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Low Energy Case Study - Oxlet
by David Olivier

Introduction

Like many houses which are built by sub-contractors and project-managed by the owners, this one took a number of years. The project was first conceived in 1997-98. Design was underway in the early 2000s and was completed by mid 2003. Construction began in late 2003 on a largely direct labour basis. The owners moved in in summer 2006. The house received a Completion Certificate from Herefordshire Council Building Control in summer 2008.

The 5 hectare site is part of the Wye Valley Area of Outstanding Natural Beauty and is located on the northern fringes of the Forest of Dean. It is entered via a track from a B road which runs along the River Wye valley. From the entrance, the land slopes steeply up to the west-north-west. The plot boundary, at the top of the hill, is 50m higher than the level of the B road. There are no mains services on site except electricity and telephone. Mains water is available nearby if needed, although a private water supply is used at present. This is fairly standard for rural Herefordshire.

Planning Issues

The site had a chequered planning history. This included several refusals for barn conversions or holiday let(s). The owners did not regard it as ideal but they purchased it in 1999 in the hope and/or expectation that it could be made to work; ie. that they could eventually secure permission for something close to what they wanted. They had been searching since 1997. There was no time to make a new planning application before signing a contract, because the property market was rising at the time. However, they spoke to a planning consultant before purchase and received very useful advice. He subsequently worked with their architect and helped to overcome the site's difficult planning history.

The owners' first planning application, in 2001, proposed to demolish the existing cottage and milking shed and to replace them with a single, much larger stone and rendered house, built partly into the steep east-south-east-facing slope. This position was felt to be more suitable than siting the replacement house within the curtilage of the original stone cottage, which was very close to the B road. The planners were sympathetic to this scheme. Subject to numerous conditions, it gained approval under their delegated powers.

Brief Description

Approaching from the south, one sees nothing from the B road. 75m along the drive, after a steep climb, one arrives at a 3.5-storey house with a flight of steps up from basement floor level to ground floor level. On the west, the basement is concealed by the rising ground level and the external wall becomes a retaining wall. Some first floor spaces in the house are double-height and are lit from above by rooflights. Other first floor rooms have a normal ceiling height for this house; ie. 2.6m, with space for rooms in the roofs above.

At present, the roof is used only as a services zone and for warm, dry storage space. There are plans to build some habitable rooms in the roof and to build a split-level extension into the hillside to the west.

The external aesthetics of the replacement dwelling are based upon the design of lateral-chimneyed Welsh farmhouses. It presents this appearance to anyone who is walking on the adjacent right of way. However, what appears at first sight as a substantial stone chimney on the east facade, is actually the hall external wall, and above that the stone structure houses a ventilation stack. Given the excess heat loss caused by a woodstove or glass-doored open fire, even when the stove or fireplace is not in use, the owners decided not to have a chimney.

For those desiring further information, the owners have set up a website at www.oxlet.co.uk.

Thermal Envelope Details

Basement Floor (ie. on ground)

75mm sand-cement screed, 100mm EPS insulation, DPM, 150mm concrete slab, 150mm hardcore.

U-value = 0.31W/m^{2}K

Excludes the impact of the surrounding soil (a coarse sandy loam).

Intermediate Ground Floor (ie. above basement) and First Floor

From top: 50mm sandstone flags, 75mm sand-cement screed containing underfloor heating pipes, 175mm beam-and-block floor, 38mm softwood battens, 90mm Kingspan Thermopitch TP10.

Second Floor

Timber I beams, joined to and part of the timber pitched roof structure.

External Walls

(1) Wall type 1: cavity wall with stone outer leaf.

13mm dense plaster, 100mm dense concrete block, 70+50mm ‘Kooltherm’ phenolic foam slab, 25mm residual cavity, 135-150mm local sandstone.

U = 0.16W/m^{2}K.

Based on the stainless steel wall ties increasing the effective conductivity of the cavity insulation by 10%.

(2) Wall type 2: externally-insulated and rendered wall.

13mm dense plaster, 100mm dense concrete block, 200mm blown cellulose fibre between 'TJI' I beams on 600mm centres, 9 mm 'Panelvent' sheathing, breather membrane, 50mm cavity, 20mm render on stainless steel lath.

U-value = 0.21W/m^{2}K.

Based on timber fractions of 15% for solid timber in the I beam flanges on both sides and 3% for the OSB webs. Omits any non-repeating thermal bridges.

Care was needed to make the two types of external wall the same thickness. It was important to the appearance of the finished house that they should closely match up. At the design stage, the goal was to achieve similar U-values in both wall types.

Owing to the thermal bridging caused by the timber and OSB in the I beams, along with the more conductive insulation material, the thermal properties of the externally-insulated wall are not as good as those of the cavity wall. The latter utilises a very high-performance, albeit costly insulant.

Basement Wall

From outside; tanking, 160mm cast reinforced concrete between 2 x 100mm dense concrete blocks as permanent shuttering, 80mm mineral fibre, 50mm mineral fibre between 50 x 50mm softwood studs on 600mm centres, polyethylene membrane, 13mm plasterboard.

U-value = 0.27W/m^{2}K.

The above U-value excludes the thermal benefits from the depth of earth cover on the west, south and north sides of the house. These thermal benefits include a time delay in the resulting temperature swings, a dampening in the resultant temperature swings and a small added R-value. The basement wall construction was based on the then recommendations of Canadian authorities. Because of the steepness of the site, the transition between basement wall and external wall construction is somewhat complex. Even on what one might regard as the 'ground floor' of the house, some of the wall on the west-north-west is still below ground and is constructed as a basement wall. This can be seen on the floor plans.

Roof

Reclaimed Welsh slate, felt and battens, breather membrane, 250mm deep OSB-webbed I beams on 600mm centres, filled with 250mm blown cellulose fibre. Polyethylene membrane for airtightness, sealed meticulously at all seams and sealed to the plaster on the walls. 38mm PU foam internally, bonded to 12mm plasterboard, skim coat of plaster.

U-value = 0.13W/m^{2}K.

Windows

Danish oak-framed windows, by Vrogum, with 16mm argon-filled low-e double glazing.

U-value = 1.4W/m^{2}K. The UK agent was www.vitekwindows.com. The owners regard the windows themselves as being of excellent quality. But see the important feedback below concerning the use of local green oak for the lintels and window surrounds.

External Doors

There are several opaque doors with glazed panels in the top half. Ecoplus brand supplied by Green Building Store Ltd. There is an insulated wood-faced panel and the glass above is warm edge, low-e, argon-filled double glazing.
For the whole door, U-value = 1.4W/m^{2}K.

Rooflights

Velux double-glazed argon-filled low-e. U-value = 4.8W/m^{2}K. Please note that this is an estimate for sloping glazing of this specification and includes the impact of the kerb. It is taken from published estimates in the 2005 ASHRAE Handbook, pp. 31.8-31.9. European-made manufacturers of rooflights still quote U-values which are based solely on the performance of the glazing. They also assume that the glass is situated in a vertical position. This diverges significantly from the physical reality of the situation.

Air Leakage

The air permeability has not yet been measured. Given that the owners planned to use MVHR, the energy consultant suggested a target of 1ac/h@50 Pa for a concrete-floored, masonry house. He also said that on the basis of the information that he was given, under UK conditions 2ac/h@50Pa would be a creditable result. On a detached house, 2ac/h@50Pa corresponds to an air permeability of approx. 2m/h@50Pa.
Most of the construction details adapted appear to be consistent with reaching this figure. But the green oak - see feedback below - could make the figure more difficult to reach. The timber second floor could also present problems, because it is difficult to seal a membrane that physically has to pass through a row of timber joists.

Space and Water Heating

A Kensa ground source heat pump supplies underfloor space heating. There are fewer pipes in the screed than normal, thanks to the reduced heat load. For a house with 290 m^2 of treated floor area, the M&E engineers calculated a peak space heat demand of 6kW(t) at -1ºC, based on continuous cold weather heating. This low loading of 21W per m^2 compares well to previous UK low-energy projects, such as the Elizabeth Fry Building at UEA. The supplier indicated that it would not be possible to supply hot water from the heat pump. So Thermomax solar collectors and dual immersion heater coils supply DHW. The heat pump is being retrospectively adjusted to supply some of the water heating and thereby to displace electric resistance heating.

The main DHW tank is 0.165m^3. It is insulated with 50mm of PU foam and has one solar coil and twin electric immersion heaters. A further 0.56m^3 heat dump store, with the same level of insulation, accommodates output from the solar system at times of surpluses. The factory level of insulation is felt by the owners to be a bit inadequate, but it was all that was available at the time. The owners have fitted loose mineral fibre jackets on top of the foam, so the effective overall level of insulation is probably equivalent to 60-65mm PU foam. The DHW pipes are insulated throughout the house with 19mm of foam insulation.

Space Cooling

There is no active cooling system. In heatwaves, the windows are opened by night and closed by day. The curtains are also closed by day to reduce the level of solar gains entering the building. This has given tolerable internal conditions.

On a future project, the owners would include an earth tube in the MVHR system. This could help to precool the incoming summer air and preheat the winter air. On a site such as this, with a full basement, an earth tube could be buried quite deeply and yet still 'drain to daylight'. They would also refine the design and shading of the SSW-facing windows to keep greater amounts of solar gain out of the building.

Ventilation

A Regavent 650 DC MVHR system. This was energy-efficient for the time, with electronically-commutated DC motors.

Cooking

Mostly LPG, using 19kg bottles, each containing c. 250kWh. Gas hob and electric oven. There is much more cooking on the hob than would be usual for a household of this size. This is because the owners make large amounts of jam for sale every autumn.

Lighting

Extensive use of 7W compact fluorescent downlighters.

Electrical appliances

A+ models were purchased wherever possible. There were some, even in the early 2000s.

Other Renewable Energy

The owners plan to install a 1.5kW(e) micro-hydro generating plant, which utilises the 45m height difference between the house and the stream entering the site at the top of the hill. It will be grid-connected. The upper reservoir will be the remnants of two 22m^3 former fish ponds. Between them, this reservoir is able to store about 3kWh(e).

Other Environmentally-Beneficial Features

All the walling stone used in the house is reclaimed or was reused from the demolished former cottage on the site. All the roofing slate is reclaimed too. The render finish on part of the walls is durable and also represents a lower embodied energy than fired clay bricks. A large amount of local oak from the Forest of Dean was used. This material was very green in two senses; ie. it was freshly-cut, and it should have a very low embodied energy. But see below for the problems which its movement caused.

All the toilets in the house are dual-flush Ifö.

Measured Energy Consumption and CO_2 Emissions

The owners have read their electricity meters regularly since June 2006. Heat for drying-out was probably complete by March 2007. The total below also includes a slight extra electricity consumption due to such events as the failure of the heat pump compressor.

The small amount of LPG consumed for cooking has been estimated from the owners' information on the number of 19 kg cylinders consumed.

Figure 1. Average Energy Usage Figueres 2007/8 and 2008/9

Form of Energy	***Purpose***	***Energy Usage kWh/m²yr***	
		Delivered	***Primary***
Electricity	*Space and water heating, lights, appliances, ventilation and heating system pumps, fans and controls*	*38.8*	*107.8*
LPG	*Cooking*	*1.7*	*1.9*
Total	*All purposes*	*40.5*	*109.7*

Figure 2. Greenhouse Gas Emissions

Form of energy	***Emissions Coefficient kg/kWh***	***CO_2 Emissions kg/m²yr***
Electricity	*0.61*	*23.7*
LPG	*0.25*	*0.4*
Total	*All purposes*	*24.1*

NOTE: The above emissions coefficient for electricity applies only to low-voltage loads eg. the domestic sector. The UK-wide average is 0.59kg/kWh. For those loads which are supplied at high voltage such as railways and factories, the figure would be correspondingly less than 0.59kg/kWh.

Cost

It is impossible to produce a cost estimate of the same kind as the figure that is available for the first case study. This is for three reasons. Firstly, the house was constructed over a period of several years. Over this time, tender prices varied significantly. Secondly, in acting as the general contractor the owners contributed considerable amounts of management time. Thirdly, not all the tasks were actually undertaken by sub-contractors. The owners undertook some tasks where they considered that the standard of workmanship was critical to the success of the finished project.

Labelling, Rating and Certification

None were sought. As stated earlier, the project preceded all current UK standards or rating systems such as Ecohomes, CSH, AECB Silver Standard, Passivhaus Standard or similar.

Grants and Subsidies

None except for one day's help courtesy of EDAS. See below.

Experience/Feedback

When the project was conceived, in 1997-98, the owners found that some BRECSU literature was invaluable. On the other hand, they found some of it to be of no use at all. They also found some useful information in the UK's three main self-build magazines. Nowadays, the owners feel that they could design such a house largely using information gleaned from the internet. However, this source was in its relative infancy in the late 1990s.

In 2002, one day's outside advice from an energy expert was received under the government's Energy Design Advice Scheme (EDAS). At the time, EDAS was administered by the Bartlett Graduate School at UCL. It was always aimed mainly at non-domestic buildings but the floor area threshold meant that relatively large private houses found themselves eligible for help, as did RSL and other schemes comprising several small houses. The owners found this scheme very useful and consider that this day's input accounted for about 60% of the energy-related features which were incorporated into the building.

A common problem to many self-builders was the limited understanding of energy efficiency by the building workers available. The owners resolved to utilise outside labour for standard tasks; e.g. laying concrete blocks, laying beam-and-block floors, and pouring concrete, but they personally took on many small tasks which were critical to the energy performance of the finished building. For example, David Wadge filled in the ends of the beam-and-block floors with mortar to ensure that a proper air seal could be achieved when eventually plastering the walls. Also, he installed the polyethylene air barrier in the roof.

In the early 2000s, the specification of this house was considered highly advanced by UK standards and ground source heat pumps were relatively unusual. Next time, the owners would recommend further simplifying the heating system and using even better insulation and airtightness. They would also look into wood-fired heating systems.

The owners made extensive use of green oak as lintels in the external walls. They would strongly recommend all others who construct their own one-off house not to make this same error. The drying movement of this 'traditional' material is excessive and it has no role in an energy-efficient thermal envelope.

Since moving in, one heat pump compressor has failed. Fortunately, this happened relatively soon after installation. So it was replaced under warranty. But it was still very inconvenient.

In the cold winter of 2008-09, with the ambient temperature on successive days falling below -6ºC, it turned out that the heat pump system controls were not fully commissioned. With the owners' electronics knowledge, they attempted to diagnose the problem themselves using the internet. The company then confirmed on the telephone that their diagnosis was correct and that they could go ahead and make the alterations without calling out a technician.

Experience with the 7 W CFL downlighters has been very satisfactory.

Conclusions

Conversations with the Oxlet's owners confirm that information sources to self-builders wanting an energy-efficient house have considerably improved since the late 1990s and early 2000s. As the project shows, owners who were able to play a hands-on role in the construction process could deliver very impressive end results, although they were not employed in the construction industry and had no particular specialist knowledge pertaining to buildings' energy use.

Not all the floorspace is heated to such a high standard. This is because, although the basement is nominally within the thermal envelope, it has no direct sources of heat; the underfloor heating pipes are confined to the ground and first floors. But these still appear fairly low figures for a house which was conceived a decade ago and was fully-designed by early 2003.

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Those involved

Clients – David and Felicity Wadge.

Planning consultant – Wall, James and Davies, Stourbridge.

Architect – Neill Lewis, Malvern.

QS – Colin Jones, Hereford.

Structural engineer – Allan Pearce, Ledbury.

M&E design, underfloor heating system – Richard and Anne Walker of Conservation Engineering Ltd., Troston, Bury St. Edmunds.

Energy consultant – one-day consultation under EDAS with David Olivier of Energy Advisory Associates, Leominster.

Structural warranty – NHBC.