Achieving the 2050 carbon reduction early?

The Technology Strategy Board's 'Retrofit for the Future' competition has given the emerging low carbon retrofit industry a chance to calibrate progress. £15 million was available for carbon reduction in social housing, with up to £155,000 per project. This was intended to deliver a target performance of 17kg/m² of CO_2 emissions per year and a primary energy requirement of no more than 115kWh/m² per year from each of the homes involved. Equivalent to an 80% reduction in emissions on a notional house built to 1990 standards, this meant that projects had to go much further than loft insulation and a fuel change. Charlie Baker explains ...

Bramall Construction, in partnership with Rotherham 2010 (the Council's Arms Length Management Organisation or ALMO) got through the first bidding stage of the competition. Bramall wanted to strengthen its second stage bid so as a result of our 'eco-vision' for the local Dearne Valley approached us, together with engineers AECOM, to assist. We were keen to be involved in both this and a parallel TSB project with Bramall for Wakefield District Housing, since it gave us an opportunity to trial the 'Beyond Decent Homes' standard that we had developed for the Sustainable Housing Action Partnership (SHAP) in the West Midlands[1]. The completed Rotherham scheme won Sustain's refurbishment award in March this year, increasing our confidence that the project has a lot to offer in the debate about how to achieve the 2050 target for household carbon emission reductions.

Two short terraces of three houses each were chosen by the landlord, in consultation with the tenants. Selection was based on their good tenancy record and the need for 'Decent Homes' work, rather than any particular tenant interest in environmental issues. The decent homes' works - new kitchens and bathrooms - came from a separate budget.

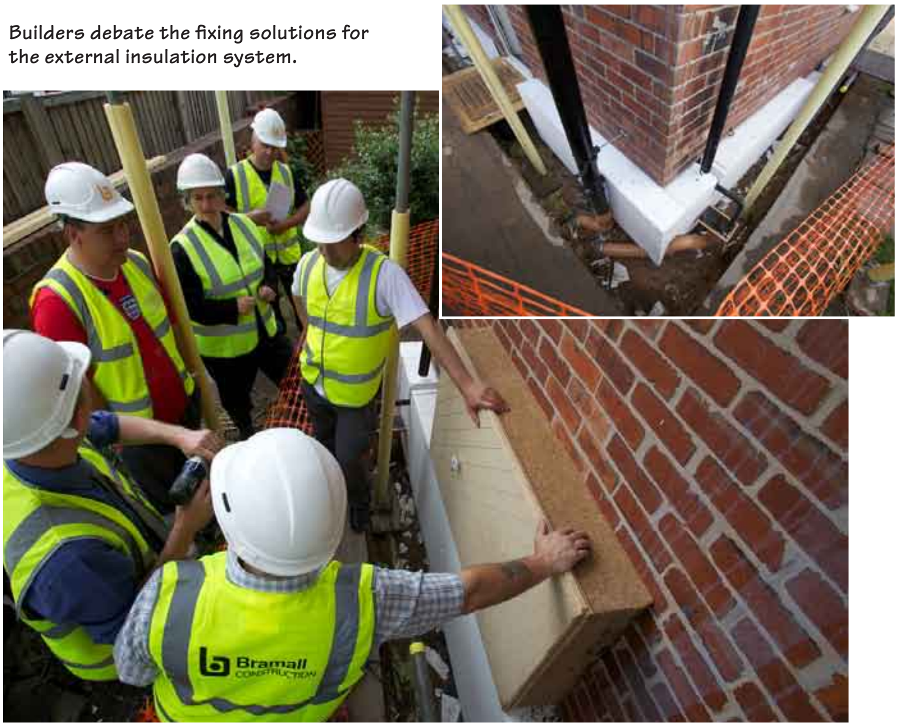
The houses are typical of much of the stock built in the middle of the last century. Whilst small, at around 80m², they were drafty and expensive to heat. The standard of construction was a key challenge. The walls of the lower floors had a very small cavity, whilst above the feature brick courses were single brick solid walls with poorly applied coarse render. There had also been a haphazard approach to servicing in the past, with surface mounted mains electricity supplies and randomly arranged drainage.

Our strategy was to implement demand reduction first, based on fabric improvements. Reducing space heating energy use by around 90%, whilst also reducing hot water heating demand with low-flow fittings, and electricity use through energy efficient lighting and A++ appliances. We then explored options for heating, ventilation and renewable energy technologies to reduce emissions further, with each house receiving a different combination of technologies. We saw this as both a chance to trial different kit in the field on similar houses, but also to match each to the resident's particular circumstances.

During initial site visits we discussed retrofit options with the tenants for both fabric and services. As a result, one block had a 'minimal disruption' option, whilst the other residents were willing to undergo a greater degree of disruption. It was also agreed that each house would receive a different heating and ventilation system.

We then worked through calculations for the performance of potential measures using a spreadsheet developed for the SHAP work. This was based on SAP (Standard Assessment Procedure) and as a design tool allowed us to model variations more rapidly than with standard SAP software, allowing us to adjust the mix of measures until we achieved just the output required by the TSB, without over specifying expensive kit. These calculations were then checked and validated using approved SAP software. We then re-visited the tenants to talk them through the combinations you see in the table. At this point, Bramall Construction took the lead to deliver the project, as URBED and AECOM were not appointed to provide full design services. This was more likely to reflect the delivery structure for a mass-market roll-out.

Builders debate the fixing solutions for the external insulation system.



Working across six houses meant we had the opportunity to compare technologies in a similar setting. Along with the other TSB retrofit projects, the houses will be monitored for a minimum of two years following completion. Useful information has already been gathered during the construction phase, and it will be possible to look at the ongoing maintenance implications of each of the approaches used. However, direct comparisons between the houses is problematic as there are considerable variations between the houses in occupancy levels and patterns. Some houses are occupied almost all day by a full family, and others occupied only in the evening and at weekends, or by a single person. Similarly, thermostat settings appear to vary between 19º and 24ºC.

Fabric

The primary aim of the fabric works was to improve thermal performance and reduce space heating demand. This required a good degree of attention to detail, especially in relation to thermal bridging and air-tightness. Seemingly small matters such as the re-arrangement of drainage and the provision of new porches had to be considered.

Wall insulation

We chose to use external insulation to minimise disruption to the residents and avoid reducing the internal floor area of the houses, as well as to help to improve the look of the properties. This had to achieve a U-value of 0.15W/m^{2}K. The lack of a cavity on the first floor, the presence of floor joists embedded in the front and back walls, the exposed location, and the fact that there would be no opportunity to install an internal vapour barrier, meant we had to consider moisture movement, and so chose to use a vapour permeable insulant. To minimise costs on site we needed a product that could:

- cope with the uneven existing wall surface
- required no levelling render
- could go on in a single application
- required no additional structure.

We struggled to find a UK product to match these criteria. Having tried it on our pilot for much the same reasons, we specified 200mm of Unger's Udireco from Germany (see photo above, top right). This is a single board made from two different grades of wood fibre, one pliable and able to take up unevenness in the existing walls, the other a harder tongue and groove board to carry render. To minimise thermal bridging at the floor-wall junction, we continued the external insulation to the footings, approximately 600mm below the internal finished floor level, using 200mm of expanded polystyrene insulation suitable for below ground use.

There were plenty of challenges at the roofline, as there was little space between the tile plane and the internal corner of the room. We specified aerogel for maximum thermal performance at the narrowest point, while still leaving room for eave's ventilation. This will be a detail to look out for in future projects on houses of this type.

The small eave's depth created an issue in dealing with rainwater and capping the insulation. Our preference was to create a parapet gutter detail, however the contractor felt it was easier to lift the bottom rows of tiles, extend the rafters, and add extra rows of tiles lifted from where they would be later covered by photovoltaics and solar tubes.

Windows

The windows had already recently been replaced on the three properties. Rather than replacing the whole window, we simply reglazed them with higher-performing locally made units. On the other three properties our target window U-value was 0.8W/m^{2}K. We wanted to specify the least environmentally damaging frame material while helping to develop a more local supply chain. Ideally we would have liked to specify a locally made Passivhaus standard window. However, this is still a niche and expensive market. A local supplier won out, but cost required we settled for uPVC (see photo above).

The SAP calculations suggested that just reducing cold bridges would reduce energy demand by up to 7%. A key measure was embedding the windows in the insulation. by fixing them to the front of prefabricated boxes. This had the added benefit of maximising the glazed area of the windows whose light transmittance was reduced by the triple glazing. Bramall's own joiners made the boxes but our hope is that over time this will be done by manufacturers as they see the benefits of this approach.

Lofts

All the loft spaces had 400mm of fibre insulation installed. To retain storage use without compromising the insulation, the rafters were made into trusses on a 2.5m wide centre section of loft to accommodate a storage deck. The loft hatches had to be moved as the access level was now 400mm higher. New proprietary loft hatches were insulated and air-sealed, to remove this potential weak-point in the thermal envelope of the building. These were a German import, however, since carrying out this work Bramalls have been able to source a UK manufacturer to produce a similar product much more cheaply.

Floors

There were three different existing ground floor constructions. A ground bearing concrete slab to the rear of each house, with a suspended timber floor to the front over either a varying depth undercroft in the end-terrace properties, or a part basement in the mid-terrace. We used four different floor insulation methods which were developed to match the tenants requests with regard to levels of disruption:

Floor insulation solution 1: minimal disruption, suspended timber floor

This represents an experiment; the air bricks have been fitted with periscope-type extensions so that the air is taken in from just above the ground under the floor. A recycled glass pumice called 'Misapor' has been poured into a few openings to create a layer about 200mm deep, with at least a 50mm clear space below the bottom of the joists.

Floor insulation solution 2: minimal disruption, ground bearing slab

Concrete floors were left in place, and a 200mm wide trench filled with Misapor was added externally to the 200mm of EPS perimeter insulation as the footing (see photo at top of previous page). This achieved a calculated U-value of 0.43W/m^{2}K .

Floor insulation solution 3: major disruption, suspended timber floor

The floor boards were lifted and formaldehyde free glass wool was placed between the joists. We had proposed nylon webbing to support the insulation, the contractor chose chicken wire instead.

Floor insulation solution 4: major disruption, ground bearing slab

The concrete floors at the rear were dug up at the same time, replaced with an insulated concrete slab incorporating ground granulated blast-furnace slag (GGBS), to reduce cement content. A new softwood floor was then laid throughout.

Services

The servicing of the houses is where we have made most use of having six similar houses on the same site to compare different systems. The houses all have south facing roofs, which we used to collect solar energy, either using solar photovoltaic or solar thermal systems. Three different ventilation options were also chosen - from leaving the existing extract fans in the house with a requirement for absolute minimal disruption, to the installation of passive stack systems and MVHR units.

Three houses have solar thermal evacuated tubes, with either a wood-burner or a gas boiler, feeding into >>

UK regulations require an uncontrolled air supply for a wood burner. The M&E contractor installed an air-brick to deal with this (somewhat compromising air tightness).

This shed, which houses the heat store and expansion tanks, was considerably smaller at the design stage. Not providing a full architectural service, only pre-works design advice, was instructive.

This equipment is all inside the shed pictured above.

Achieving the 2050 carbon reduction: the resident's perspective by Marianne Heaslip

Until recently, most low carbon retrofits have been carried out by experts and enthusiasts on their own houses. However, retrofit needs to move rapidly into the mass market if we are to meet our carbon reduction targets. This TSB project is a step on the way to the mass-market. Residents' primary motivations for involvement were reduced fuel bills and improved comfort, rather than green issues. Initial monitoring has revealed the importance of usability and personal control in achieving these aims for the residents. In this they are likely to be closer to the typical mass-market customer than the early pioneers.

Residents say that their involvement in initial design discussions, and the active interest that some took during construction, helped their understanding of the work. Once the work was finished, they each received a contractor-produced handover booklet and a pack containing all manufacturers' information during a formal hand-over session with a tenant liaison officer. Residents have suggested that this was less useful than they would have hoped. The handover booklet concentrated too much on familiar features, such as the bathroom and kitchen fittings, whilst the manufacturer's information pack was too detailed and confusing, and the tenant liaison officer wasn't able to explain all the works to their satisfaction.

All the residents can use the control systems for their heating and ventilation as required, though they do not use all the features available on often complex control units. Several prefer to use a manual setting to flick heating on and off, as this allows them to feel more in control of their energy use. It is difficult to know whether this will increase energy use overall, as is often assumed by government initiatives to encourage the use of thermostats and timers. Residents are generally cost conscious and the houses require minimal heating, so assumptions about more sophisticated controls being more efficient may not hold true.

Many technologies, such as MVHR or solar thermal systems, are not 'fit and forget', and require fine-tuning and seasonal commissioning. This highlights the need for high quality after care and training for maintenance teams, which could have significant implications for a wider roll out, for example as part of the 'Green Deal'.

The residents have been in the houses throughout one of the coldest winters in recent memory. They are happy with the retrofit work, especially the insulation measures and new heating systems. Their expectations of lower fuel bills and greater comfort have been met – or in some cases exceeded. Indeed, several of the tenants said they hadn't realised how cold this winter had been.

The 'big things' that make a real and measurable difference to people's bank balance and general well-being have been a success. However, as ever, the devil is in the detail. Initial research points to the importance of matters such as the specification of controls, the quality of handover information, the importance of communication whilst the works are in progress and the need for ongoing customer care. This is likely to have management and cost implications in any mass market retrofit scheme.

See in particular: www.superhomes.org.uk and www.refitwest.com

See also the interesting graph on the development of technology from early adopters to the mass market in D Norman (1998) 'The Invisible Computer', MIT Press, Cambridge MA.

One of the most content residents has a biomass system, which is especially well liked as it gives them full control over their heating costs - they know exactly how many logs they have burned.

a 560 litre thermal store. The remainder use high efficiency gas condensing combination boilers for heating. We had hoped to use different makes of solar collector, so we could compare performance in use, but in the end Navitron collectors were used throughout to minimise cost.

UK vs continental comparison

Very few mainland European manufacturers supply wood-burners with back boilers that are UK Clean Air Act exempt and most supply parts only for unvented heating systems. As most UK manufacturers commonly supply for fully vented systems, we took this opportunity to compare these different approaches. One of the biomass/solar installations is an unvented German system, the other is an English vented system, which uses a wood-burner made locally in Huddersfield. The price differential was considerable, but it's too early tell whether this is echoed in the performance.

A second major difference between the systems is in the space they take up. There is nothing produced in the UK like the Consolar range of stratifying thermal storage tanks, they are tall and wide, so we had to install a shed in the back garden to house them. In contrast, the UK thermal store fitted into the existing airing cupboard.

Conclusions

The construction work on the houses was completed in autumn 2010. Detailed conclusions on energy performance will not be sensible until a full year of data has been collected. Whilst comparisons are complicated due to different occupancy patterns and thermal comfort preferences in each of the houses, many useful lessons have already been learned. These have primarily related to the construction process and performance of the supply chain. We also believe that these houses provide proof of concept for an affordable 80% reduction in carbon emissions. Indeed, this project did much to inform our recent work on the 'Community Green Deal' for SHAP and the HCA . The main lessons to highlight are:

- An 80% CO_2 reduction is possible, and can be much more cost effective to achieve without 'eco-bling'
- This is still a very new industry and common understandings have not yet developed. The relationship between specification choices and consequences for environmental performance are not yet fully understood across construction teams.
- Experienced designers need to be able to control the process until more standard approaches have been developed, as attention to detail is paramount and some of the detailing required is challenging.
- Information about the existing condition of the building is based on a detailed assessment, together with an allowance for unforeseen circumstances. This is critical to minimise potential unforeseen costs.
- A fuller understanding of the implications of super-insulation and air-tightness on building physics is critical across the industry, not just among designers and specifiers.
- The supply chain and product manufacturing base needs to develop in the UK if the economy is to benefit fully from the projected expansion of the retrofit market between now and 2050.

Charlie Baker

For more information about all of the Retrofit for the Future schemes: www.retrofitforthefuture.org

For more information on where we're going with our learning from this: www.shap.uk.com/projects and watch www.carbon.coop

Also worth seeing is the AECB/TSB low energy buildings database at: www.carbonlite.org.uk/carbonlite/lowenergybuildings.php

URBED (Urbanism, Environment and Design) Ltd does what our name suggests. We specialise in urban design and environmental sustainability in an urban context orientated around the communities involved. We work across the UK from our base in Manchester for public and private sector clients. Our background is in urban regeneration recent work has ranged from low-carbon retrofit design and strategy advice, to town centre strategies and outline planning applications for large commercial masterplans, from university estate strategies to urban design guidance.

Charlie Baker trained as an architect, but feeling the people affected were missing from the equation set up housing, workspace, design and fabrication co-operatives, creating anything from furniture through housing and workspace to neighbourhood design, work he has continued since with URBED. Starting off retrofitting a Victorian semi, he has subsequently devised large scale retrofit standards as well as co-operative finance and delivery models.
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