Energy Efficient Refurbishment of Interwar Housing

An energy efficient housing stock has the potential simultaneously to alleviate the problems of climate change, fuel poverty, and the UK's over-dependence on imported fossil fuels. The Government is committed to ensuring that all new homes in England are built to zero carbon standards by 2016, although precisely what solutions developers will be allowed to use is still being debated. The progressive lowering of the target Dwelling Emission Rate (DER) contained within Approved Document Part L is the mechanism that is currently being used to move towards the zero carbon standard. However new dwellings represent only a small fraction of the UK's housing stock. For real progress to be made, urgent action is required to improve the energy efficiency of the existing housing stock. Next year the Government is launching the potentially multi-billion pound Green Deal scheme to improve the energy efficiency of homes and lower carbon dioxide (CO_2) emissions from the housing stock.

The Green Deal is likely to tempt thousands of new entrants into the energy efficient refurbishment sector seeking to capitalise on such large scale investment, especially given the harsh economic climate currently faced by many areas of the construction industry. There are though very few documents in the public domain providing definitive guiding standards for domestic refurbishment to a low or zero carbon standard. Without suitable performance standards and available in-depth case studies to use as guidance, there will inevitably be many refurbishments that fail to reach the energy performance required to generate sufficient returns on the investment made and meet the Government's targets for reductions in carbon emissions.

The lack of specific and detailed low carbon refurbishment guidance for many types of dwelling is a real concern. Although no two houses will ever be identical, it is reasonable to assume that many houses of comparable period and construction type will possess similar energy performance characteristics. A case study of a 1920's council house was undertaken to establish what intervention would be necessary to enable it to reach a zero DER standard. Some 3.7 million dwellings from the interwar period are still in existence, representing 17% of the UK housing stock.

The case study dwelling is a 70m^2 two storey semi-detached house of masonry cavity construction. A whole house survey revealed there to be significant thermal bridging, thermal bypasses, air leakage paths and outdated heating systems. From the data gathered during the survey it was established that the dwelling resided in SAP band G with a DER of 126.27 kg $CO_2/(m^2/year)$, based on the SAP 2005 methodology.

The upgrade strategy followed a 'whole house' approach. Selection of appropriate improvements to the building fabric and services preceded consideration of onsite renewable energy generation (microgeneration). Due to the limited guidance available for refurbishment, building fabric standards modelled were based on values primarily developed for new build dwellings. The following standards were modelled using the SAP 2005 methodology: Approved Document Part L (1a & 1b), Passivhaus guidelines and the Energy Saving Trust's Code for Sustainable Homes Level 6 (EST CSH) recommendations. An assessment was then made of the performance and suitability of each standard for use in low carbon refurbishment of interwar housing.

Fabric Improvements

Retro-filling the 50mm wall cavity with mineral fibre insulation reduces air movement and thermal bypass, but does not result in the lower exterior wall u-values demanded by the more stringent standards. The addition of insulation to the external walls is necessary to produce the desired thermal performance. Assessment of the dwelling determined that exterior insulation would be more effective than internal insulation at reducing thermal bridging, improving airtightness, utilisating thermal mass, retaining interior floor space and protecting the deteriorating exterior of the dwelling. Although this process would entail extending the eaves, it provides the opportunity to ensure continuity between roof and wall insulation at the eaves. Triple glazing systems are necessary to reach the required u-values.

Warm roof construction is favoured as this allows the loft space to be used for storage space and reduces penetration of services (such as MVHR ducting) through the insulation and air barriers. Replacing suspended timber floors with a concrete slab increases airtightness and the efficiency of under-floor heating systems. To increase the level of airtightness demanded by the more demanding standards, pressure testing before and after renovation is recommended to identify air leakage paths and allow rectification.

Building Services Improvements

The selection of space and water heating systems within a dwelling must consider a range of economic, environmental, and political factors. Selection of the appropriate fuel source is crucial, as future energy prices will have long term financial implications for a building's occupants and the different carbon intensities of fuel sources will crucially affect the carbon emissions from the dwelling. However the evolution of relative fuel prices and relative carbon intensities is uncertain over the useful lifetime of the space and water heating systems.

Government incentives can also increase the attractiveness of a particular fuel source. The Renewable Heat Incentive has increased the attractiveness of heat pumps and biomass technology. Current biomass boiler technology is not advised as demand for biomass fuel is expected increase substantially during the decade, due to its increasing use in centralised power stations and domestic uptake. With a limited domestic supply and imports necessary to meet demand, biomass could suffer the same fate as many other commodities and experience sharp price rises.

Gas currently has a significantly lower CO_2 Emissions Factor than mains electricity in SAP calculations, although this may not always remain the case. If reasonable progress is made towards the government's 2020 renewable energy target, the inherent CO_2 associated with mains electricity will begin to decline. Presently, heat pump systems with efficiencies over 250% already result in less CO_2 emissions than condensing gas boilers of 90% efficiency.

A combination of these factors resulted in the choice of a heat pump to provide space heating and some hot water demand, with the following caveats: that low temperature emitters (such as under-floor heating) are used, that the building is highly insulated and airtight, and that an immersion heater is provided as a contingency for hot water supply and to maintain the efficiency of the heating system. A MVHR system is deemed necessary to maintain air quality within the relatively airtight dwelling and to lower heating demand.

Microgeneration

Microgeneration should only be considered once the building envelope is functioning in an energy efficient manner, as investments made in renewable energy generation are easily negated in an inefficient building. Energy efficiency measures are more cost effective than microgeneration; however the incentives offered by the Feed-in Tariff scheme have resulted in financial viability for investors in refurbishment projects. Photovoltaic (PV) installations are preferred to wind turbines due to fewer planning restrictions and their suitability for use on a greater number of dwellings.

Results of Modelling Standards

None of the currently existing standards managed to achieve the zero DER target when modelled on the dwelling. With the addition of photovoltaic panels to the roofs of the modelled dwellings, Passivhaus and EST CSH recommended standards achieved the zero DER target. Modelling also revealed that PV installations are more effective that solar thermal collectors at reducing CO_2 emissions per m^2 of roof space.

EST CSH and Passivhaus standards arrive at very similar levels of DER, but achieve these results by different means. The Passivhaus standard requires an extremely high level of attention to airtightness and thermal bridging. EST CHS recommendations place greater emphasis on the high performance of thermal elements to attain low CO_2 emissions.

Implications for Low Carbon Refurbishment

Passivhaus and EST CSH standards require high levels of airtightness and low levels of thermal bridging that are potentially unrealistic for many refurbishment projects. Existing standards for low carbon buildings were primarily envisaged for new build dwellings where airtightness and thermal bridging can be minimised at design stage. During refurbishment these factors need to be physically removed from the existing structure. Refurbishment performance standards must account for the reality of adapting existing structures with potentially hidden defects. This may require higher thermal insulation standards to compensate for lower airtightness and thermal bridging standards.

Microgeneration is essential if a refurbished dwelling is to reach a zero DER. New build dwellings can be designed to exploit passive solar gain, reducing the need for renewable energy generation to perhaps a small turbine or one PV installation to reach a zero DER. For dwellings such as the case study it would be necessary to utilise both roofs for PV energy generation to reach a zero DER. In this scenario it is proposed that a south facing PV installation subsidises the north facing PV.

Large DER reductions are relatively straightforward to achieve on very inefficient dwellings, such as the case study dwelling. As a dwelling becomes increasingly more efficient, additional emission reductions become progressively more expensive and difficult to achieve, a clear example of the law of diminishing returns at work. Poor performing dwellings are the priority for achieving large emissions cuts in the UK housing stock. Targeting these dwellings first for energy efficiency improvement could help ensure the UK meets the 2020 household emissions reduction target, and contribute to reducing fuel poverty. The sterner challenge lies in finding reductions from dwellings that already have a reasonable level of energy efficiency to enable the more stringent targets for carbon emission reductions by 2050 to be met.