Technology Strategy Board
Driving Innovation

BPE Dissemination

Future works – The case study

These two timber frame homes were designed to achieve the very demanding Passive House Standards but to cost no more than typical social housing. As the names suggest, 'Larch House'(below) is timber-clad externally, while 'Lime House' has lime render. Both houses have solar water heating and solar electric panels on the roof.

Building type	Sector	Study type	Region	Case study stage
Domestic	Social housing	Phase 1 - Post completion and early occupation Phase 2 - In-use performance	Wales	End of Phase 1

Figure 1: Future Works - Larch House, Welsh Passive House, Ebbw Vale

Both homes have outstanding u-values: less than 0.1W/(m^2K) for walls, roof and floor. They achieved exceptional air-tightness, far better than the minimum requirements in current and proposed Building Regulations. They should both comfortably meet the UK Government's proposed 2016 'Zero Carbon Compliance' standard.

Like other Passive Houses, they use heat recovery ventilation. The ventilation system works well, with low fan energy use, and no intrusive noise. There were some problems with installing the solar water heaters and adequate insulation for pipework, but these are now resolved.

The project reported here is part of the Technology Strategy Board's Building Performance Evaluation programme and acknowledgement is made of the financial support provided by that programme. Specific results and their interpretation remain the responsibility of the project team. The downloadable copy of this case study, further case studies and full details of the Technology Strategy Board's BPE programme can be found at https://connect.innovateuk.org/web/building-performance-evaluation.

There is now a comprehensive set of monitoring instruments in both homes, and tenants moved in in April 2012. Preliminary findings suggest that even in winter there is minimal heat loss when the ventilation system is off. At present the bedrooms are slightly warmer than other rooms, and air in the homes is a little dry when they are unoccupied. Both homes look set to have very low energy bills.

The designers used very different approaches to designing windows for each home – driven by the weather data they used in their calculations. Larch House has much larger windows and external shading (because of cautious assumptions about colder winters). Inevitably, this made it much more expensive to build.

	Larch House	Lime House
Floor area	99m^2	78m^2
SAP rating	112 (A)	97 (A)
Heat loss coefficient (W/K)	60 ±16	41 ±8
Air permeability (m^3/(m^2.h)at 50Pa	0.26	0.55

Table 1: Key Performance Indicators

Context

These two examples of passive house design for social housing were built on the site of a former steel works – one of the largest steel works in Europe. The homes were opened to the public during the Eisteddfod (a Welsh cultural festival) in Ebbw Vale to showcase low energy design. It is an exposed site in one of the wettest parts of the UK, with mist and cloud being particular issues.

Although it was a design and build contract, with the United Welsh Housing Association appointing contractor Pendragon Design, the design was fully detailed by the design team as they and the client realised that this was the only way to achieve Passive House Certification. In addition, bere:architects provided on-site training, and they were paid by the housing association up to completion of the works.

The main contractor was nevertheless technically answerable to the housing association. The ambiguity of the arrangement caused a few minor difficulties, such as the architect's inability to issue instructions to rectify work that did not comply with the specification; however the works were mostly carried out satisfactorily due to the diligence of the site manager.

Both houses were built using timber frames, developed specifically for the project by Holbrook Timber Frame (based relatively nearby in Bridgend). Holbrook worked closely with bere:architects to ensure the exacting passive house standards for airtightness and cold bridging were achieved, at the same time as making use of locally produced timber.

Holbrook also used a closed panel system from timber for walls. This had a very low u-value even by passive house standards: 0.095W/(m^{2}K). U-values for the floor slab and roof are similarly exemplary: 0.076 and 0.074, respectively, for Larch House.

The most obvious differences between the two homes is that Larch House has timber cladding externally, while Lime House has a lime render.

Figure 2: These design drawings show Larch House's much higher glazing area (55% of the south side), compared to Lime House's 20% glazing ratio.

Larch House also has significantly more glazing on the south side: a 55% glazing ratio, compared to just 25% for Lime House. This brings reduced potential for passive solar gain, but also reduces the risk of summer overheating.

Like all passive houses, these homes both have heat recovery ventilation systems (MVHR). These provide supply and extract ventilation, along with space heating. Both use a Paul Focus 200 unit, with a hot water heating coil in the airflow. Air is supplied in bedrooms and living rooms, and extracted from kitchens and bathrooms.

In Lime House incoming air enters the MVHR from the back wall, towards the top, via the frost heater to the right. It passes through the heat-exchanger in the MVHR, and then on through the heater battery at the top near the ceiling. Then it circulates around the house, to return as extract air through the vertical duct towards the back. Finally extract air passes once more through the HRV unit to leave the house through the lower duct in the back wall.

Figure 3: Lime House MVHR

In Larch House the ventilation unit is located in the storage cupboard by the front door. Intake and exhaust terminals face onto the street. Ducts run in a limited zone between joists from the ventilation unit to the kitchen, dining, shower room and living areas. The ducts rise in the airing cupboard to run in lowered bathroom and landing ceilings. Bedroom supply terminals are mounted on the walls, and the ceiling is higher in bedrooms.

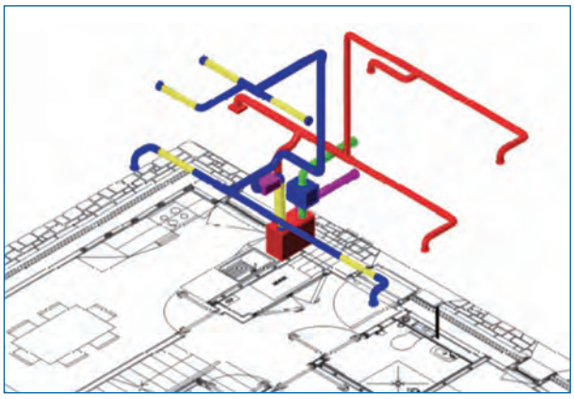

Figure 4: Larch House ventilation. Damp exhaust air is removed from the kitchen and bathroom ceilings (shown in red), passed through the heat exchanger in the MVHR, and pre-heated fresh air is brought into bedrooms and living areas (shown in blue).

There are small (6kW) boilers in airing cupboards in the bathrooms of both homes, and these provide both hot water and heating for the coil in the ventilation system. In Larch House it also heats a towel rail in the bathroom. The boiler is controlled by a thermostat in the living room of each house. Typical running temperatures are 75°C flow and 65°C return in Larch House (because the heating coil was smaller than planned), and 53°C flow, 46°C return in Lime House (with a larger heating coil).

Supply air temperatures were measured between 33°C and 38°C in different rooms in Larch House, and this was sufficient to provide comfortable room temperatures.

Door undercuts were found to be too small once carpets had been fitted (<5mm), and this caused higher air velocities under the doors, and brings a risk of higher infiltration losses.

Both houses have solar water heaters, with 3.3m^2 panels (Lime House) and 4m^2 panels (Larch House) on the roof providing hot water to twin-coil hot water tanks in the bathrooms. The tanks are 210 litre capacity, and have 100mm of insulation (more than usual).

Energy

Both houses achieved very good SAP ratings: Lime House was A-rated, with a SAP rating of 97, and estimated annual energy consumption of -14kWh/m^2, while Larch House achieved an even more impressive SAP rating of 112, with estimated annual energy consumption of -52kWh/m^2.

The project team has estimated annual energy consumption based on nine months of monitored data (see table below):

- Lime House nearly 6,000 kWh per annum gas and nearly 3,000 kWh per annum electricity
- Larch House 3,500 kWh per annum gas and towards 5,000 kWh per annum electricity.

(All kWh)	Larch House	Lime House
Gas	3534	5955
Space heating	1013	1661
DHW	795	1590
Total electric	4858	2954
PV generated	3696	1495
PV exported	2487	903
PV used	1209	593
Grid imported	3650	2361

Table 2: Energy use and generation in Future Works homes[1] (Based on nine months' data May 2012-Jan 2013)

It is not surprising that the larger Larch House (with higher occupancy) has significantly higher electricity use and this is compounded by high consumption of the tenants' own oven. However, the difference in gas use is unexpected, and was found to result partly from a bedroom window left open at night. (A controls change is planned to see if reduced heating will mean occupants close the window at night.)

The team estimates that the PV array generated 51% of the electricity used in Lime House, and a very impressive 76% of electricity used in Larch House. Unsurprisingly, electricity generation was much higher in summer than winter (around four times as much in both houses).

Electricity use profiles are similar for both homes, with the vast majority (65%) of electricity used for plug-in appliances, see pie charts below. Larch House uses significantly more electricity for cooking, and a little more for lighting. However, Lime House uses twice as much, as a proportion, for the mechanical ventilation system. Lime House also uses a larger fraction of electricity for parasitic loads. It is not yet clear why electricity use by the mechanical ventilation, and for parasitic loads, is so much higher in Lime House. This may be because it has been left at a higher ventilation rate in an attempt to make the bedroom feel cooler at night.

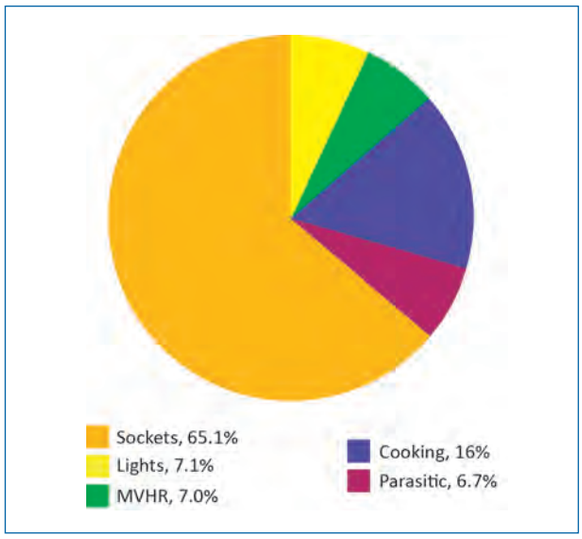

Figure 4: Larch House Electricity use breakdown[1]

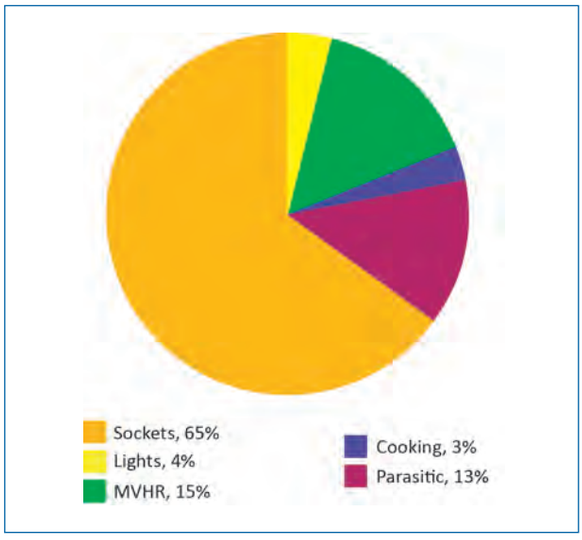

Figure 5: Lime House Electricity use breakdown[1]

[1]Ian Ridley (2013) Performance of the Larch and Lime Low Energy Houses: Three Month Performance Summary, February 28th 2013 (internal report). Melbourne: RMIT University.

Interventions as a result of the BPE study

Insect filters in the air intake louvres serving the ventilation systems were checked, and found blocked (see photo). The filters were difficult to clean and access, so the project team removed them, relying instead on the easily-replaceable pre-filter to remove fluff and insects. This filter will be checked and changed regularly as a matter of course.

figure 6: Built-in insect screens in the external intake terminals were hard to access and became blocked. The project team removed them and relied on the pre-filters to remove insects.

In initial commissioning the airflow was set with 60% of the air supplied to bedrooms and 40% into the living room. Most of the extract is downstairs so some of the ventilation air from bedrooms was drawn through downstairs rooms, providing more fresh air when bedrooms are unoccupied. However, this led to higher upstairs temperatures in the first winter of occupation: typically 2°C higher upstairs warmer in bedrooms than downstairs, so the ventilation was re-adjusted to provide 60% downstairs and 40% upstairs.

This is a perennial issue with airside heating, and balancing heating/ventilation controls is a skilled job.

The solar water heating systems on both homes were incorrectly installed: Lime House originally had the wrong pump fitted and sensors installed in the wrong place, and Lime House's pump failed and had to be replaced.

Future use of the BPE results

Designers bere:architects, Holbrook Timber Frame and the contractors learnt an enormous amount from building the two houses, and from subsequent teething problems and the building performance evaluation. In particular, lessons about how to install solar water heating, and how to make the best use of relatively narrow-section UK timber, will feed into future designs.

There is also a lot of intangible knowledge about who has (or does not have) the skills to carry out specific tasks on site, and potential problem areas that need extra scrutiny to make sure they deliver as intended - knowledge that can be applied on a wide range of building projects and not just Passive Houses.

Client's view

Client and owner, United Welsh, now has a position of leadership in low energy housing in Wales. Larch and Lime houses have now been occupied for over a year, and signs are that passive house buildings can provide added rental income security, as well as protecting vulnerable tenants, because the tenant is not forced to choose between paying the utility companies or the landlord. Actual energy bills appear to be a fraction of equivalent bills for social housing in Wales.

Shortly after moving in, the tenants themselves said: "We absolutely love this house. We can't believe how lucky we are. It's a dream – everything we could wish for and more. We look around the rooms, how warm it is, it's amazing, so well built, so well thought out, the kids love it, it's a dream come true."

Process

The evaluation included very detailed monitoring of total electricity and gas consumption, and sub-metering of the electricity demand. There was a comprehensive set of temperature and humidity sensors, an external weather station, and sensors measuring water use. There were minor problems with the location of some temperature sensors initially (when they were hit by direct sunlight), but they were subsequently moved to more suitable locations.

The project team also did a second air pressure test, infra-red photographic studies, a heat flux study to measure actual floor and wall insulation, and a co-heating test. They also re-commissioned the MVHR system.

Conclusions and lessons

Passive House design is like other innovations in housing in that it requires designers and contractors to do things differently. In some cases the differences are significant, and trying to apply traditional approaches simply does not work. Sometimes there is a tension between Passive House requirements and UK Building Regulations, which can lead to confusion on site.

Meeting Passive House standards requires more site supervision than standard construction practice, and there is more potential for different trades to undermine each others' work. This means that communication between the different parties working on site, and suppliers, is even more important than usual.

There was also a lesson about individual site operatives: even though the initial team of builders receives meticulous briefing or training, there is no guarantee they will continue working on the project to the end. Especially for sites with a series of buildings, there is at least some chance that new operatives will join the site – and they will need additional briefing.

A glazing ratio of around 20% on the south side, without external solar shading, is more cost-effective and ultimately more robust than higher glazing ratios with external shading.

Name of project	Lime House and Larch House, Futureworks
Address	Ebbw Vale, S Wales
Procurement method	Traditional tender
Occupation date	April 2012
Project team	bere: architects, United Welsh Housing Association, Pendragon Design, Alan Clarke, Andrew Farr from Green Building Store, Jason Palmer of Cambridge Energy
Contact details	
Technology Stategy Board evaluator name and details	Ian Mawditt, FourWalls, ian@fourwalls-uk.com
Floor areas	**Larch House** - 99m^2 **Lime House** - 78m^2
Fabric performance	**Larch House** - 67W/K **Lime House** - 61W/K
Occupancy pattern	
Energy calculations	**Larch House** - Space heating 13.0 kWh/m^2 **Lime House** - Space heating 30.0 kWh/m^2,
Occupancy survey	Between 26th January 2011 and 3rd February 2011, BUS Methodology survey, 31% response rate
Carbon Buzz/ EST cross reference/ link	
URL of project team	www.bere.co.uk/ http://www.greenbuildingstore.co.uk/
Key features	Passive House, solar water heater, PV, MVHR
Technology Strategy Board unique reference number	450019

Future Works – The case study

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Table 2: Building type, sector and stage