

Passive House Object Documentation



1.1 Larch House - Detached house Ebbw Vale, Wales



Project Principal Passivhaus Consultant: Dr Robert McLeod
Project Architects: bere:architects
Passive House Database ID 1849

This detached house known as the 'Larch House' was built for United Welsh Housing Association at the Future Works Development Site, in Ebbw Vale, Wales. The building is a timber frame construction built on an insulated raft slab and is oriented almost due south (173°). It is a two storey dwelling with living areas on the ground floor and three bedroom on the first floor. Special features include: Solar collectors for hot water, and a $4.7\text{kW}_{\text{peak}}$ PV array, the project was also certified to Code Level 6 (zero carbon) under the BREEAM Code for Sustainable Homes rating scheme, making it the first dwelling in the UK to officially achieve both Passivhaus and Code 6 (full UK zero carbon) status, and as such it would meet the Passivhaus-Plus dwelling requirements under the current criteria.

U-value exterior wall $0.095\text{W}/(\text{m}^2\text{K})$
U-value ground floor $0.076\text{W}/(\text{m}^2\text{K})$

U-value roof $0.074\text{W}/(\text{m}^2\text{K})$
U-value window $0.78\text{W}/(\text{m}^2\text{K})$
PHPP primary energy demand $107\text{kWh}/(\text{m}^2\text{a})$
Heat recovery 89% Pressure test $n_{50} 0.2\text{h}^{-1}$

PHPP Annual heating demand **13** $\text{kWh}/(\text{m}^2\text{a})$

2.2 Short description of the construction task

The Larch House was the UK's first zero carbon (Code for Sustainable Homes Level 6), low cost Certified Passivhaus. The Larch House along with its neighbouring Passivhaus dwelling (the Lime House) were built as prototypes for social housing.

The three bedroom house is built at 300m above sea level in a very hilltop location. The area around Ebbw Vale is characterised by maritime upland micro-climatic conditions typical of the Heads of Valleys (HoV) region. Long term climatic data from the nearest local weather station, at Tredegar, shows that the months of January and December typically only receive around 40 hours of sunshine per month, with rainfall exceeding 200mm per month in January and hill fog and cloud prevailing for much of the winter months. Monthly mean wind speeds are very high in the HoV region and monthly minimum temperatures of 0.5 – 1.0°C are typical during December - February.

Despite these conditions (which would appear to be unfavourable for passive solar design), most energy needs are met by heat from the sun, occupants and appliances. The Larch House generates as much energy from the sun from solar thermal collectors and photovoltaic array as it uses for the whole year; making it 'zero carbon' by the original Code for Sustainable Homes UK definition (DCLG, 2007).

The Larch House offers a very comfortable living environment for an affordable housing prototype, despite having a TFA of only 87m². It was developed in close consultation with the Building Research Establishment Wales (under the direct supervision of Dr Robert McLeod who acted as Principal Passivhaus Consultant throughout the project), working closely with bere:architects and United Welsh Housing Association.

The project was completed in July 2010 and was opened by the Welsh First Minister for Housing at the Welsh National Eisteddfod festival. The project was certified by BRE Passivhaus UK in 2011. The Larch house recorded a final air pressure test of 0.19 h⁻¹ @n₅₀, which was the lowest test value ever recorded in a UK dwelling at the time. Both the Larch and Lime Passivhaus dwellings are regarded as 'Flagship' projects in the Welsh Government's transition to zero carbon buildings.

2.3 Pictures of elevations from all accessible sides



Figure 1. Image showing South and East Elevations of Larch House



Figure 2. Image showing North elevation of Larch House



Figure 3. Image showing North and West elevations of Larch House



Figure 4. Image showing South and East Elevations of Larch House, under construction

2.4 Sample picture of the interior



Figure 5. Image showing interior hallway, stairs and half landing



Figure 6. Image showing ground floor shower-room, designed for mobility impaired access

2.5 Cross section of the implementation plan

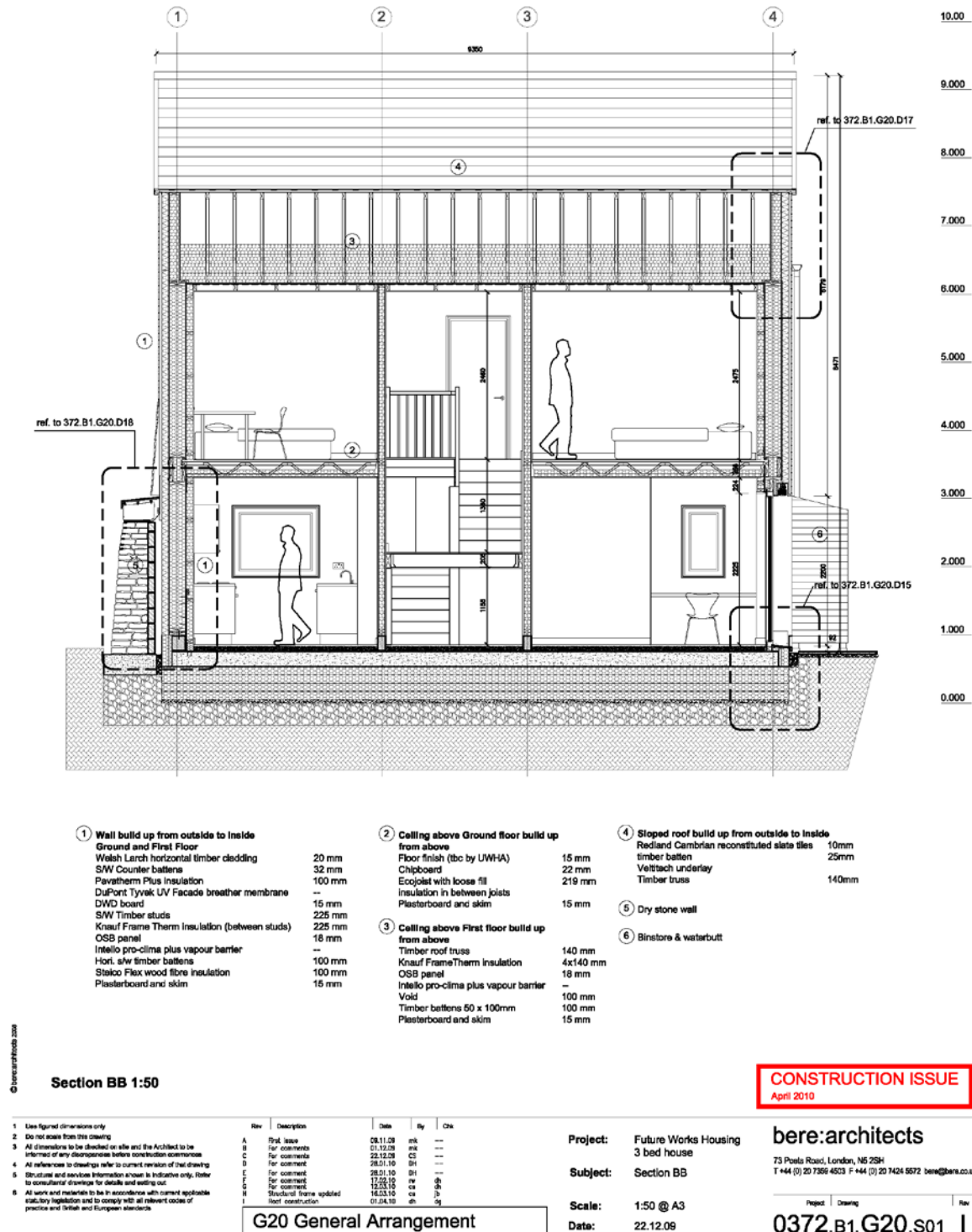


Figure 7. Cross-section West-East showing the construction implementation plan (copyright bere:architects)

2.6 Floor plans

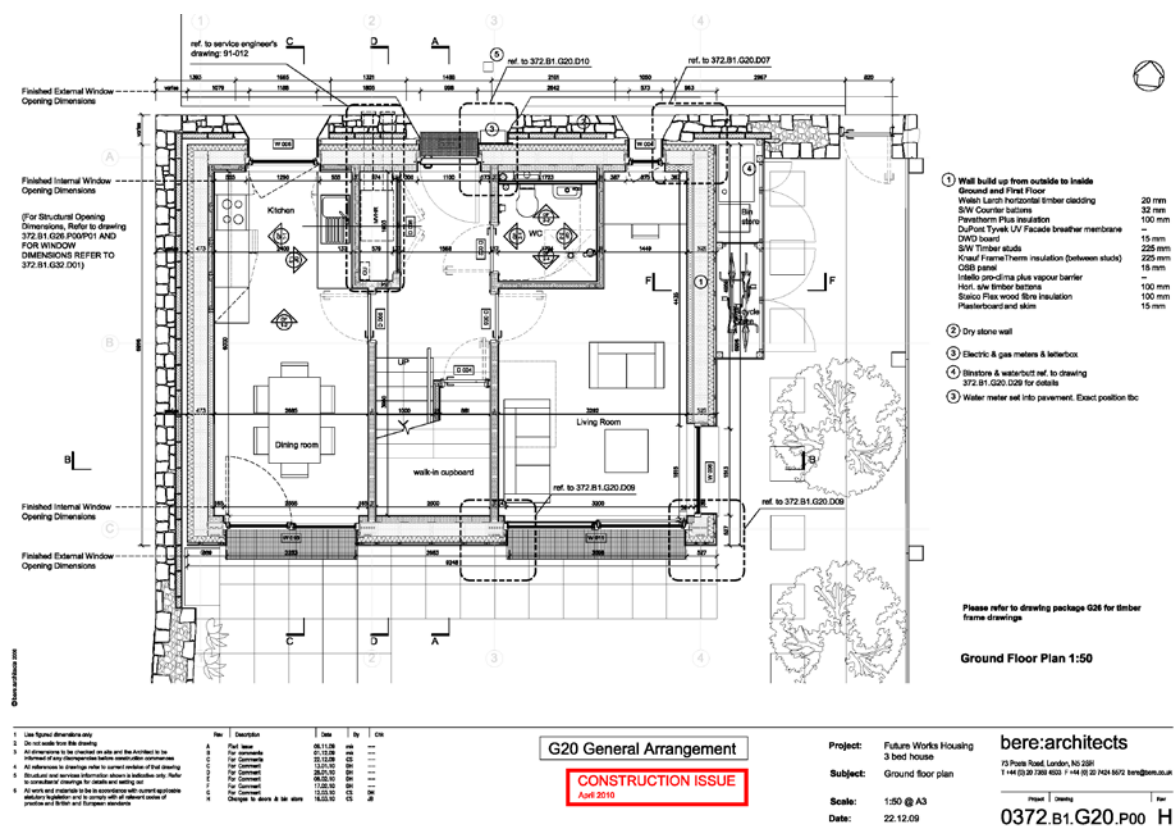


Figure 8. Ground Floor Plan (copyright bere:architects)

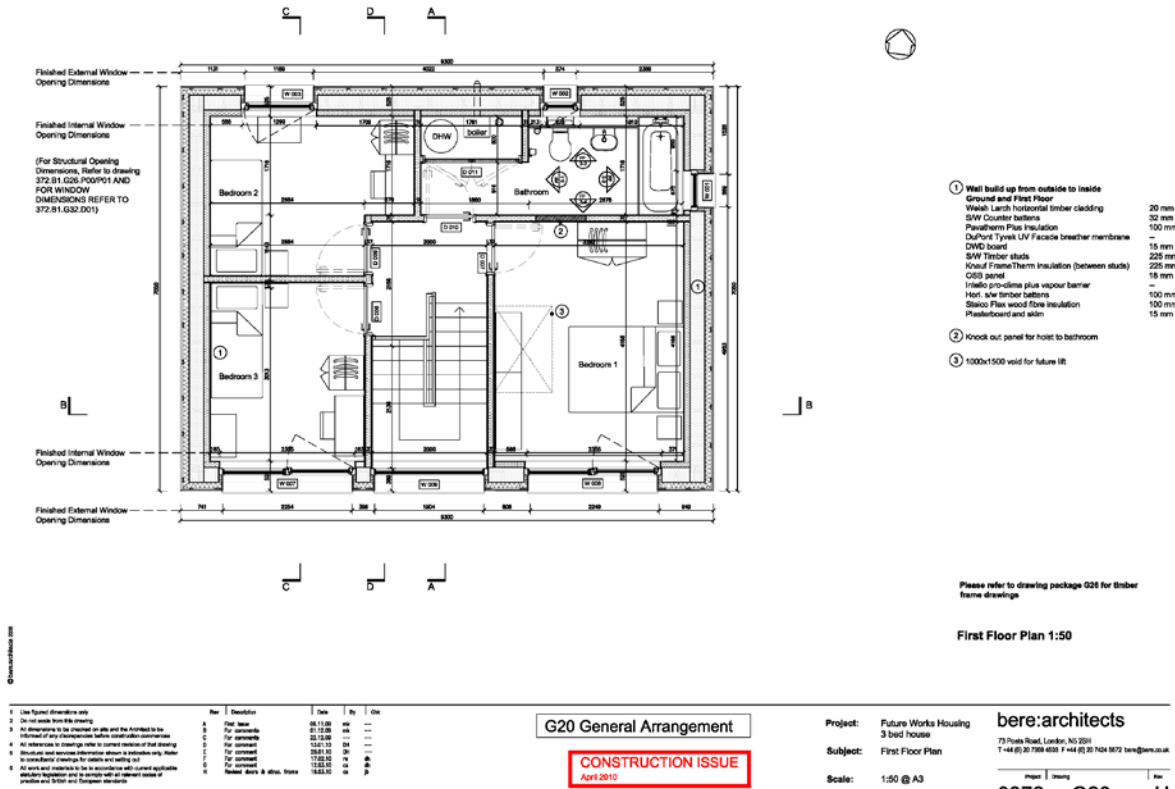


Figure 9. First Floor Plan (copyright bere:architects)

2.7 Construction details of the Passive House envelope and building services

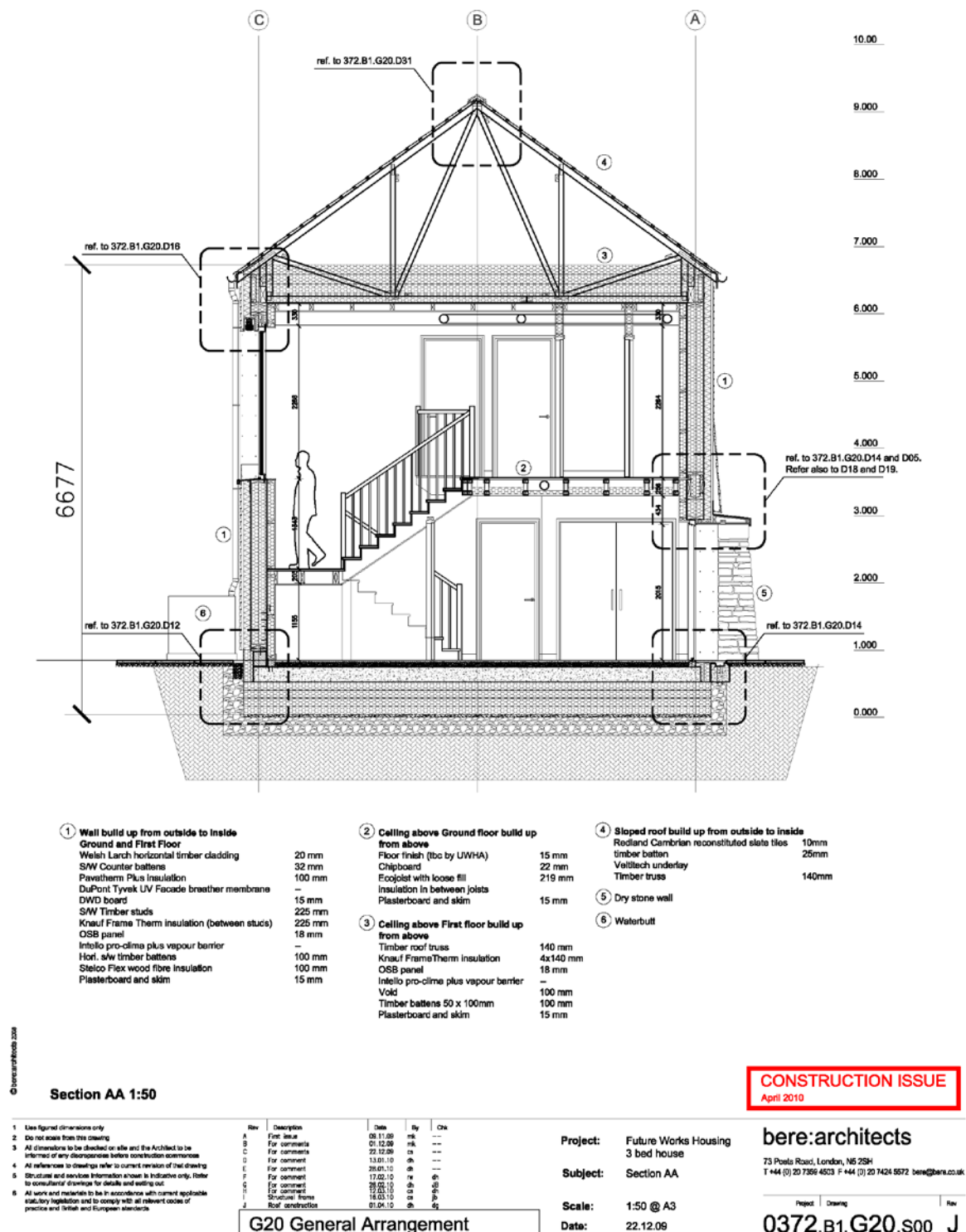


Figure 10 . Cross section N-S showing Passivhaus thermal envelope construction details

2.7.1 Construction including insulation of the floor slab or basement ceiling with exterior and interior wall connections

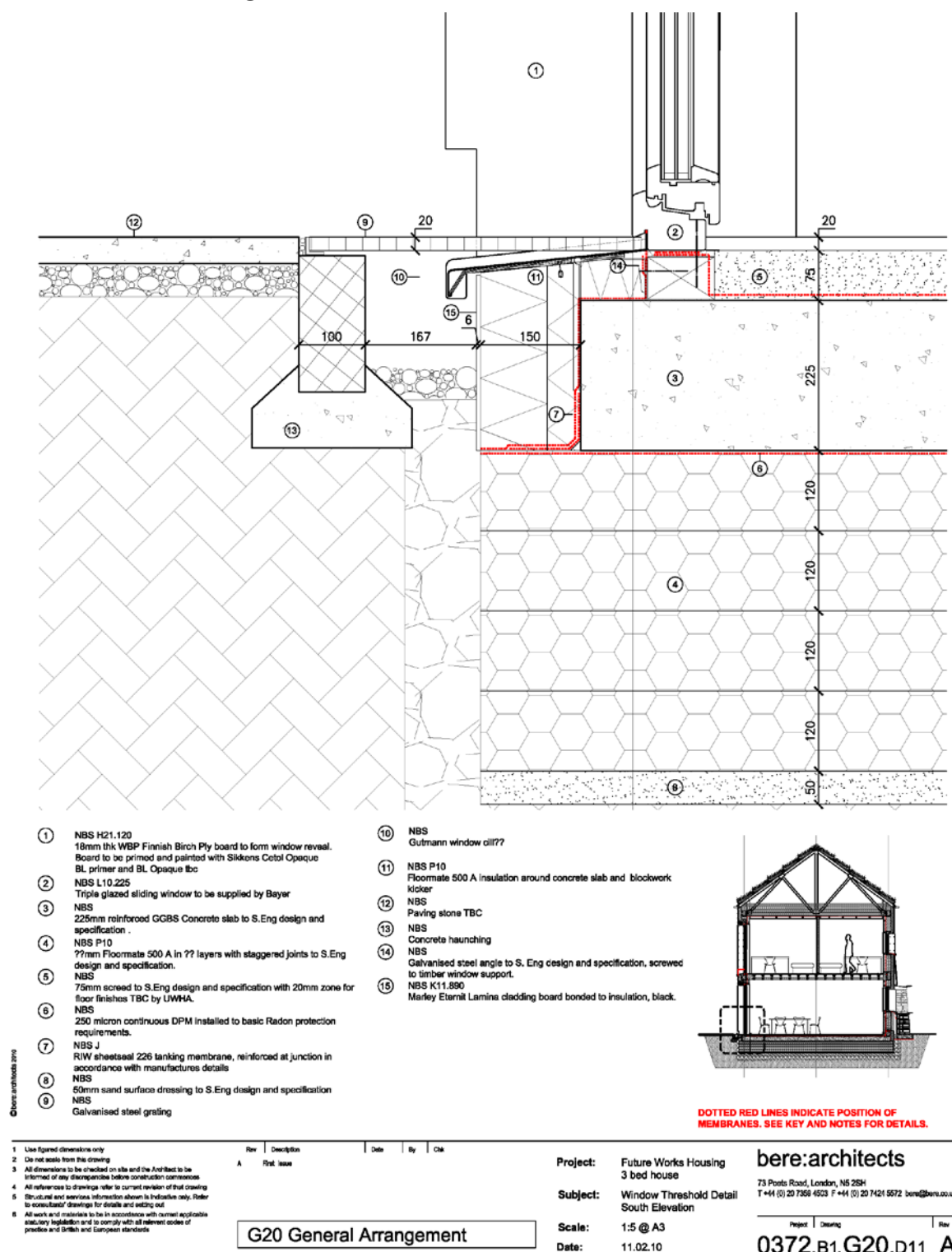


Figure 11. Sliding window threshold detail and connection to ground floor slab (image copyright bere:architects)

As shown in Figure 11, the ground floor slab is a warm raft-slab construction. This was formed with four layers of 120mm thick (total 480mm) XPS Styrofoam insulation boards laid with staggered joints (to prevent thermal bypass at the joints) over a

50mm sand blinding layer (to ensure the XPS boards were laid flat). A 150mm thick layer of XPS insulation then forms the perimeter upstand around the edge of the slab and the block work kicker. A 250 micron DPM layer provides radon and moisture protection to the underside of the slab. A 225mm thick GGBS (cement replacement) reinforced concrete slab then sits on top of this DPM membrane layer forming the load bearing slab. The slab is then finished internally with a 75mm thick screed levelling layer on which finished floor surfaces were laid.

2.7.2 Construction including insulation of the exterior walls with connections to other walls

The external wall construction is based on a traditional solid-stud timber frame approach, as this was the construction method most familiar to the local timber framing contractors. This conventional framing approach had to be adapted to meet the low U-values (U-value exterior wall 0.095W/m²K) required for this project, and the external wall build up is described as follows, from the outside to the inside:

- 20mm – external Larch timber cladding (horizontal boards)
- 32mm – ventilated cavity formed using SW counter battens
- 100mm – wood fibre board insulation
- 15mm – high permeability exterior sheathing board
- 225mm – solid timber stud, fully filled with glass fibre mineral wool insulation
- 18mm – OSB-3 internal sheathing panel
- 0.2mm – Intelligent vapour check membrane (to form continuous airtight layer)
- 100mm – horizontal SW battens, fully filled with wood fibre board insulation
- 15mm – plasterboard and plaster skim finish

This construction build up is used for all external walls, with the exception of slight variations on the ground floor North and West facing walls. On these facades a fully ventilated external dry stone wall cladding was used as an external architectural detail to create an aesthetic link between the project and its surrounding landscape.

Internal walls are comprised of a standard 89mm timber stud construction which is filled with wood fibre insulation (see Figure 12) to provide enhanced acoustic attenuation and additional active thermal mass.



Figure 12. Internal wall and ceiling framing under construction

Figure 12 shows the framing of internal walls, during construction. Figures 7-10 (above) and Figure 13 (below) provide illustrations showing details of the external wall insulation layers and connections to internal walls.

2.7.3 Construction including insulation of the roof with exterior and interior wall connections

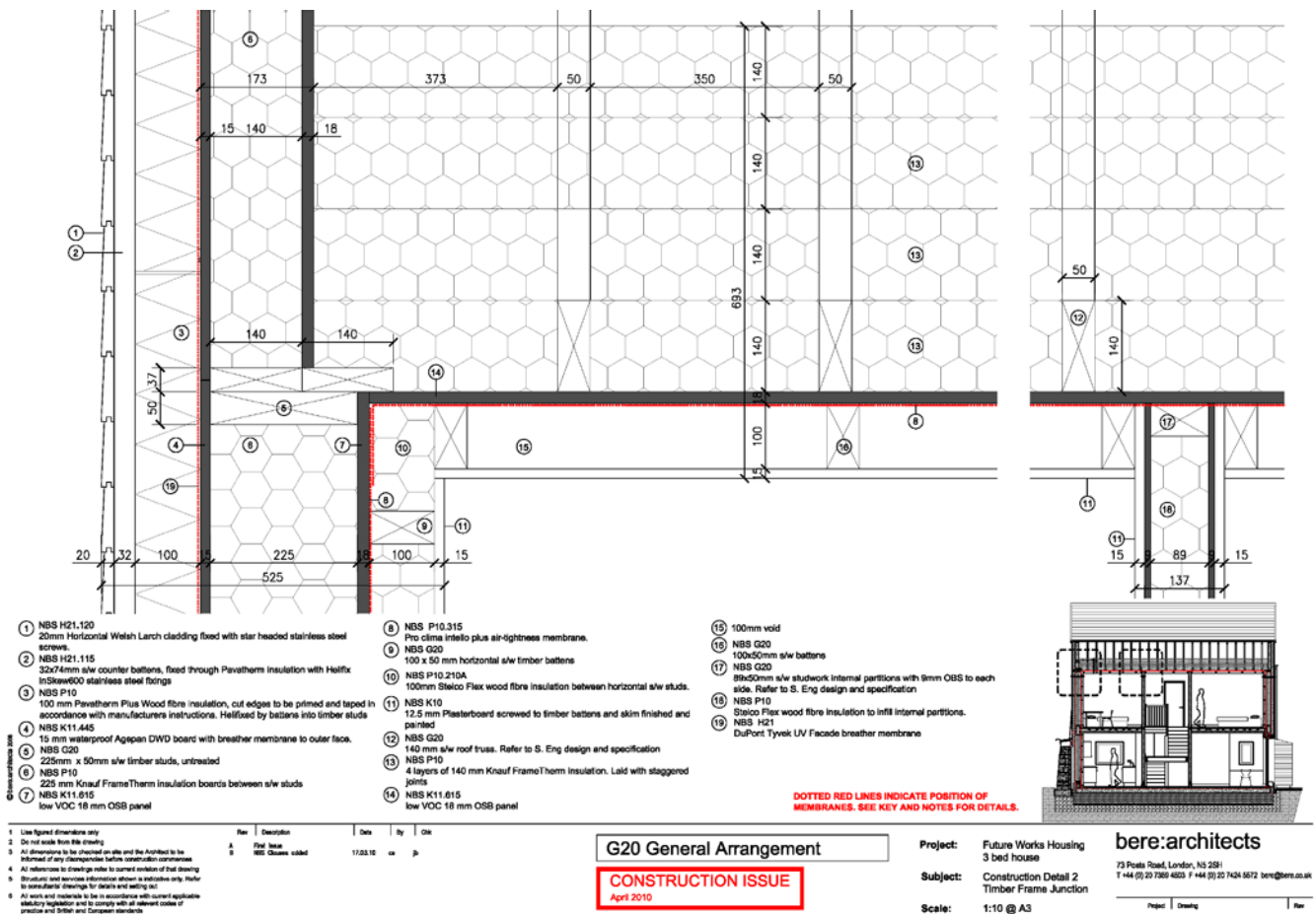
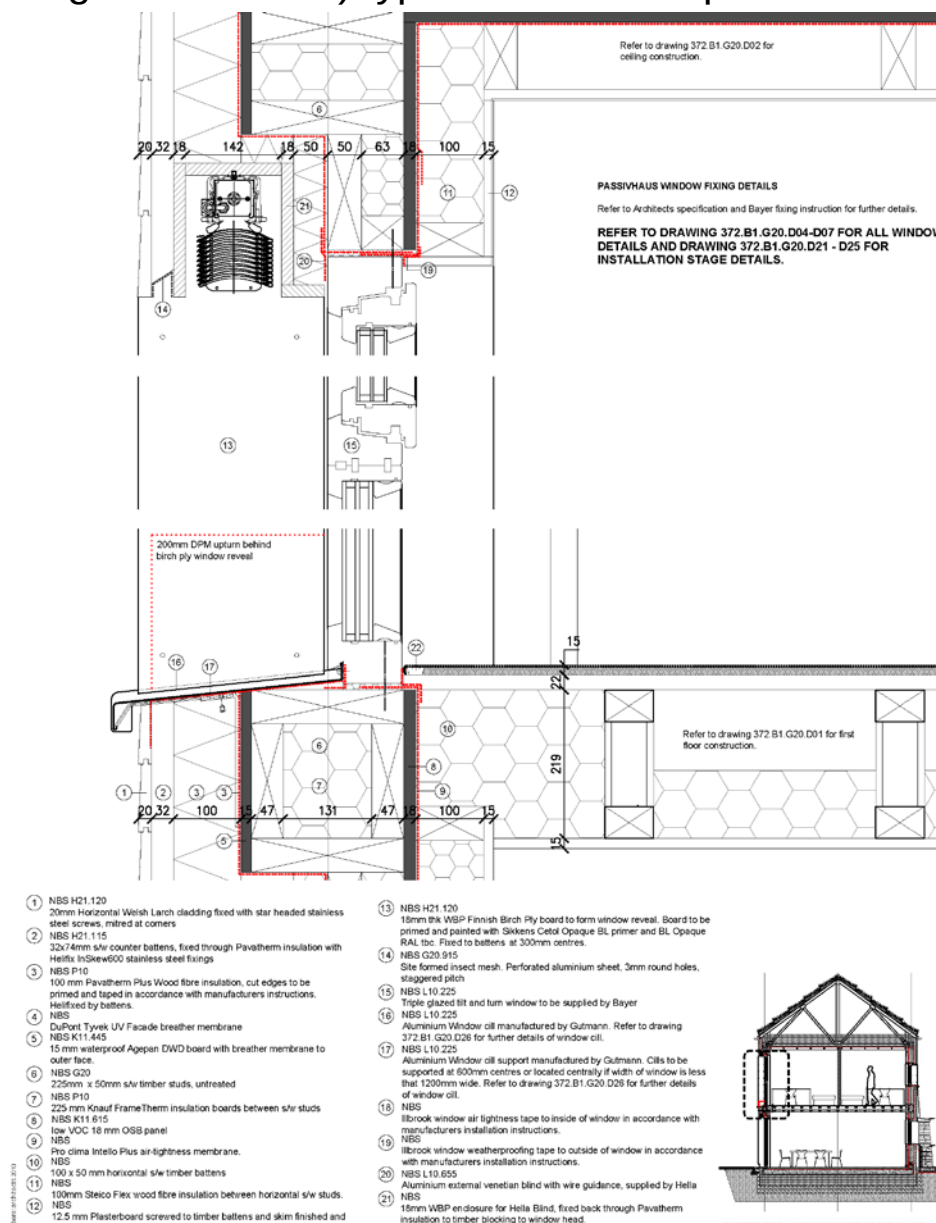


Figure 13. Showing the insulation of the roof (attic ceiling) connection to exterior and interior (image copyright bere:architects)

The roof construction is based on a cold-roof construction with insulation in the plane of the ceiling joists. In order to maintain the airtight integrity of the ceiling plane there is no internal access to the attic space, with the only access being via an external hatch in the gable end wall. A very low roof U-value of 0.074W/(m²K) was achieved by using four layers (each 140mm thick) of mineral wool insulation (total insulation depth 560mm). The insulation is laid in a staggered joint manner to avoid thermal bypass in the construction and the insulation sits on top of an 18mm OSB (low VOC) sheathing layer which lines the underside of the roof trusses. Beneath the OSB layer an intelligent VBL membrane was used to ensure continuity with the airtight membrane used in the wall construction (as shown in Figures 12 and 13). Beneath the airtight VBL membrane there is a 100mm services void to allow for downlights and electrical cabling runs.

2.7.4 Cross sections of windows including installation sketch (to a recognisable scale) type of window / specific values



14. Showing the insulation of the roof (attic ceiling) connection to exterior and interior (image copyright here:architects)

The windows used on this project were supplied by Bayer- Schreinerei of Elzach Germany (as there were no suitable UK manufactured windows available at this time). The windows were Passivhaus certified timber windows (with a thermally broken frame) with an overall $U_w=0.8 \text{ W/m}^2\text{K}$ and $U_g=0.6 \text{ W/m}^2\text{K}$ and with a solar heat transmission coefficient (g-value) of 0.5. Tilt and turn gearing was predominantly used throughout with the exception of the large sliding doors on the ground floor.

Installation of the windows was carried out by local sub-contractors following a detailed fitting demonstration and tool box talk given on-site by Herr Walter Bayer (of Bayer- Schreinerei). The installation of the windows involved airtight taping both the outside and inside of the window frames (Figure 15a) using specialist wide roll (80-110mm wide) airtight tapes. The windows were float fitted using specialist air cushions to position them and then back-filling the perimeter gap using a proprietary sealant, before taping to the VBL layer (Figure 15b).



Figure 15. a) Pre-fitting of airtightness tapes b) installation taping connection to VBL

2.7.5 Description of the airtight envelope; documentation of the pressure test

The airtight envelope was formed using a continuous Pro-Clima Intello Plus airtightness membrane on the internal side of the construction. The membrane was located inside a 100mm deep internal fully insulated service void (as shown in Figure 12). Placing the membrane in this location allowed it to be fully visible and accessible during the first fix pressure tests and then subsequently protected from damage (e.g. from tenants screwing fixings into the walls and ceilings). The wall membrane was returned under the screed to create an airtight bond to the slab (using a primer system).

The first pressure test was carried out at first fix stage by Paul Jennings (ATTMA) (Figure 16), with Rob McLeod (BRE) present to supervise diagnostics and remediation with timber frame contractor. During the first test an initial recording of $0.39 \text{ h}^{-1} @ n_{50}$ was achieved. After an extensive mark-up of the air leakage paths a further test was undertaken with substantially improved the performance. A final test recording of $0.19 \text{ h}^{-1} @ n_{50}$ was

achieved at the commissioning test stage at the completion of the project. At the time (2010) this was the best air-tightness result ever achieved in a UK dwelling.



Figure 16. Interim blower door set-up for ATTMA (EN13829) pressure test

2.7.6 Ventilation plan for the ductwork

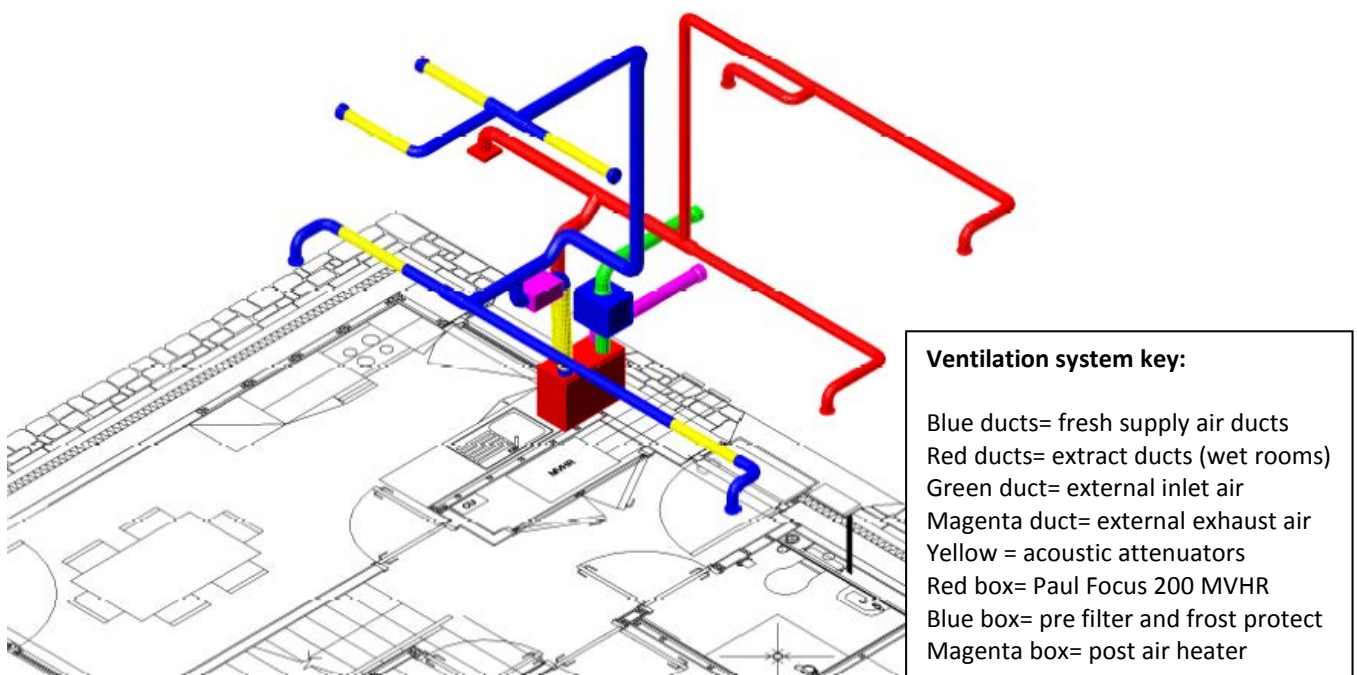


Figure 17. Showing 3D view of ductwork layout (image courtesy Green Building Store)

The balanced heat recovery ventilation system in the Larch House provides supply and extract ventilation using a Paul Focus 200 MVHR unit (Figure 15). The system is configured to provide post-heating of the supply air using a VEAB hydraulic heating coil connected to the DHW cylinder. The heated air is distributed via insulated ductwork to the supply zone diffusers (in the bedrooms and living rooms). The room supply and extract terminals are predominantly Lindab steel terminals with a filtered kitchen extract grille. The ductwork is Lindab spiral wound galvanised metal. Supply ducts are insulated with foil faced mineral fibre insulation and the inlet and exhaust ducts between the MVHR unit and the exterior terminals are insulated with vapour tight Armaflex. An electric frost protection pre-heater protects the heat exchanger from frost damage using a Paul ISO unit with a G4 pre-filter and PTC electric element controlled by an electronic thermostat which ensures the supply air does not enter the MVHR unit below a set point of -1°C .

2.7.7 Ventilation plan for the central unit / type / specific values



Figure 18. Showing the Paul Focus MVHR unit and preheater and pre-filter box (black polystyrene) and insulated post heater and risers (wrapped in foil-faced mineral fibre)

2.7.8 Heat supply

The heat supply in the Larch House is via a VEAB duct heater battery which is connected to (as illustrated in Figure 15). The duct heater is supplied with hot-water directly from the Rehema Avanta 18S gas fired combi boiler which is located in an airing cupboard on the first floor (above the MVHR unit). The boiler also supplies heat to two towel radiators located in the shower room (Figure 6) and bathroom and also a small radiator in the airing cupboard which is used for clothes drying. These additional radiators are heated in tandem with the duct heater and are controlled by a single Honeywell DT90 Thermostat which is located in

the living room. The additional radiators are needed to meet the peak load of 11 W/m^2 (in a mean weather year, at 20°C set-point) and provide additional thermal buffering to prevent the boiler overheating (since it has a minimum rated output of 6kW).

2.8 Brief report on important PHPP results

Specific Demands with Reference to the Treated Floor Area				
Treated Floor Area:	86.7	m^2	Applied:	Monthly Method
Specific Space Heat Demand:	13	$\text{kWh}/(\text{m}^2\text{a})$	PH Certificate:	15 $\text{kWh}/(\text{m}^2\text{a})$
Pressurization Test Result:	0.2	h^{-1}		0.6 h^{-1}
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	107	$\text{kWh}/(\text{m}^2\text{a})$		120 $\text{kWh}/(\text{m}^2\text{a})$
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	57	$\text{kWh}/(\text{m}^2\text{a})$		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	60	$\text{kWh}/(\text{m}^2\text{a})$		
Heating Load:	11	W/m^2		
Frequency of Overheating:	5	%	over	25 $^\circ\text{C}$
Specific Useful Cooling Energy Demand:		$\text{kWh}/(\text{m}^2\text{a})$		15 $\text{kWh}/(\text{m}^2\text{a})$
Cooling Load:	2	W/m^2		

Figure 19. PHPP Verification table showing important results

The important PHPP values are shown in the excerpt from the PHPP “Verification” worksheet in Figure 16. These highlight the annual space heating demand of $13\text{kWh}/\text{m}^2\text{a}$, the Peak Space Heating load of $11\text{W}/\text{m}^2$ and the airtightness of $0.2 \text{ h}^{-1} @ \text{n}50$. The building model showed an overheating frequency of 5% of the year at or above 25°C according to the design stage predictions.

2.9 Construction costs

circa $2100\text{€}/\text{m}^2$ living space/usable area (construction and building services)

2.10 Costs for the building:

circa $120,000\text{€}$ (ex-preliminaries, overhead and profit)

2.11 Year of construction

2010

2.12 Information on the architectural design

The architectural design was carried out by bere:architects.

2.13 Information on the building services planning

The building services planning was carried out by Alan Clark, with additional input from Rob McLeod (BRE) and Andrew Farr (Green Building Store).

2.14 Information on building physics and Passivhaus planning

The building physics, design optimisation, site specific climate data generation and passivhaus planning was carried out by Rob McLeod (BRE) in collaboration with Carrine Oberweis (bere:architects). Rob McLeod (BRE) was the Principle Passivhaus consultant responsible for checking all project data, approving the specification and preparing the certification files and documentation. The project was independently certified by Kym Mead of BRE Passivhaus UK and the certification was checked and independently verified by the PHI.

2.15 Information on the structural analysis planning

The structural engineering was carried out by Bob Johnson, in conjunction with Holbrook timber frame.

2.16 Experiences (user opinion, actual consumption values)

A post monitoring evaluation of the project was independently carried out by Dr Ian Ridley and colleague of University College London and is presented in the paper “The side by side in use monitored performance of two passive and low carbon Welsh houses” Energy and Buildings 82 (2014) 13–26. User experiences highlighted some initial problems with overheating in the first floor bedrooms (largely due to natural ventilation not being used due to a lack of insect screens on bedroom windows) and also some occupant dissatisfaction with the automated shading system. However the overall response from the tenants was that they were delighted with the very high standard of thermal comfort and extremely low running costs that the Larch house dwelling provides. The findings of the occupant studies are documented in the TSB Soft Landings Project review which is available at <http://www.bere.co.uk/films/larch-house-soft-landings-summer-workshop>

2.17 Reference to existing studies/publications on this project

Ridley et al (2014). The side by side in use monitored performance of two passive and low carbon Welsh houses. Energy and Buildings 82 (2014) 13–26

McLeod et al (2012). A proposed method for generating high resolution current and future climate data for Passivhaus design. Energy and Buildings 55 (2012) 481-493

Bere architects (2012) Ebbw Vale future homes – Larch house, Soft Landings workshops. <http://www.bere.co.uk/films/larch-house-soft-landings-summer-workshop>

2.18 Project Quality Approved Passivhaus Certificate



Building Research Establishment
Watford
Herts
WD25 9XX
United Kingdom

Authorised by:
Passivhaus Institut
Dr. Wolfgang Feist
Rheinstr. 44/46
D-64283 Darmstadt



Certificate

The Building Research Establishment certifies the building
**The Larch House, The Works Ebbw Vale, Blaenau Gwent County Borough,
Steelworks Road, Ebbw Vale NP23 6AA**

Principal **Rob McLeod**
Consultant: Building Research Establishment

Architect: **Bere:architects**
73 Poets Road, London, N5 2SH

Mechanical **Alan Clarke**
Services: The Woodlands, Woodland Close, Whitecroft, Lydney, GL15 4PL

as a

Quality Approved Passive House

The planning of this building meets the criteria for Passive Houses set up by the
Passivhaus Institut.

With appropriate execution it will conform to the following standards:

- The building features excellent complete thermal insulation and first grade connection details with respect to building physics. Estival heat protection has been considered. The heating demand is limited to

15 kWh per m² living area and year or a heating load of max. 10 W/m²

- The building shell features excellent air tightness, proven in accordance to ISO 9972, which guarantees the building to be free of draughts and reduces energy demand. The air change rate of the building shell at 50 pascal pressure difference is limited to

0,6 ach, with respect to the building's volume

- The building features a controlled ventilation system with high class filters, highly efficient heat recovery and low electric power consumption. Thus, excellent air quality is achieved in combination with low energy consumption.
- The primary energy demand for standard use of heating, domestic hot water, ventilation and all other electric appliances sums up to less than

120 kWh per m² living area and year

This certificate is to be used together with the certification documents only which describe the exact characteristics of the building.

Passive Houses offer high comfort during summer as well as in winter and can be heated with little effort, e.g. by heating of supply air. The building shell of a Passive House is evenly warm on the inside, inside such that surface temperatures hardly differ from room air temperatures. Due to the highly air tight, draughts cannot appear during normal use. The ventilation system constantly provides good air quality. Heating costs in a Passive House are very low. Thanks to their low energy consumption Passive Houses offer security against future rises in energy prices and against energy scarceness. Moreover, the environmental impact is low as energy resources are spent very economically and only small amounts of carbon dioxide (CO₂) and other pollutants are emitted.

issued:

Kym Mead, Senior Consultant
Building Research Establishment, United Kingdom

Figure 20. Passivhaus Certificate for the Larch House, Passive House Database project ID 1849