although carbon emission reductions come at the price of loss of visual aesthetics, perceived or actual. The intention of this paper is to evaluate the benefit of carbon savings thereby quantifying the retrofit adaptation benefit of PV systems in historic buildings.

This approach challenges the long held conservation principles [7] of minimal intervention to use less energy, reduce emissions and maintain comfort in buildings by advocating the adoption of effective and durable adaptations.

1.1. Domestic energy use

Fig. 2 shows that the majority of energy use in the home is for heating and hot water (63%). The options to reduce this demand in historic buildings are varied and on the whole well understood but are not fully implemented for many reasons, including conservation constraints, cost, planning restrictions and the possible risk of loss or decay of building fabric. Current orthodoxy focuses on reducing this demand through improvements to fabric and system efficiency before turning to low and zero carbon technologies (LZC). We argue here, however, that given the contribution of electricity use to overall carbon emissions, LZCs have a role to play, especially for historic building where options for fabric improvements may be somewhat limited.

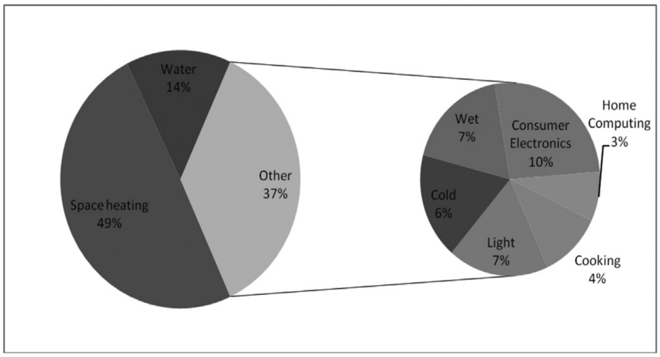

Fig. 2. Domestic CO_2 emissions by source [8].

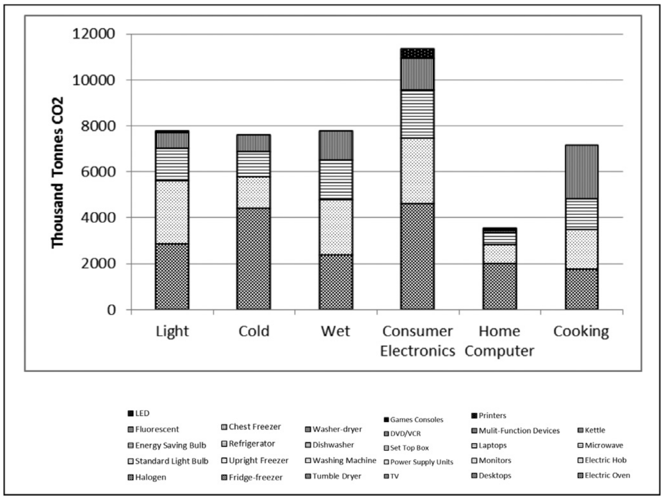

Fig. 3. Breakdown of domestic electricity use 2010 [10].

Although electricity use in dwellings is typically 15% of total energy use [8] it contributes to 37% of the total domestic carbon emissions (UK electricity currently has 2.4 times the carbon factor of gas [9]).

This is significant, because unlike heating and hot water the options to reduce CO_2 emissions arising from electricity use are both limited and distinctly different. One possibility is to reduce the carbon factor of delivered electricity; this is beyond the control of householders and is more a function of government energy policy requiring long-term structural changes to supply. Other options are to demand reduction or the adoption of LZC technology.

1.2. Domestic electrical demand reduction

The breakdown for domestic electrical use emissions is at Fig. 3, this shows there are several areas to focus attention on within the home to reduce CO_2 emissions.

One is to reduce lighting demand through increased use of low energy CFL and LED light fittings. Recent regulations [11,12] have significantly improved uptake but these remain expensive and occupants are not always satisfied by the type of light produced. Similarly, energy efficient choices are now widely available when replacing appliances. However, the most efficient A++ rating appliances currently have limited availability and are generally an expensive alternative to an A rated appliance. Furthermore, household awareness is an issue since only 16% were aware of the energy rating of their new appliance when making a replacement purchase [13], thus illustrating the problem of uptake even if more efficient appliances are on the market. Finally, another option is real-time occupant energy use feedback. The potential impact of monthly feedback on energy use patterns is usually estimated to be 5–10% [14], but it would appear that initial savings cannot be sustained in the medium to long-term [15]; this is an area of ongoing research.

Within the home there are also elements of occupant behaviour that can deliver energy savings. Examples are switching off lights/appliances when not in use, avoiding the use of standby mode for audio and television units, as well as avoiding leaving various charging units on while not charging.