Going for gold - 2

Newbuild extension

What can be achieved at reasonable cost to minimise energy consumption of a typical family by thoughtful extension and refurbishment? Will the gas and electricity meter spin any slower? Ralph Swallow, a practising structural engineer with building design practice Fluid Structures, records his first hand experiences, lessons learned, and post occupation monitoring ...

Figures suggest that the average dwelling in the UK extracts from the national grid 278kWh of energy per square metre, per year, whilst a house designed to PassivHaus standards is allowed only 15kWh/m^2/yr for heating and a total primary energy consumption of no more than 120kWh/m^2/yr. Of course a 'zero carbon' house built to level 6 of the Code for Sustainable Homes goes a huge step further and should be extracting exactly 0.0kWh/m^2/yr, from the 'grid' when averaged over a year. We had all these figures in mind when we set out three years ago to double the size of our Victorian semi, hoping by now to be wallowing in a haze of green self satisfaction. This, in some respects, is the case, but there have been some frustrating lessons learned on the way. It has also been interesting to see what a typical extend and refurbishment project can achieve in reducing energy consumption, on a modest budget with a local builder, compared to the well documented self-build and new-build case studies.

Back in 2006, with two young children who were just about learning to run, two dogs, and our modest Victorian 3 bed 'railway cottage' feeling ever smaller, we took the decision to extend, rather than trade up. Like many clients we were therefore looking for space for our family sooner rather than later and had pretty inflexible limits on our budget. We were also determined to achieve much better than average energy efficiency. I even harboured ideas that as we stepped up from approximately 80m^2 to 160, and replaced our creaky old boiler, we could maintain the same total energy consumption (I fail to understand how I have a reputation as a pessimist).

We had monitored our energy consumption at the meter every month over the two previous years and knew that our starting position was already significantly better than the 'average' UK dwelling, coming in at around 180kWh/m^2/yr. This was thanks largely to a generous blanket of cellulose fibre insulation in the loft, replacement double glazing, some insulation between ground floor joists, and a south westerly aspect that meant good daylighting and solar gain. It was therefore perhaps not going to be realistic to add 80m^2 to our floor plates without increasing the energy consumption.

The site constraints, and paying respect to the principal elevation meant there was only really one design solution to the building extension volume – we had to turn our rectangular plan into an L-shape. Good for daylighting and solar gain – but bad for the extent of external envelope. Architecturally we also needed to adopt two different claddings to break up the elevations and maintain the right scale for the street-scape. Together these factors were already beginning to mould the construction options, as was our desire to achieve wall U-values of 0.15 (as PassivHaus or AECB Gold). As we drifted away from the romantic idea of a full green oak frame, and thought hard about what a local builder would be comfortably able to tackle, we homed in on two envelope options:

- for the majority of the extension, either a full offsite timber frame, with site applied cladding, or a rendered load bearing masonry structure with timber trussed roof
- for the 'Victorian' part of the new build we were leaning towards brick clad timber frame as a better option than cavity wall.

Every project is different and in this case it was a close call, but the attractions of good thermal mass (as exemplified by Brenda and Robert Vale, Bill Dunster), and the close proximity of the very noisy mainline railway to Waterloo, led us to drop timber frame walls in favour of masonry for the main extension. A conventional cavity wall was out of the question - due to overall thickness and the need for rigorous site quality control - and even for a single leaf solid wall we couldn't afford the vernacular Bargate stone. We therefore decided upon a dense concrete block single leaf wall with external insulation and acrylic render. Applying a bit of careful structural engineering calculation, and maintaining sensible fenestration, enabled a 140mm 7N/mm^2 block to be used. This, together with selection of the Permarock insulated render system, meant a U-value of 0.15 could be achieved from a wall just over 300mm thick, an excellent marriage of performance and space saving. Availability of 'midi' size blocks meant there would be no manual handling issues. Meanwhile, for the smaller section of brick clad external wall, a ply faced 150mm timber stud construction was used to provide reasonable thermal performance, better than typical 2006 ADL1 constructions. All walls were to be wet plastered, or at least skimmed, to achieve airtightness, with the brick clad stud wall and timber roofs also including a polythene vapour barrier.

Above and far left: the main extension under construction and completed. Inset: the oak trusses on the roof which have proven to be a challenge with the airtightness expectations. Below: the placing of the novel glazed section that interconnects the old building to the new.

The hot summers of 2002/3 had given us some serious overheating in the existing house, due to its south westerly aspect, so we were concerned that our new 'room in the roof' top floor could be a real sweat box. We therefore budgeted for 200mm of dense cellulose insulation batts in the main new roof, the roof being a typical slate hung pitched construction of timber rafters supported on oak trusses. The specific heat capacity of these wood fibre batts is excellent compared to mineral wool, as well as providing useful acoustic insulation and a reasonable k-value of 0.04. The density of the Pavatherm we selected at 160kg/m^3 is obvious as soon as you grapple with lifting a couple of batts up ... Elsewhere, where the main new extension ties into the old house, there were a number of different roof design conditions, so variously mineral wools and multifoils were used where woodfibre was not suitable.

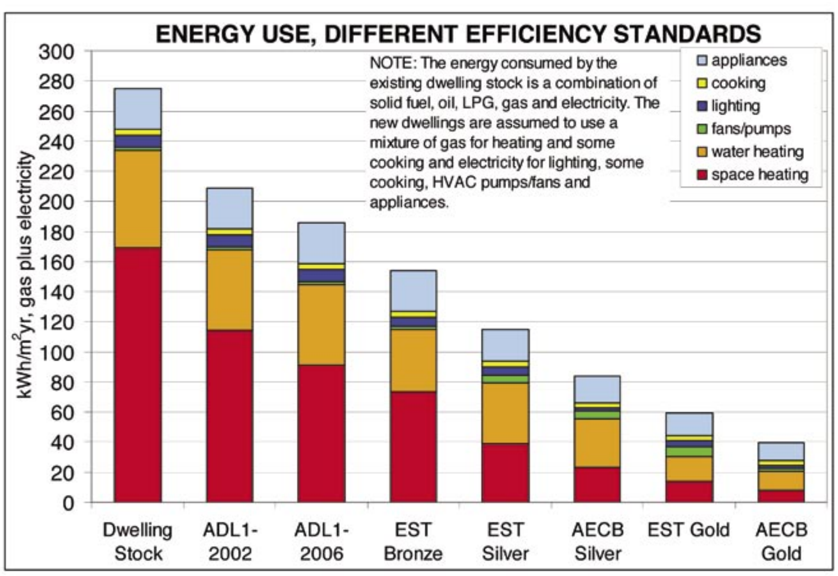
The other key components of the envelope were the ground floors and glazing. The ground floors were specified to achieve a U-value of 0.14, comprising from the bottom up: 150mm of EPS insulation, 150mm ground bearing slab, 50mm of high performance (PIR) insulation, and a 70mm screed. The prominent structural glazing, two storeys high between the two building volumes, was specified as frameless soft coat Low-E units with argon fill, giving a centre pane U-value of 1.2 approx (whole window value not calculated). The bulk of the

Table 1. Metered consumption for 6 months Jul-Dec, before and after the works.								
Year	2006 (79m²)		2007 (79m²)		2008 (166m²)		Change 2007-08	
Month	Gas	Electricity	Gas	Electricity	Gas	Electricity		
July	220	228	283	277	338	278		
Aug	188	208	188	254	204	257		
Sept	283	263	408	283	499	292		
Oct	471	356	848	297	1562	393		
Nov	1351	358	1571	349	2127	354		
Dec	1728	373	2168	365	3168	426	Gas	Electricity
Totals	4241	1786	5466	1825	7898	2000	+44%	+10%

new windows are, however, good quality, timber framed, double glazed units by Rationel, imported from Denmark, with soft low-e coating and argon fill. The budget did not stretch to triple glazing and in any case, with modest glazing areas the thermal benefits were not felt worth the cost. Whole window U-values are from 1.4 to 1.7. All the windows are free of trickle vents as we have instead opted for mechanical vent with heat recovery, MVHR. Other aspects of heating and ventilation worth mentioning are the SEDBUK top rated Vaillant 937 combi boiler, which includes small onboard tanks for immediate domestic and hot water (DHW), although peculiarly the heat losses to air from these 15 litre tanks seem to be excluded from the SEDBUK rating. We went with warm water under-floor heating downstairs but saved some money by using radiators upstairs. In the old house the original radiators and plumbing are retained.

There isn't space here to record the details and all the highs and lows of the construction period, suffice to say that almost all the offsite factory made items performed well, and almost all the site work caused difficulties or was not up to desired standard. In particular it is fair to say that even with 15 years experience in the construction industry, admittedly usually on larger scale projects, I was still frustrated by the philosophy amongst the trades

Figure 1. This shows the estimated energy use of an 80m² semi detached house meeting a range of energy standards. (source Building for a Future magazine, Vol 16 No 4, Spring 2007).



of doing what they thought was adequate, rather than building to the drawings or raising a query. Even with the employment of our client representative, we did not have eyes and ears on site every day, meaning the build was sometimes compromised, for instance:

- no airtight membrane was installed in the new roof, just taping of board edges. This membrane should have run over the topside of the oak trusses (which are now shrinking as expected, opening up air gaps)
- the edges of the ground slab were not insulated but dry-packed behind the brick plinth with sand and cement, which then had to be raked out as far as possible
- the reclaimed front door which was to be insulated and lined internally was instead treated to a sheet of glued and screwed MDF (and no insulation)
- the one window which was provided locally by our builder included 'non low-e' glazing
- the four leaf French doors made by a local joiner, which admittedly we had not detailed right down to 1:5 level, do not fit well and are not properly draft stripped, giving major air leaks. Similarly door and window cills are draughty in several cases;
- insulation was generally badly fitted (scrunched up) in the timber stud walls.

All of these items, and many others, fall into the category of 'not important' as far as many builders are concerned, struggling as they do with the various other challenges posed by getting to the end of the job as quickly as possible, winning the next one, and running a successful business. The end result is unfortunately wasted energy for the life of the building, a story repeated in various forms across the country.

There were many successes, however, in the design and the construction. Solid wall with external insulation and render is easy to build for the bricklayer, easy to seal on the inside with plaster, and requires an approved installer to apply insulation and render which almost guarantees quality. In our case this all worked well and looks great. The windows were all the right size, specification and colour, and give a firm tight closing action, as well as arriving on time. The manufacture and installation of the two 4.5m high frameless glazing units, by UK firm Able, was equally successful. And adopting wet trades and grouted tiling for the ground floor slab construction and finishes makes it quite easy to achieve good performance (hence AECB recommendations for this form of ground floor). So far the Pavatherm roof works well thermally and acoustically. The house also feels ‘comfortable’ in a very broad way that is quite hard to put a finger on, probably a combination of air and surface temperatures, relative solidity and quietness, and good daylighting and air quality.

Above: the fixing of the external Permarock insulated render system over a 140mm thick dense concrete block wall meant a U-value of 0.15 could be achieved from a wall just over 300mm thick.

After seven months back in residence the meter readings give cause for some degree of self congratulation. The good news appears to be that our electricity consumption is close to original, though slightly increased. On a square metre basis it drops from 44 to 23 units/yr. However, even with the new A-rated boiler, our total gas consumption at the time of writing, is actually up by about 44%. As we are considering a much bigger floor area, the use per m^2 drops significantly though, to ~93kWh/yr, reflecting the quality of the new construction. This gives a total for gas and electricity of 116kWh/m^2/yr. On the plus side this is a reduction of more than a third from our starting point, is 60% less than the 2006 dwelling stock UK average, and approximately equivalent to EST ‘Best Practice’. An alternative analysis could consider that 53m^2 of the original house is virtually untouched and therefore still using say 160kWh/m^2 (reflecting some benefit from the new boiler), meaning the new part of the house is perhaps working at around 95kWh/m^2 which would be approaching AECB’s Silver Standard.

As the house has been, and indeed still is currently, some way short of the intended levels of airtightness, (ie. there are numerous cracks and gaps) there should be significant improvements over the coming months and years as we steadily close up various leaky details.

Coming back to the project in PassivHaus terms our current consumption of 116kWh/m^2 equates to a ‘primary energy’ consumption at the power station of approximately 160kWh/m^2/yr, taking into account wasteful electricity power stations and distribution losses. This would therefore exceed the PassivHaus limit of 120kWh/m^2/yr. It also seems certain that of the 90kWh/m^2/yr of gas being consumed a lot more than 15kWh is being used for heating, showing that this PH limit is a really demanding standard.

Table 2. Annual consumption from Jan to Dec 2007 (the last year before the works).			
Gas	Electricity	Total	
10,743	3,502	14,245	
136kWh/m^2	44kWh/m^2	180kWh/m^2	
Predicted annual consumption for the first year in occupation, based on monitoring shown in Table 1.			
Gas	Electricity	Total	
15,470	3,852	19,322	
93kWh/m^2	23kWh/m^2	116kWh/m^2	

Conclusions

Overall the exercise has been illuminating from a technical point of view, giving a handle on what can and cannot be achieved whilst adding to a Victorian ‘semi’ with a large extension built to fairly high energy standards. Whilst we have been successful from a technical point of view, in reducing our metered consumption to 116kWh/m^2/yr, our failing is that our overall energy consumption, and therefore our carbon footprint as a family unit, have both gone up, (and this is not due to the occupancy level or pattern changing significantly). This, however, is a fundamental issue effectively ignored by all recognised design codes, as there is no distinction in any of them between a 160m^2 house occupied by a family of 8 or the same house occupied by a single adult. Really this is an issue for government, rather than building designers.

Ralph Swallow

Project credits

Architect	Marcus Beale Architects and MMM Architects
Structural engineering	Fluid Structures / Ralph Swallow
English oak structure	McCurdy & Co
Building services	En Masse Design
Client rep/project manager	Paul Hudson

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