PassivHaus Project Documentation

The Rectory (Eco-vicarage), 17 Penzer Street,
Kingswinford, West Midlands, DY6 7AA, UK.

Project ID: 4410

Dr Stephen Ball – Director of Sustainability and Certified PassivHaus Designer/Consultant for the Eco-vicarage project – Couch Perry Wilkes LLP – (www.cpwp.com).

The Rectory, commonly known as the Eco-vicarage, formed part of a series of very low energy developments for the Diocese of Worcester (client). The Eco-vicarage described herein was the first dwelling in England to achieve Code for Sustainable Homes (CfSH) Level 6 (i.e. true zero carbon) and be PassivHaus Certified.

The brief was developed during 2009 and once planning permission had been granted, construction took place across 2010 – 2011. CfSH Level 6 certification was awarded in April 2011 with PassivHaus Certification following shortly in June 2011 via UK certifiers WARM.

Key Environmental Features:

- True Zero Carbon > 144% improvement over the Dwelling Emission Rate (DER)
- 42m^2 Solar Photo-voltaic Panels
- 5m^2 Solar Thermal Evacuated Tubes
- Rehau Earth Tube – Ground to Air Heat Exchanger (GAHE)
- Rainwater Harvesting System
- Low Energy Eco-fluorescent Tubes and LED Lighting throughout
- Heavyweight Construction
- External Louvered Blinds for Optimum Solar Control

U-value external walls = 0.103W/m^{2}K	**PHPP Space Heating Demand = 14kWhr/m^2 per annum**
U-value floor = 0.089W/m^{2}K	PHPP Primary Energy Demand = 110kWhr/m^2 per annum
U-value roof = 0.086W/m^{2}K	Air Test (n_{50}) = 0.42h^{-1}
U-value windows = 0.80W/m^{2}K	Heat Recovery Unit Efficiency= 0.93%

1.0 Project Description

The Church of England is currently trying to reduce its carbon footprint by 80% and the Diocese of Worcester felt they could no longer justify current representative vicarage heating costs of c. £2,000 per annum and rising. To achieve the long term sustainability aspirations of the client, a variety of different build standards were investigated. After much deliberation, it was agreed to design and cost plan for CfSH Level 6 and PassivHaus accreditation.

The two standards are in many ways complimentary, as air-tightness, thermal bridging and very low energy consumption in-use are controlled by PassivHaus, while the renewable energy, carbon footprint and aspects such as water usage and rainwater harvesting are driven by CfSH.

The Eco-vicarage itself occupies a suburban site at Penzer Street, Kingswinford. The design organised principle rooms in a south-facing range, finished in white render; brick–faced stairs, bathrooms and plant to the north maintained privacy for both the new and the neighbouring old vicarage.

Accommodation was arranged on three levels, as shown later through the layout and elevation drawings. The ground floor contained the vicar's study and garden living room. The first floor provided kitchen/dining, a private family living room and a flexible study/guest bedroom. The top floor had three bedrooms tucked into the roofspace with top lighting. The private family living room was provided to allow for the fact that the vicarage would often be used for work purposes (e.g. home bible study groups/meetings etc), but it would also simultaneously have to function as a family home.

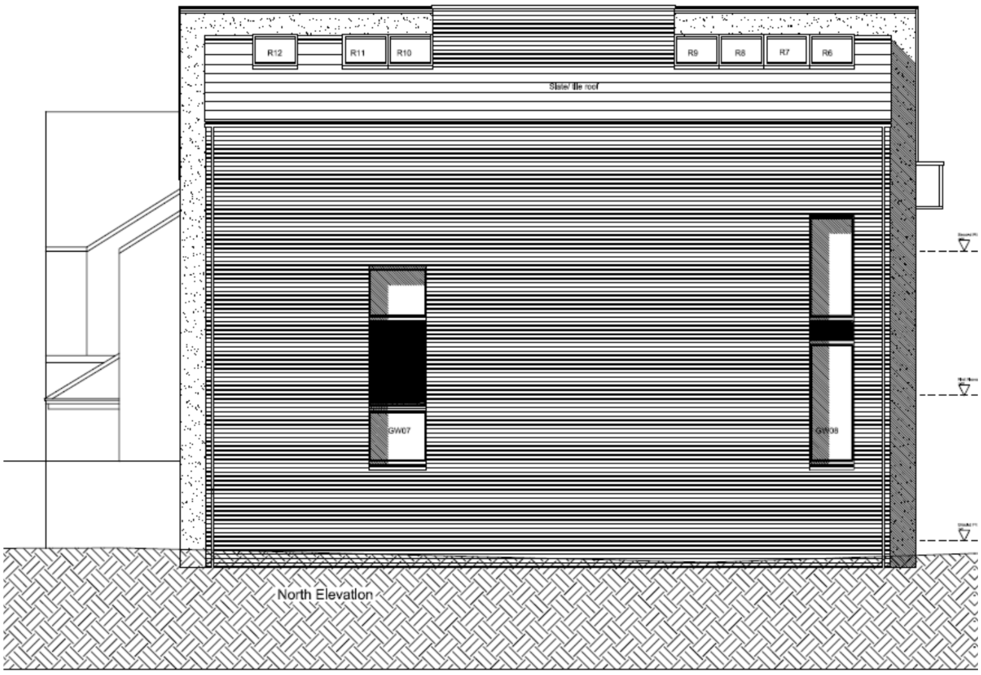
The principle rooms had large south-facing windows to collect winter sun and to give excellent day-lighting throughout the year (an imperative for low energy design). In summer these were shaded with adjustable recessed blinds. The roof had two types of solar panels; photo-voltaics to generate electricity and evacuated thermal tubes for solar hot water.

External brick and render were in sympathy with their surroundings. The blue-black slate roof toned with the solar panels and neighbouring buildings. Heavy construction throughout meant the home would heat up and cool down slowly to avoid extremes of temperature.

Although the scheme breaks new ground in many different ways, it is hoped that one day all homes in England will be constructed to this standard.

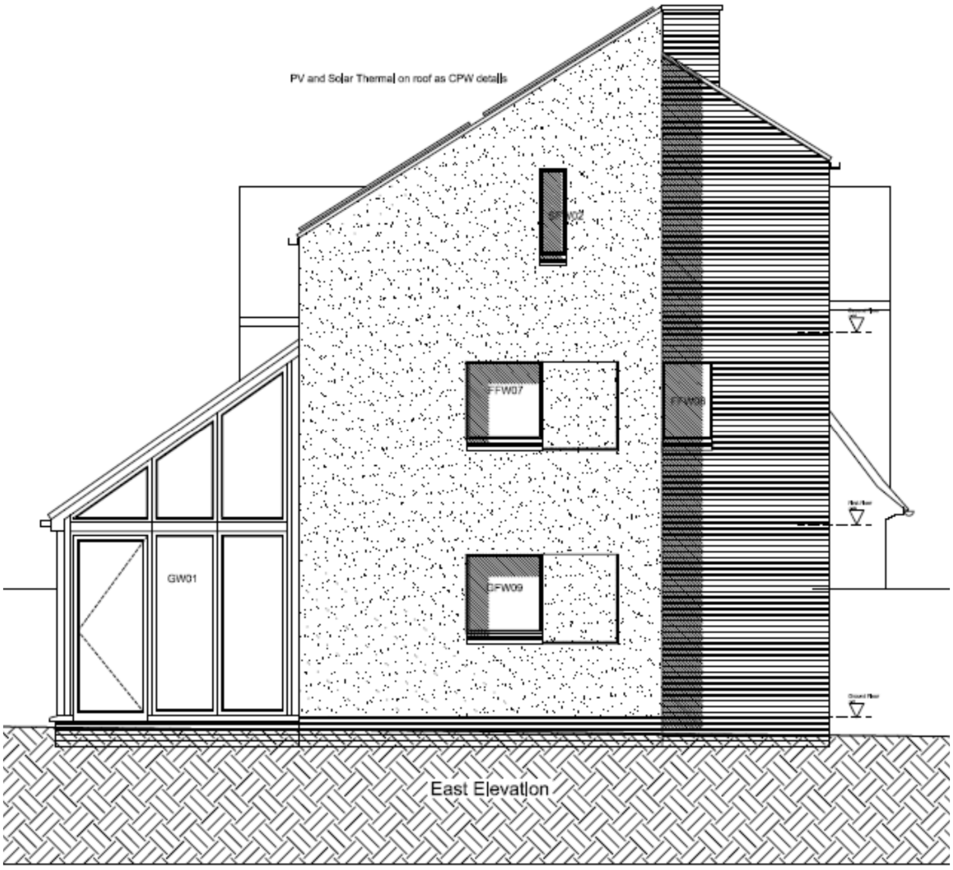
2.0 Elevations – Drawings and Photographs

Elevation drawings and corresponding photographs are shown below:

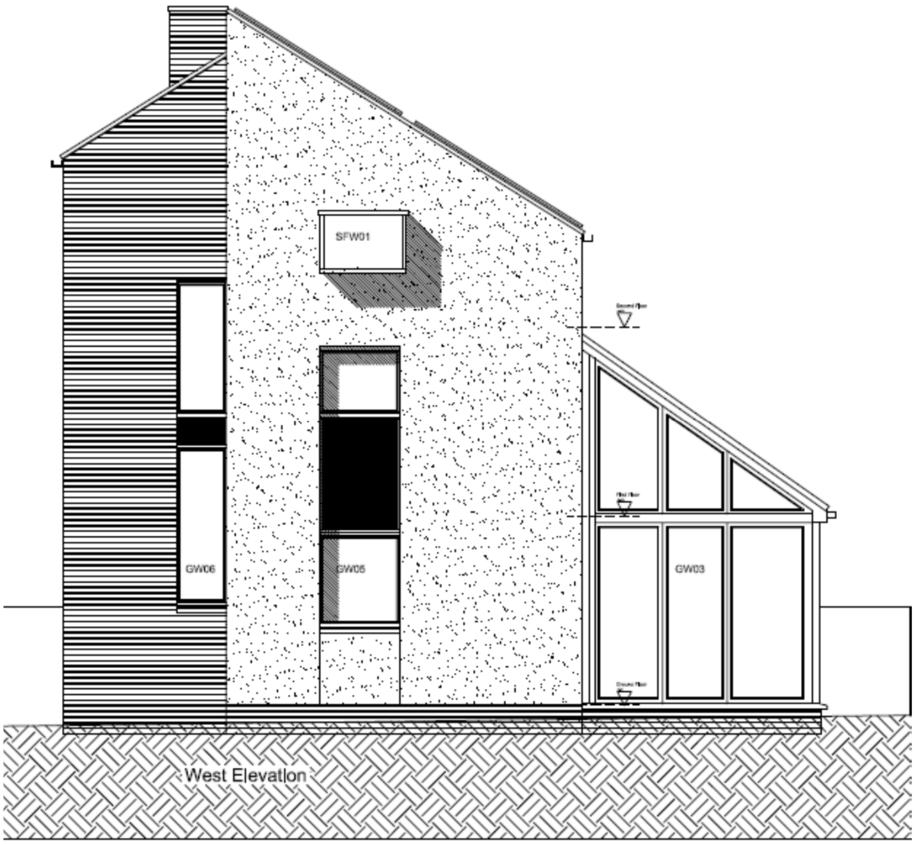


North Elevation

South Elevation



East Elevation



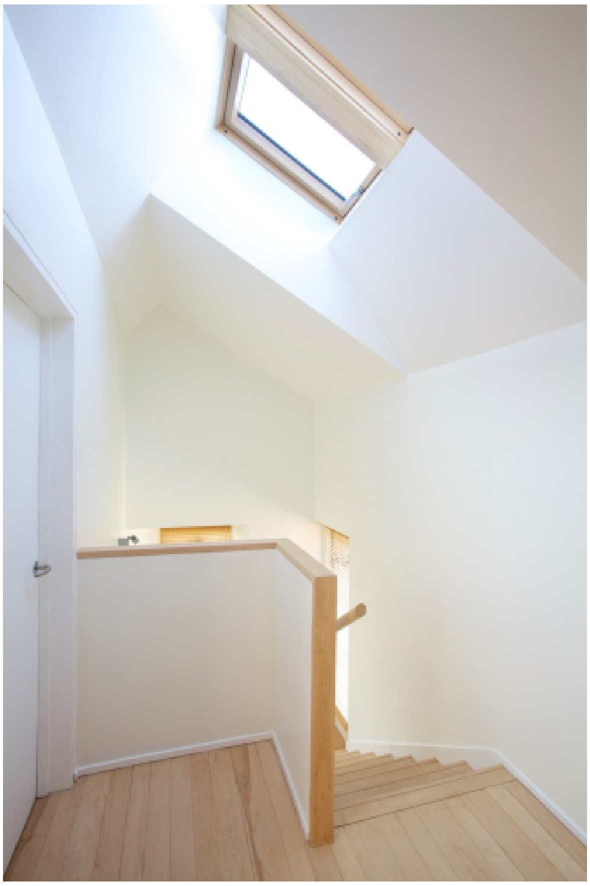
West Elevation

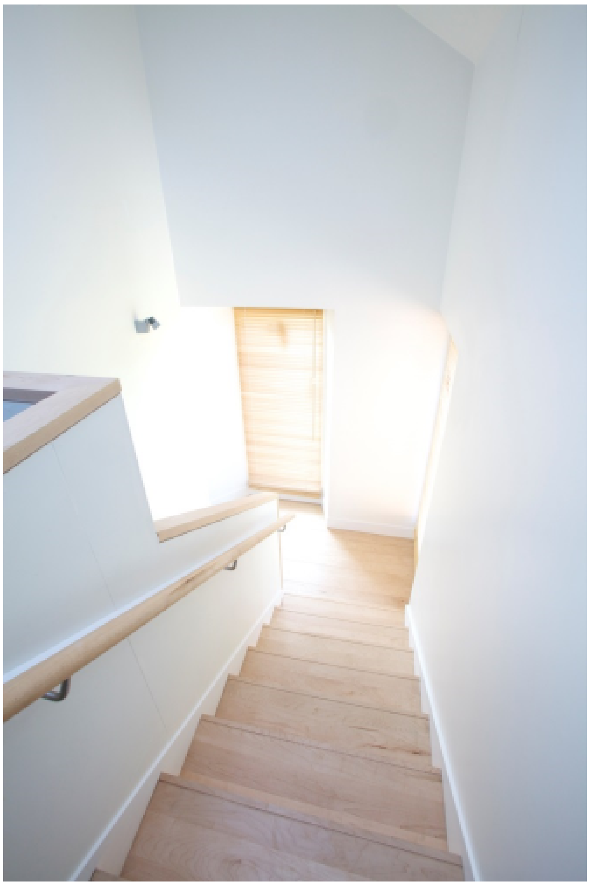
South and West Elevations

South and East Elevations

2.1 Internal Photographs

A selection of internal photographs of the completed project are shown below, and serve to demonstrate the high levels of natural daylight achieved within the space:



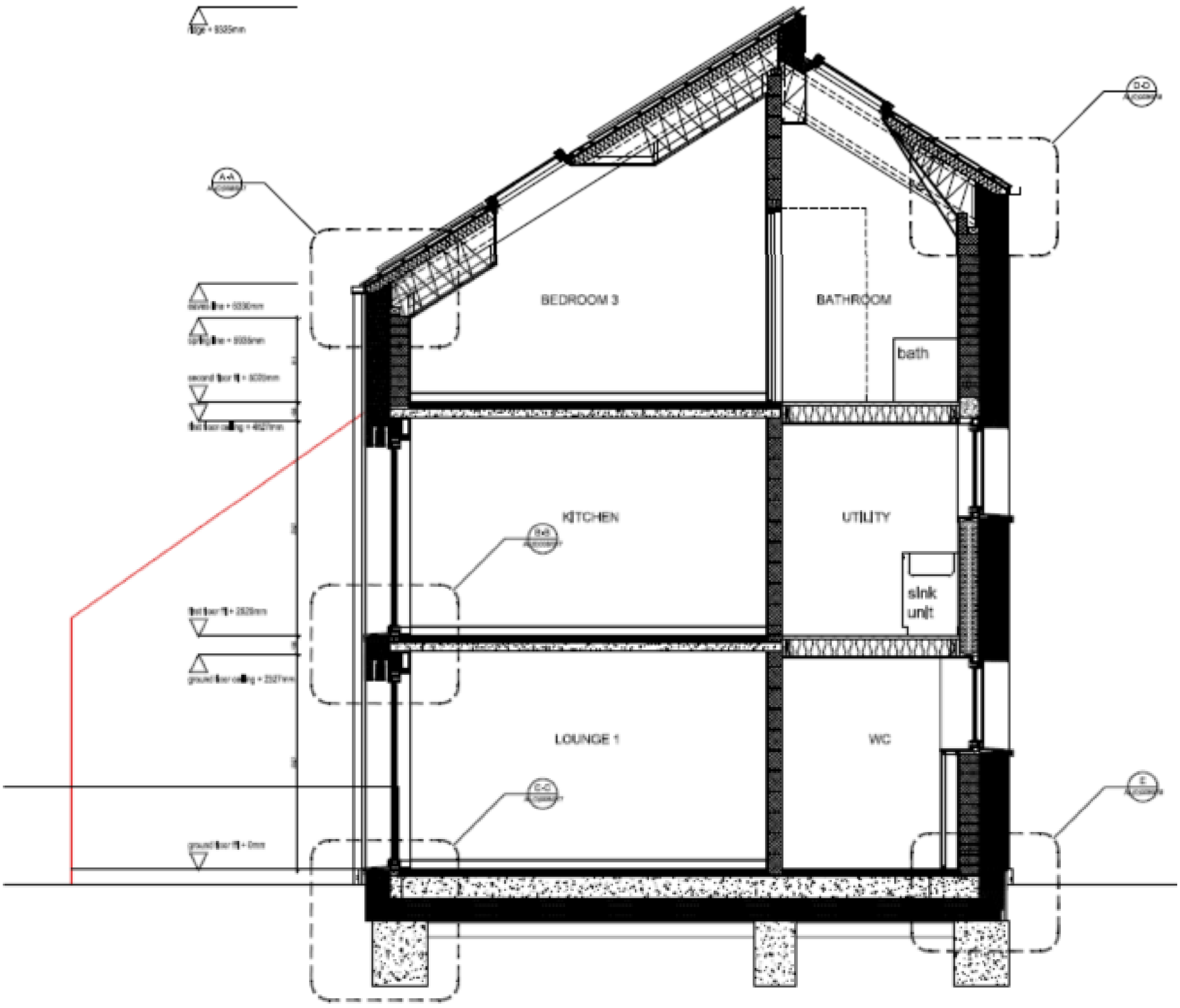


Selection of Internal Photographs

2.2 Cross-Section

A typical cross-section through the Eco-vicarage is shown below. The diagram highlights the major envelope components and also serves to identify the construction details that follow in Section 2.4. The cross-section clearly illustrates how the principle rooms were arranged on the south-facing side to maximise daylight penetration and provide useful solar gain. The smaller back-of-house 'service' and utility rooms are shown to the north. It can be seen that the envelope was designed to be heavily insulated.

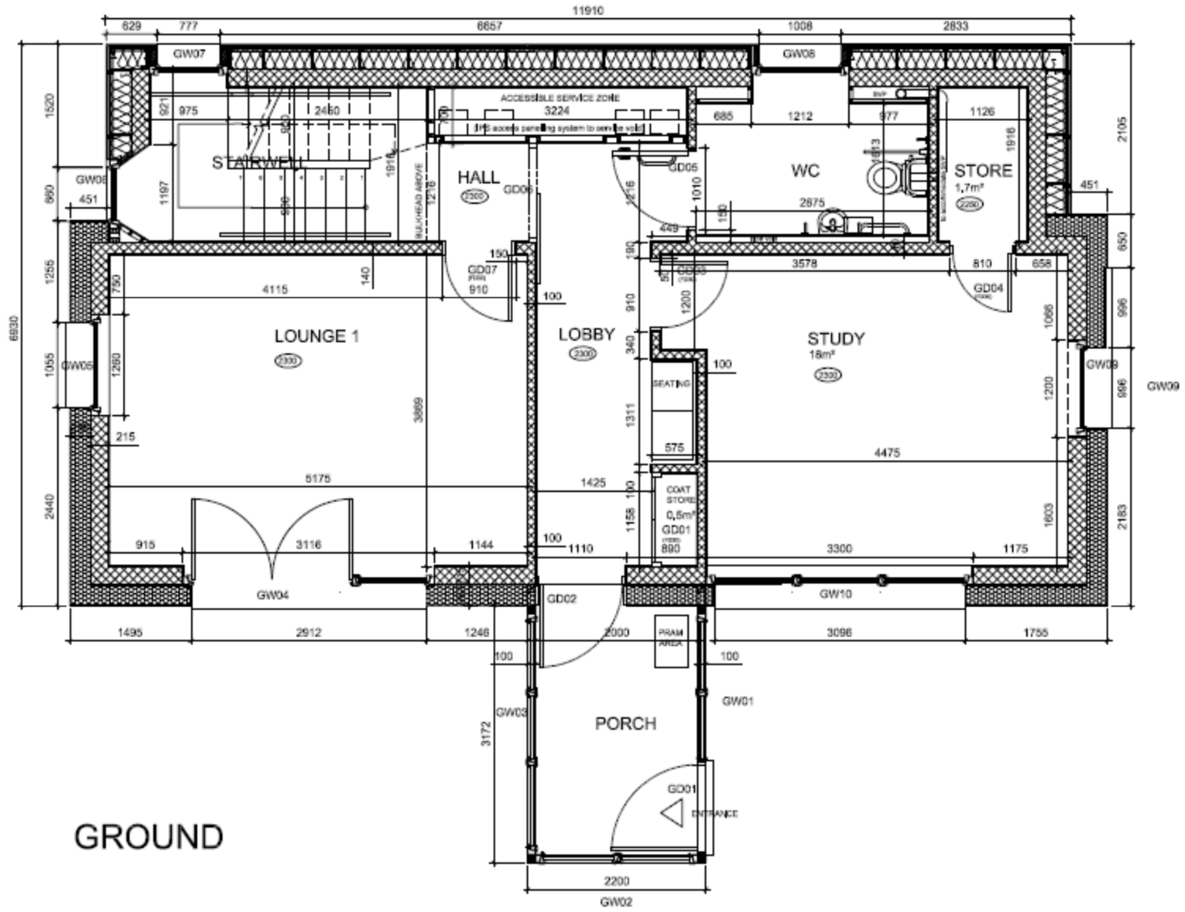
The roof provided an ideal natural pitch for the installation of solar photo-voltaic panels and solar thermal evacuated tubes. Although these technologies were not required to meet the PassivHaus criteria, they helped to decarbonise the energy supply to achieve CfSH Level 6 requirements.



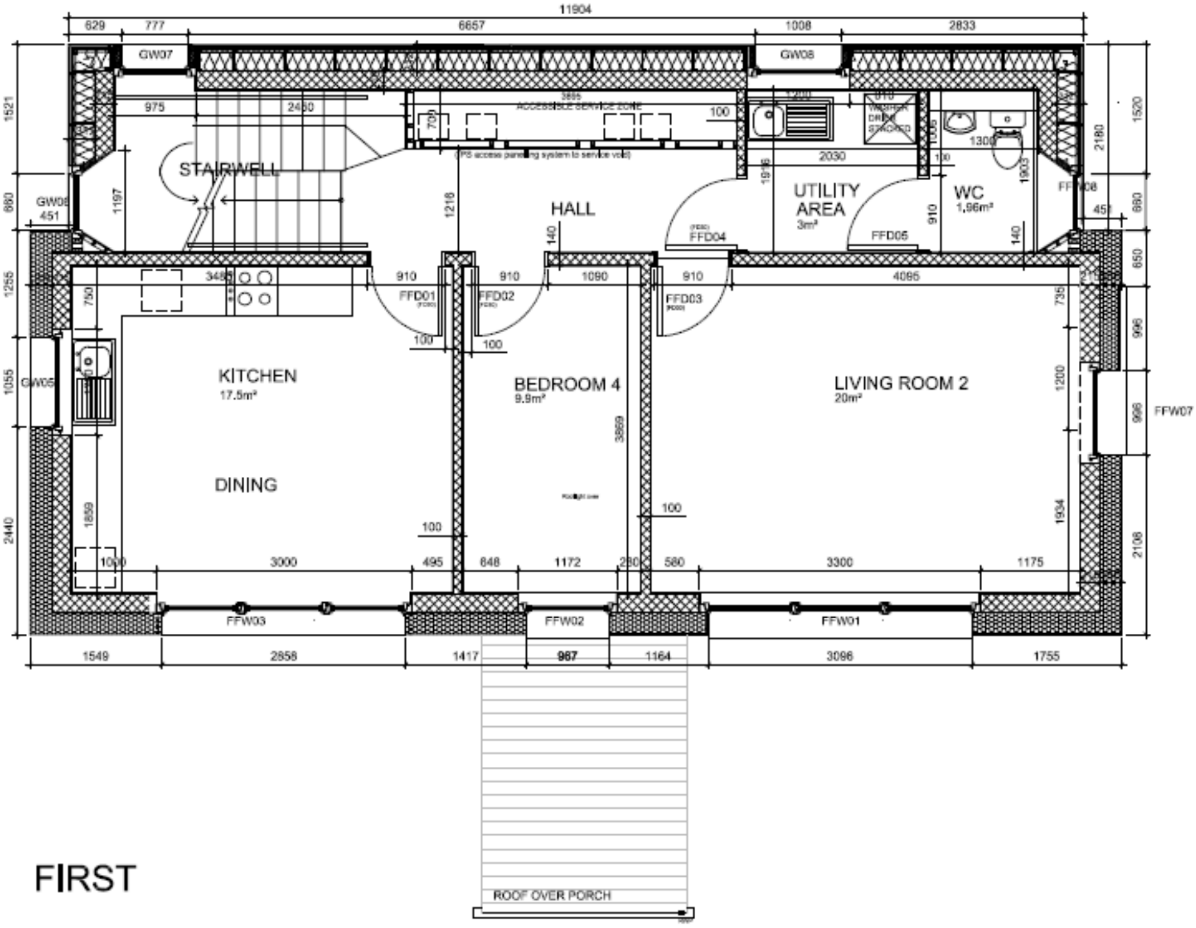
Cross-Section Showing Extent of Thermal Insulation and Construction Detail Locations

2.3 Floor Plans

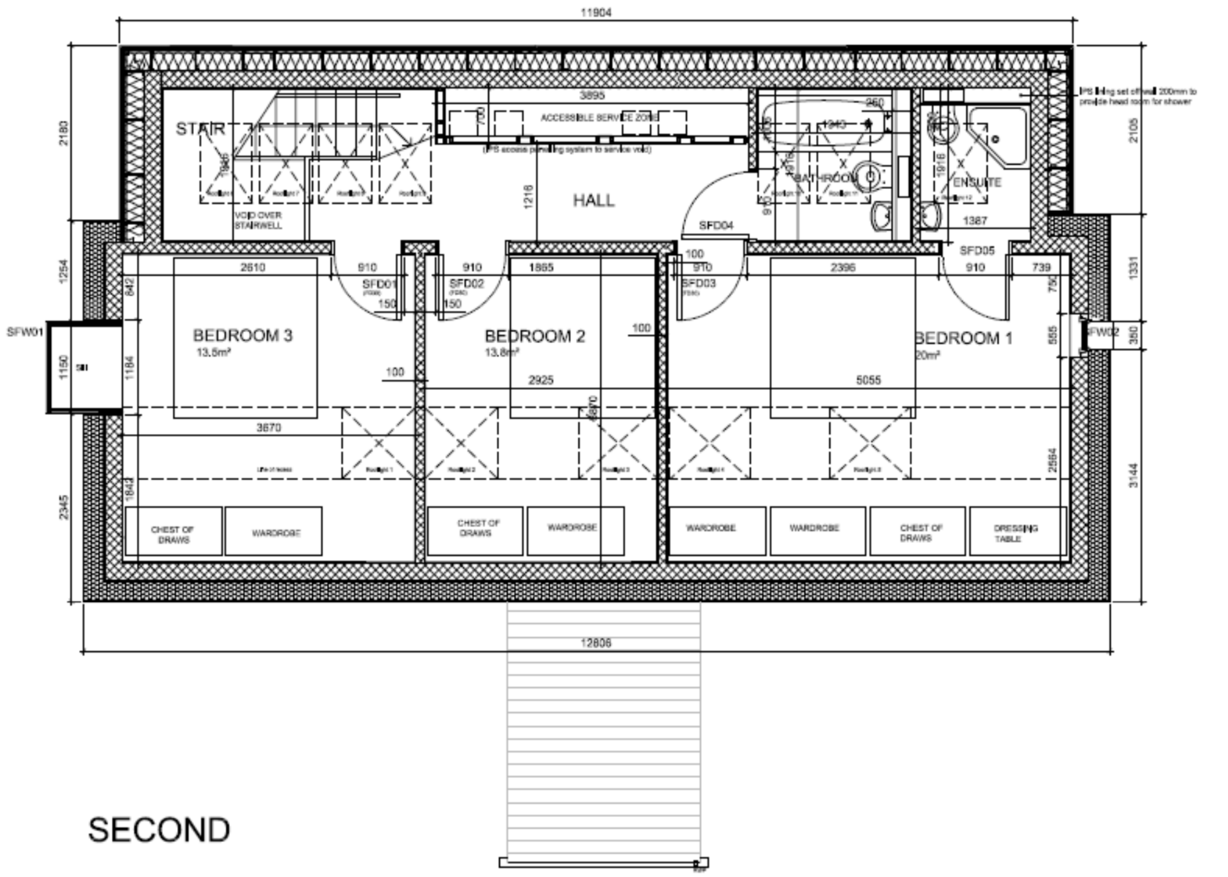
The floor plans shown below comply with Lifetime Homes standards and CfSH Level 6. The dwelling itself had to function as both a working vicarage and a private family home and this was considered at the very early stage of the design process, as described earlier.



Ground Floor Layout



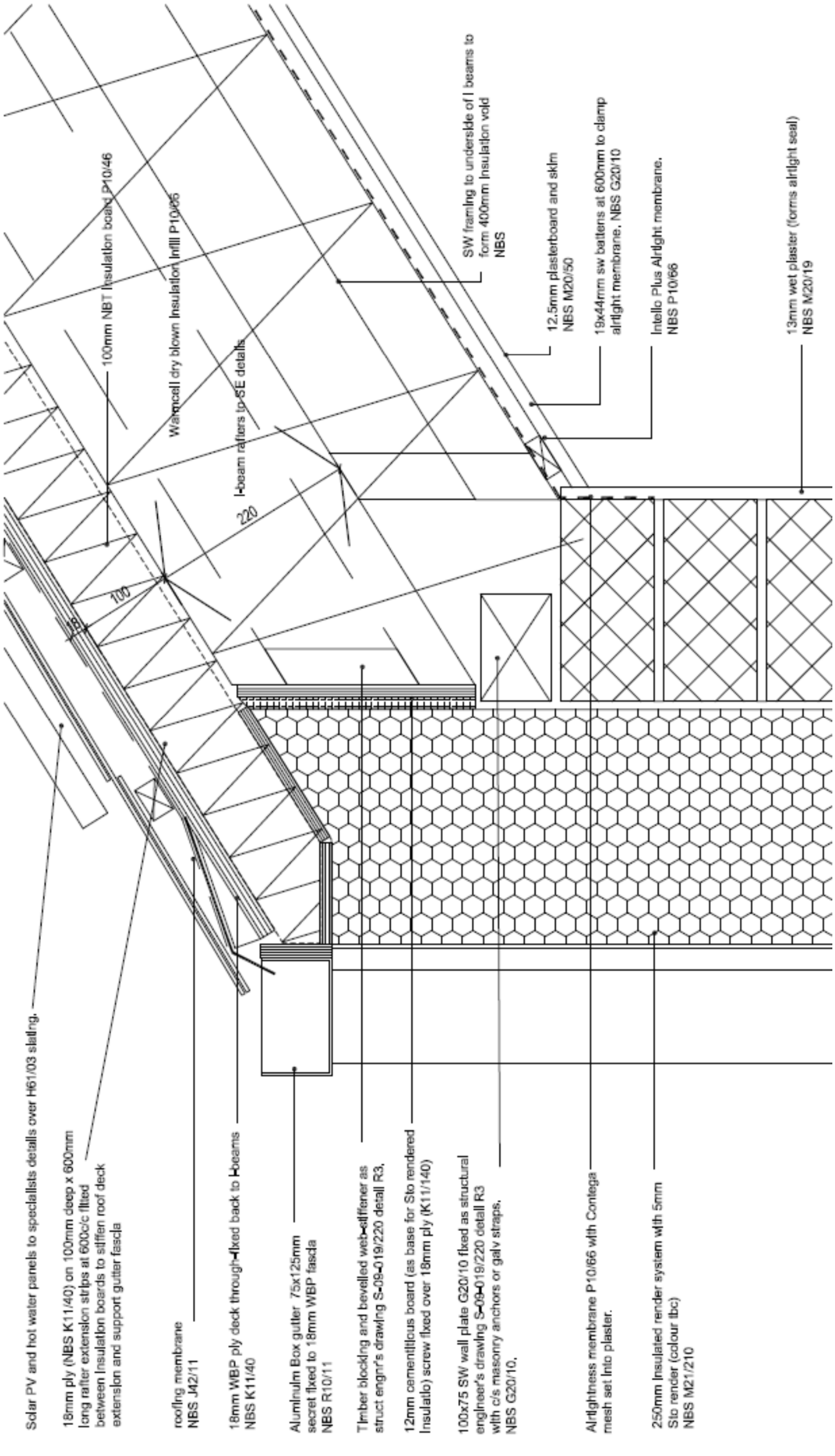
First Floor Layout



Second Floor Layout

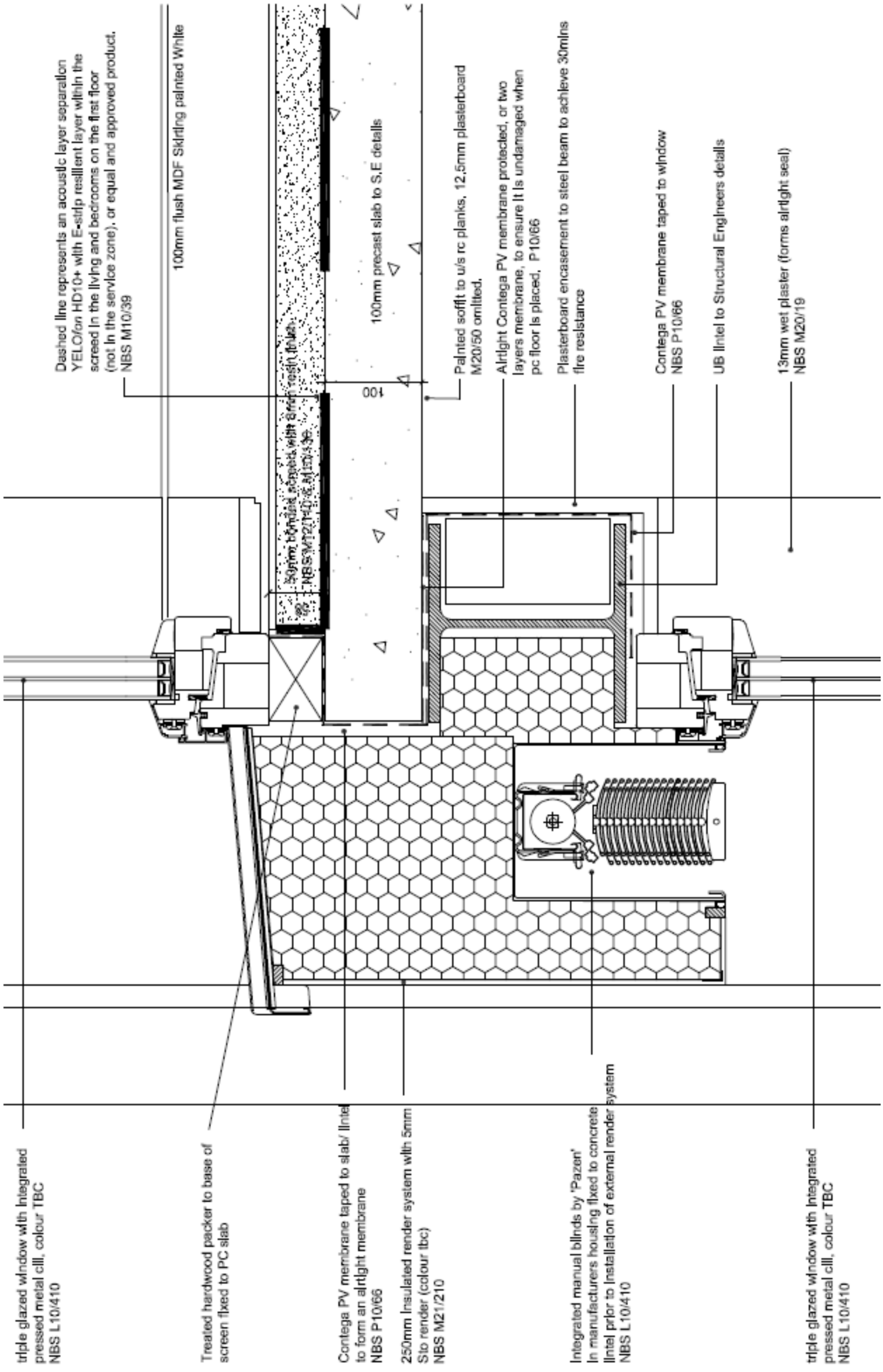
2.4 Construction Details

The construction details are shown below:



Roof/Wall Detail A-A

The roof/wall detail on the south elevation was designed to give 400mm of Warmcell dry blown insulation between I-beams and 100mm insulation board. The blockwork wall of 215mm thickness had 250mm of Lamatherm insulation and was finished in white Sto façade render. Roof/wall interfaces were addressed using pro clima air-tight membranes and tapes with plaster reinforcement e.g. CONTEGA PV. A layer of plaster formed the air-tight seal.

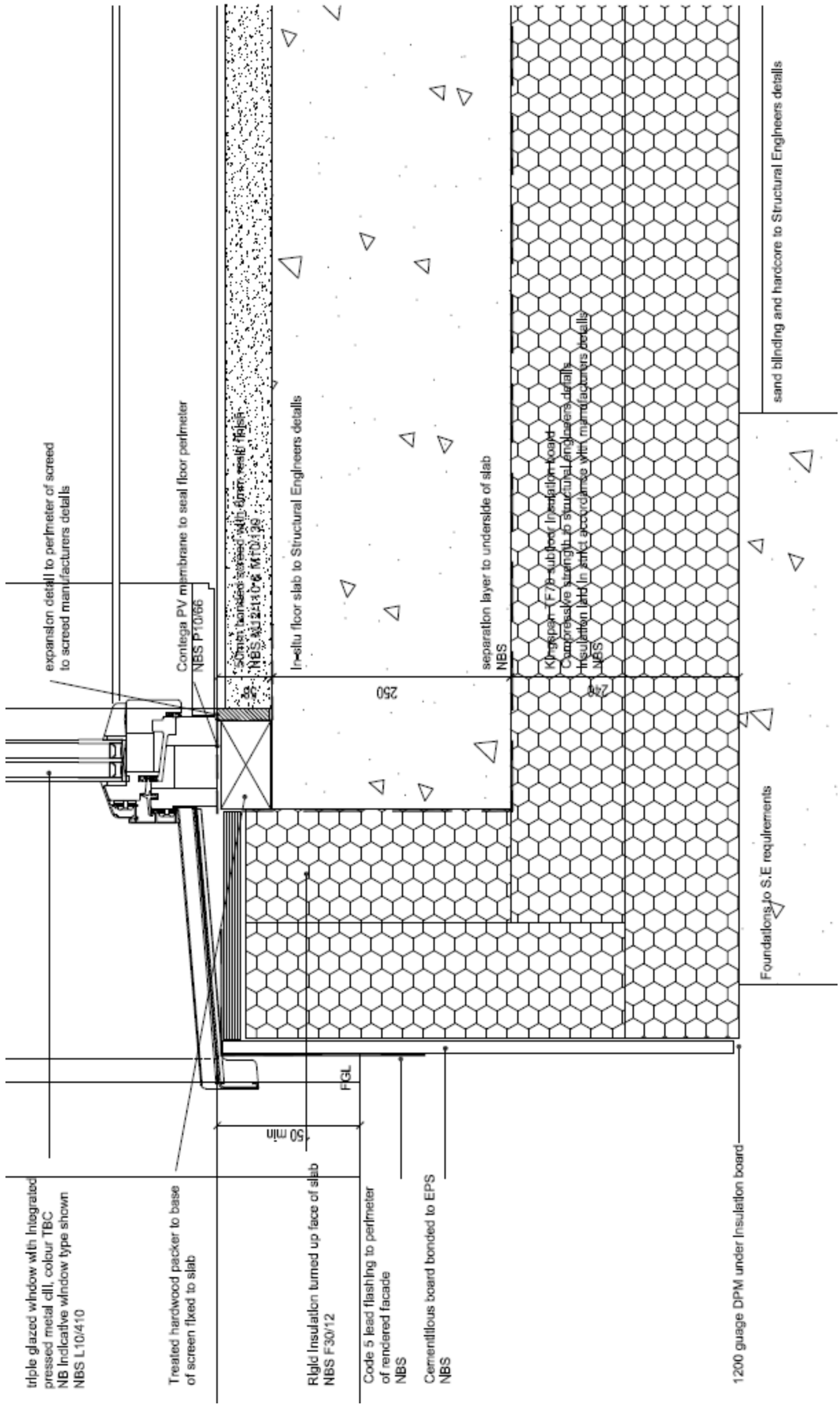


Window Detail B-B

Windows on the vertical elevations were PassivHaus Institute certified timber-aluminium composite 'Pazen Premium Maxi' and 'Pazen Futur Maxi' with a glass U_g value of 0.5W/m^{2}K and U_f values of 0.71W/m^{2}K and 0.73W/m^{2}K respectively. Rooflights were Fakro FTT pivot type with a glass U_g value of 0.49W/m^{2}K and U_f value of 1.67W/m^{2}K. PassivHaus certified rooflights were not available to the UK market during the time of construction.

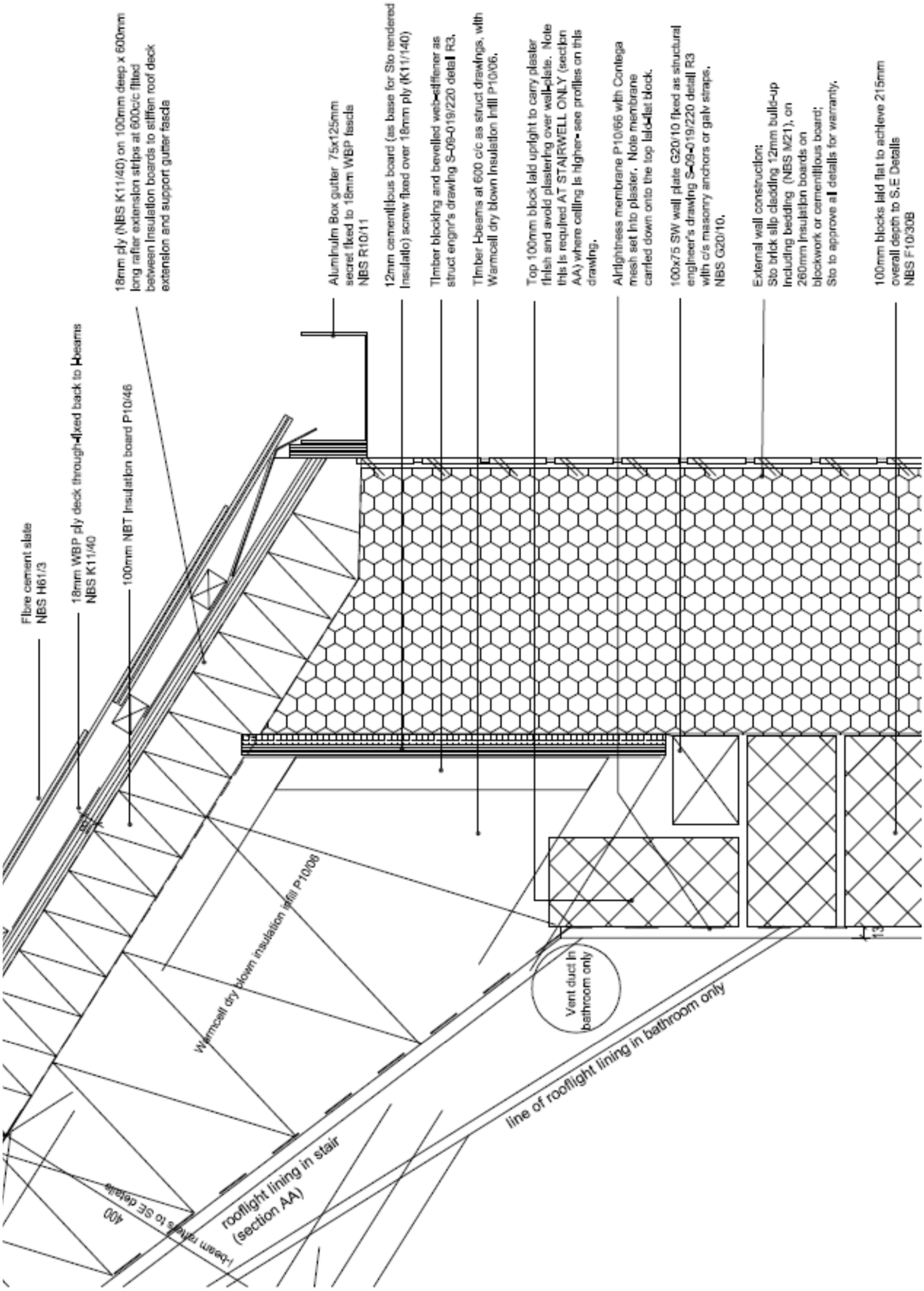
250mm of Lamatherm insulation was used together with pro clima air-tight membranes and tapes, as described previously and plaster forming the air-tight seal.

Integral blinds were incorporated on the south elevation within the manufacture's housing (Pazen) to provide solar protection during the peak summer months.



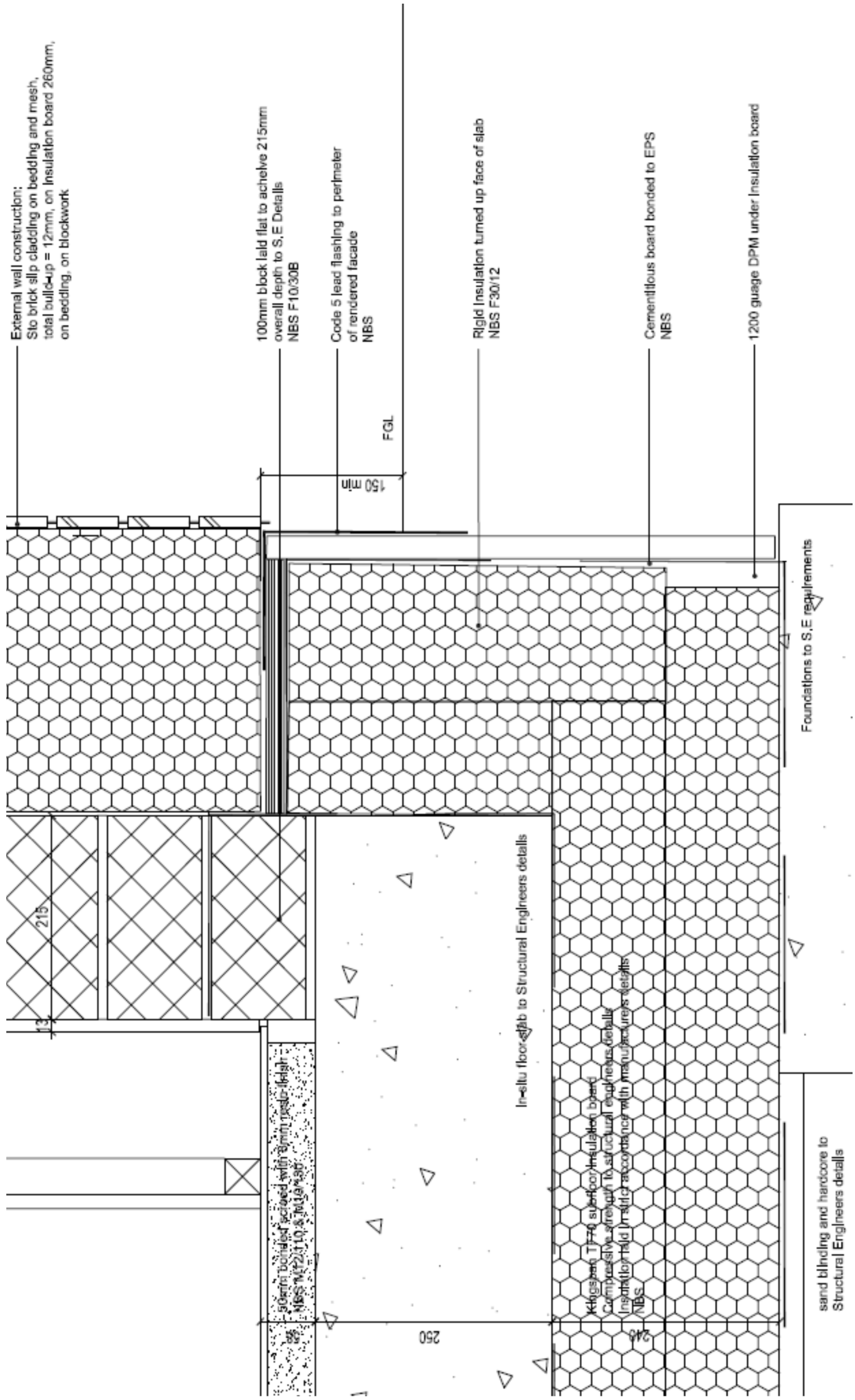
Ground/Wall Detail C-C

The ground floor slab (250mm) and 50mm bonded screed with 8mm resin finish sat on 240mm of high performance rigid thermoset polyisocyanurate (PIR) Kingspan TF70 sub-floor insulation. Specialist pro clima tapes (e.g. CONTEGA PV) were used to seal the floor perimeter.



Roof/Wall Detail D-D

The roof/wall detail on the north elevation was again designed to give 400mm of Warmcell dry blown insulation between I-beams and 100mm insulation board. The blockwork wall of 215mm thickness had 250mm of Lamatherm insulation and was finished in Sto brick slip cladding on bedding and mesh. Roof/wall interfaces were addressed using pro clima air-tight membranes and tapes with plaster reinforcement e.g. CONTEGA PV. A layer of plaster formed the air-tight seal.



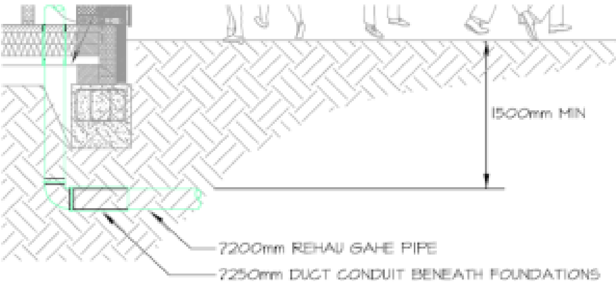
Ground/Wall Detail E-E

The ground/wall detail on the north elevation mimics that on the south apart from the external wall cladding being Sto brick slip as opposed to Sto white render.

2.5 Air-tight Envelope

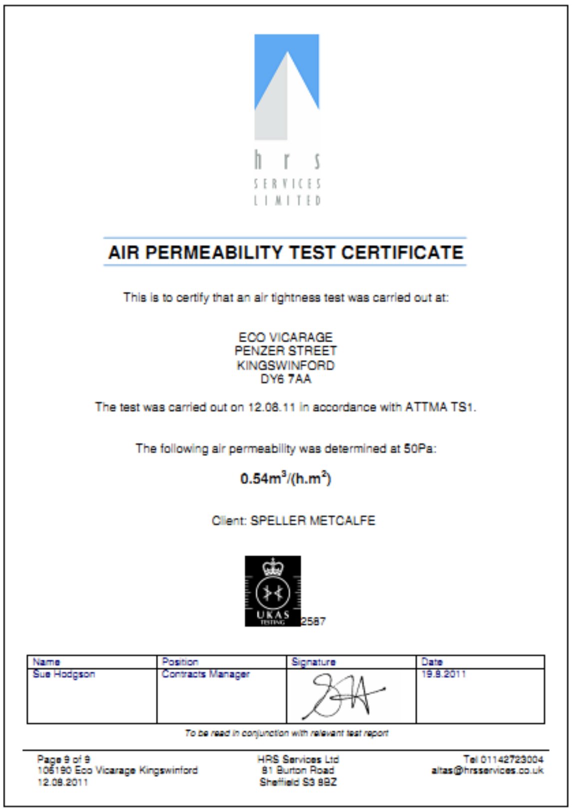
The air-tight line of the heavyweight blockwork construction was provided by the plaster layer over specialist pro clima tapes with plater reinforcement (e.g. CONTEGA PV) at junctions e.g. wall/window interface. To help ensure integrity of the air-tight line, sockets, switches and chasing on outside walls were avoided.

Where services penetrations were required, e.g. for entry of the Rehau GAHE pipework, these were carefully detailed, as shown below left with a Uponor PWP (pressure-waterproof) wall seal, as shown below right.



Schematic Diagram of Rehau Penetration (above left) and Uponor PWP Wall Seal (above right)

To ensure the exacting air-tightness and insulation standards were transferred to physical reality, early engagement with the main contractor was essential. Acting as air-tightness champions, the Site Managers programmed comprehensive toolbox talks for all trades who worked on the project.



h r s
SERVICES
LIMITED

AIR PERMEABILITY TEST CERTIFICATE

This is to certify that an air tightness test was carried out at:

ECO VICARAGE
PENZER STREET
KINGSWINFORD
DY6 7AA

The test was carried out on 12.08.11 in accordance with ATTMA TS1.

The following air permeability was determined at 50Pa:

$0.54m^3/(h.m^2)$

Client: SPELLER METCALFE

UKAS TESTING 2587

Name	Position	Signature	Date
Sue Hodgson	Contracts Manager		19.8.2011

To be read in conjunction with relevant test report

Page 9 of 9
106190 Eco Vicarage Kingswinford
12.08.2011

HRS Services Ltd
81 Burton Road
Sheffield S3 8BZ

Tel 01142723004
altas@hrsservices.co.uk

Air-tightness Certificate (above left) and Diligent Window/Wall Junction Installation (above right)

A stringent checking procedure during construction was instigated. Areas particularly prone to air leakages such as window frames (see above), wall/ceiling junctions, and services penetrations were signed off by the Site Manager before covering up to ensure air-tightness.

As a result of this diligence, the final air-tightness result was (n_{50}) = 0.42h^{-1} shown above as (Q_{50}) = 0.54m^3/m^2 per hour @ 50Pa in UK parlance.

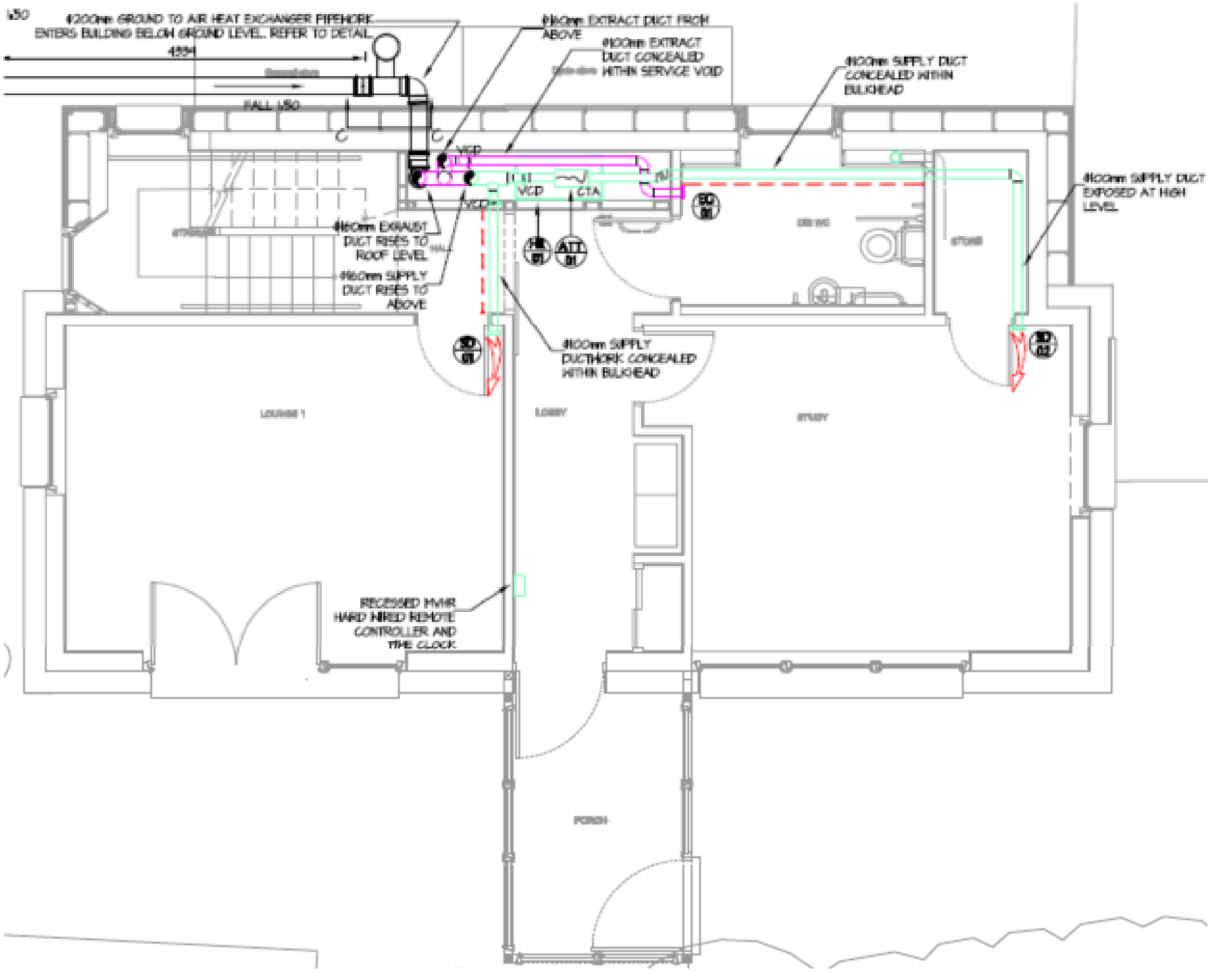
2.6 Ventilation Strategy - Layout

The ventilation strategy provided whole house ventilation via a PassivHaus Certified Mechanical Ventilation Heat Recovery (MVHR) unit. The air entering the MVHR unit was pre-heated in winter and pre-cooled in summer by a Rehau GAHE system (see later).

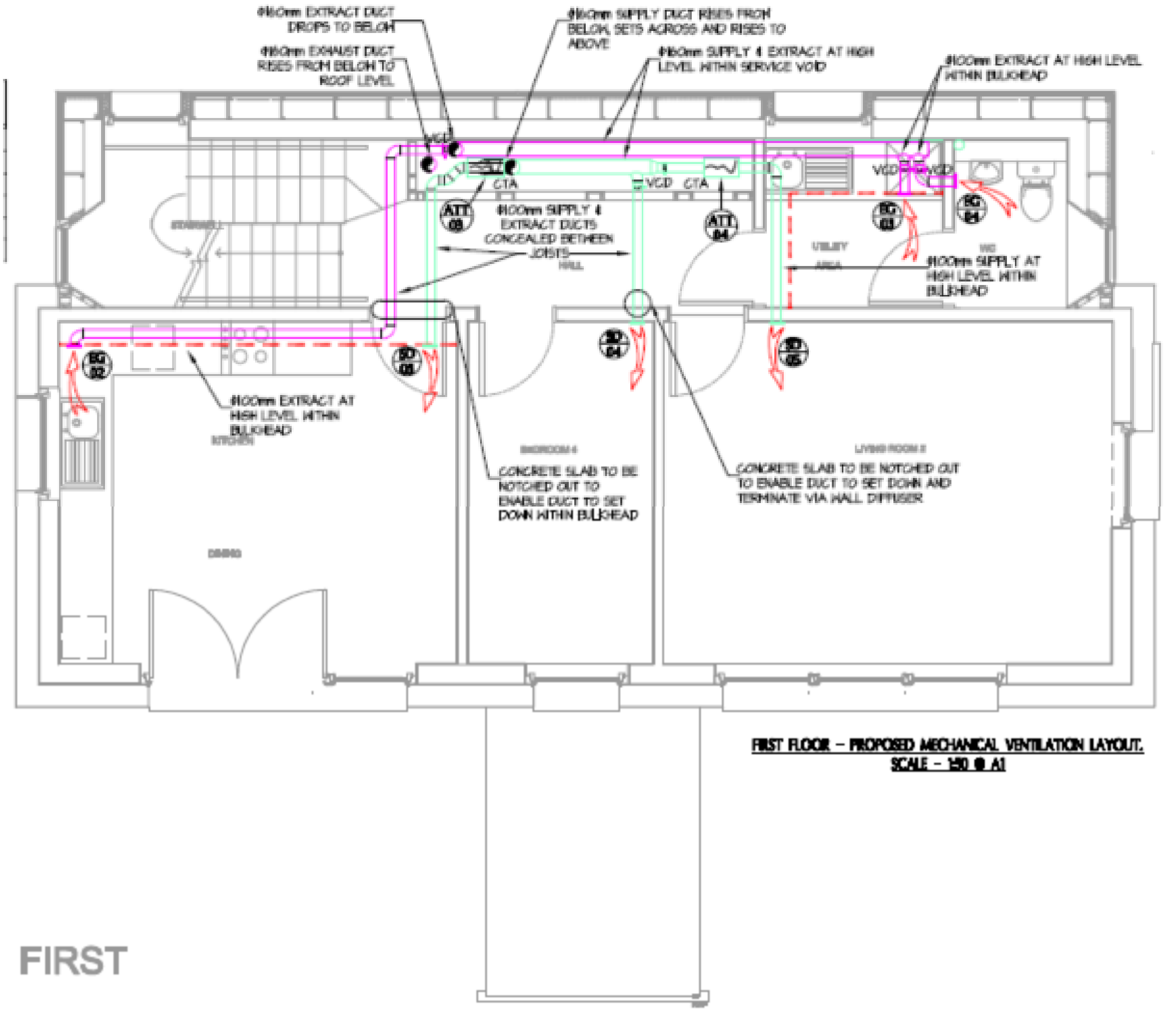
The ventilation supply and extract ductwork layout is shown in the schematic diagrams below, across the three floors. The location of the attenuators (TEK Ltd), supply and extract grill diffusers (TEK Ltd) and volume control dampers are also shown.

The plant and ductwork were contained within the northern corridor to limit the length of duct runs. The majority of the ductwork was concealed within high level bulkheads or within the service voids and riser (see below).

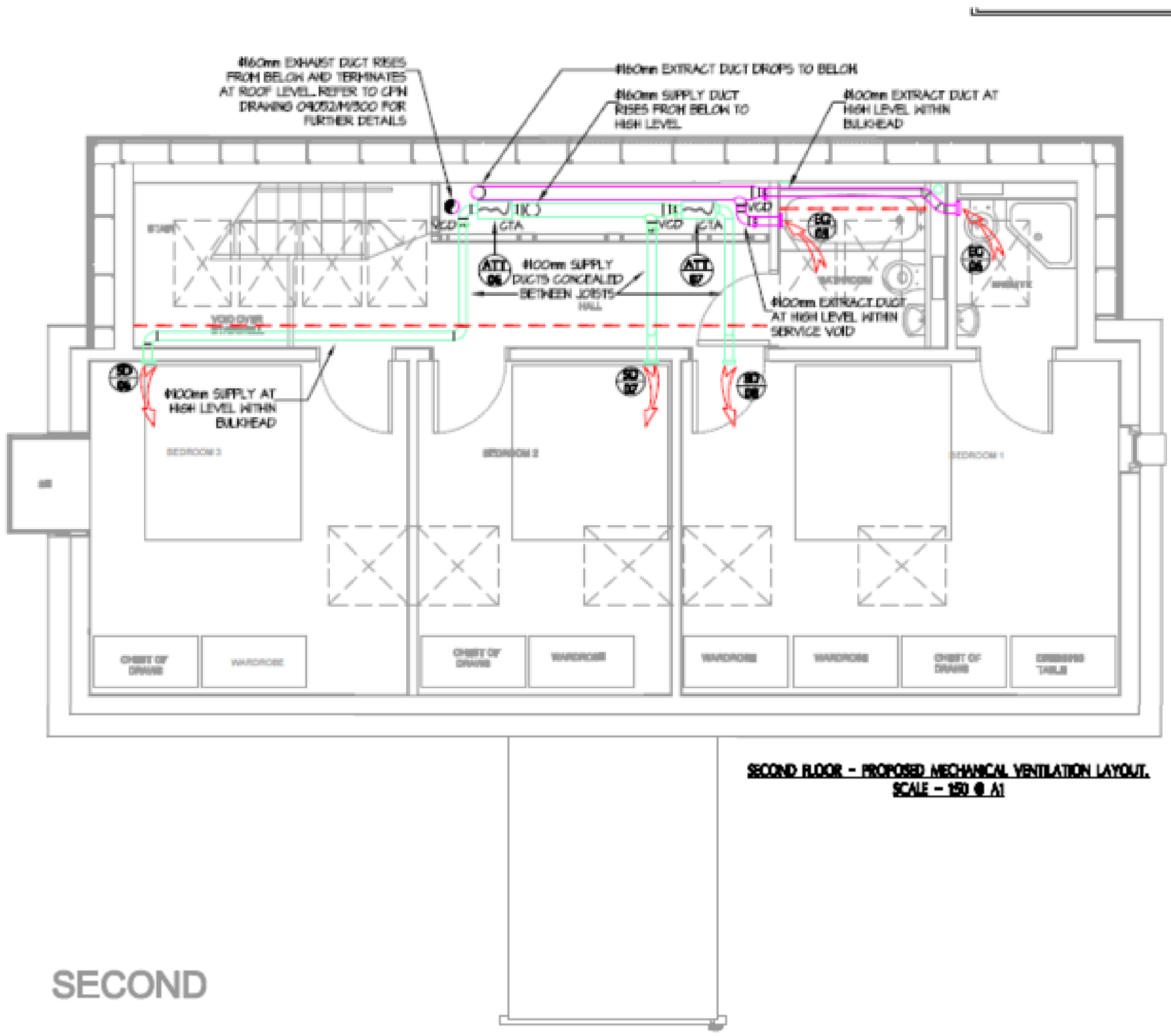
First Fix of MVHR Ductwork in Service Riser



Ground Floor Ventilation Ductwork Layout



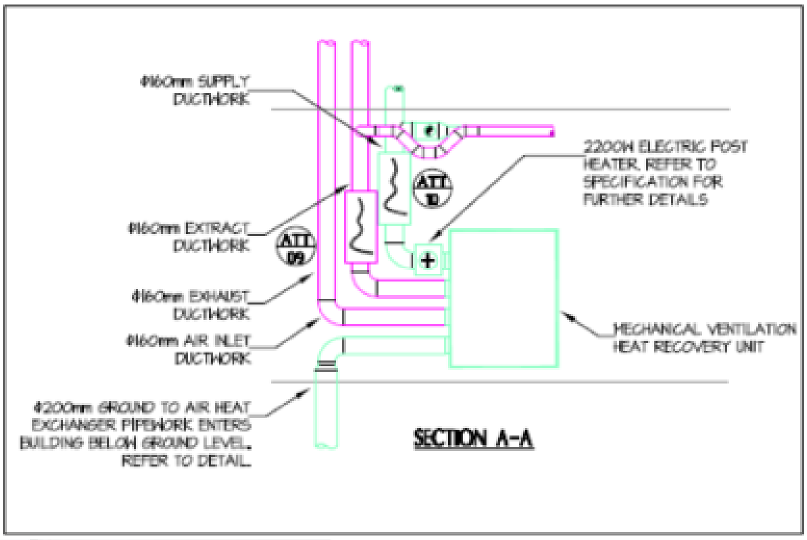
First Floor Ventilation Ductwork Layout

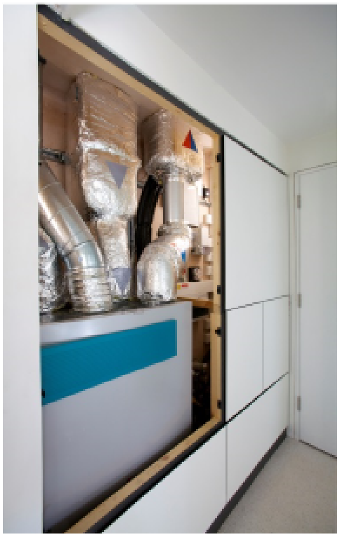


Second Floor Ventilation Ductwork Layout

2.7 Ventilation Strategy – MVHR, GAHE and Heat Supply Equipment

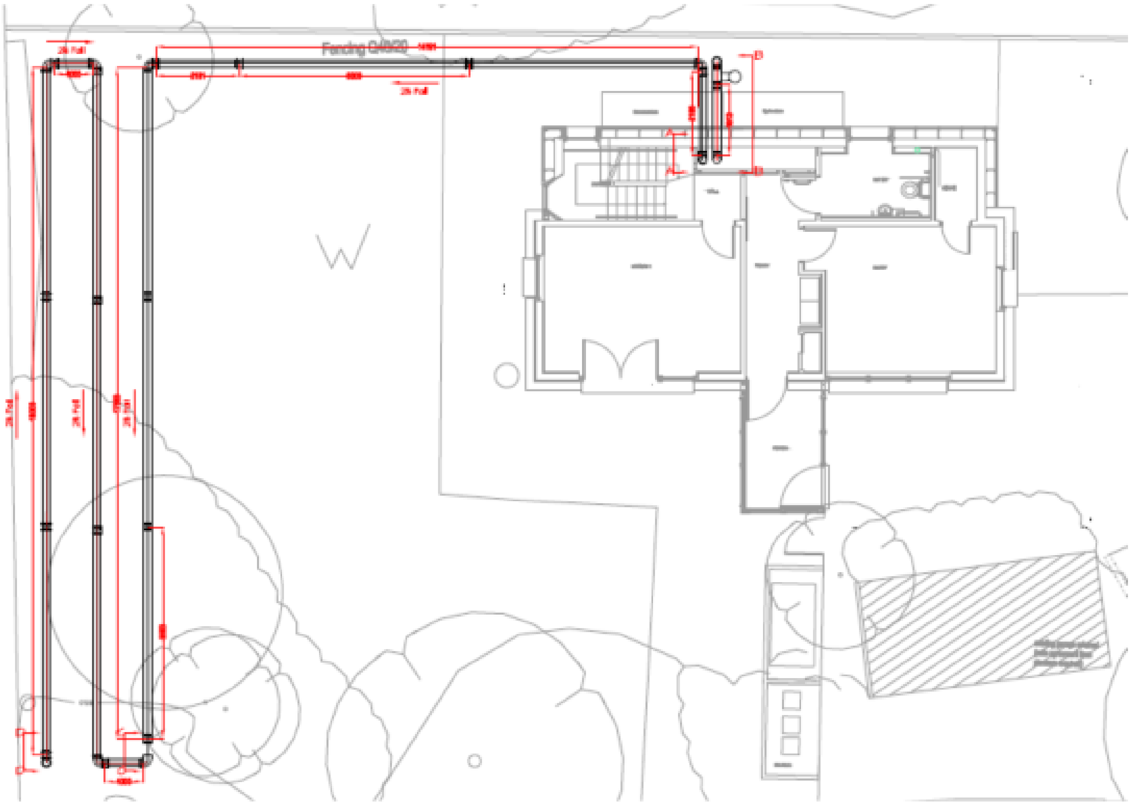
The MVHR unit was a PassivHaus Certified PAUL Novus 300 with a heat recovery efficiency of 93% and an electrical power consumption of 0.24Wh/m³. The unit is shown in schematic form (below left) and as installed in the service void, below right, within the thermal envelope.





Schematic Diagram of MVHR unit (above left) and as Installed (above right)

The air entering the MVHR unit was pre-heated in winter and pre-cooled in summer by a Rehau GAHE system. The 200mm diameter ductwork of c. 70m in length was buried at a depth of c. 2m to the west of the development as shown below.



Rehau GAHE Layout

The MVHR had a summer by-pass motorised valve fitted upstream on the intake side to provide the option of taking air from the GAHE or directly from ambient and by-pass the heat recovery element. Sensors were installed to monitor outside and MVHR inlet/extract temperature.

The system controller and integrated time clock (shown left) was located in the lobby on the ground floor.

Additional heat input was provided by a 2.1kW electric duct heater. The duct heater was enabled by a function of room temperature, duct temperature and temperature set-point, all monitored/adjusted via the MVHR control system.

MVHR System and Temperature Controller

A small electric towel rail was provided in the main bathroom and the en-suite facility on the second floor to provide occupant comfort.

3.0 PassivHaus Planning Package (PHPP) Result

The output from the PHPP software Verification Tab is shown below. It can be seen that the limiting requirements for space heating demand and primary energy demand have been achieved.

Building:	The Rectory 'Eco-vicarage'		
Location and Climate:	UK - West Midlands	7-Midlands	
Street:	17 Penzer Street		
Postcode/City:	DY6 7AA Kingswinford		
Country:	UK		
Building Type:	Residential		
Year of Construction:	2011		
Number of Dwelling Units:	1	Interior Temperature:	20.0 °C
Enclosed Volume V_e:	720.0 m^3	Internal Heat Gains:	2.1 W/m²
Number of Occupants:	4.8		

Specific Demands with Reference to the Treated Floor Area

	Applied:	Monthly method	PH Certificate:	Fulfilled?
Treated Floor Area:	168.0	m^2		
Specific Space Heating Demand:	**14**	**kWh/(m²a)**	**15 kWh/(m²a)**	**Yes**
Heating Load:	**11**	**W/m²**	**10 W/m²**	
Pressurization Test Result:	**0.4**	**h^{-1}**	0.6 h^{-1}	**Yes**
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	**110**	**kWh/(m²a)**	120 kWh/(m²a)	**Yes**
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	72	kWh/(m²a)		
Specific Primary Energy Reduction through Solar Electricity:	60	kWh/(m²a)		
Frequency of Overheating:	5	%	over 25 °C	
Specific Useful Cooling Energy Demand:		kWh/(m²a)	15 kWh/(m²a)	
Cooling Load:	6	W/m²		

Output from PHPP Software

4.0 Construction Cost

The construction cost was £1,965/m², but this included uplift to CfSH Level 6 standards i.e. true zero carbon and necessitated the installation of systems and equipment not required to meet PassivHaus accreditation including; 42m² solar photo-voltaic panels, 5m² solar thermal evacuated tubes and an underground rainwater harvesting system.

5.0 Construction Time-frame

The brief was developed during 2009 and once planning permission had been granted, construction took place across 2010 – 2011. CfSH Level 6 certification was awarded in April 2011 with PassivHaus Certification following shortly in June 2011.

6.0 Architectural Design

The architectural design was driven by the need to achieve both CfSH Level 6 and PassivHaus accreditation with an appreciation of the typical suburban style of surrounding buildings and local planning restrictions on height. The dwelling itself had to function as both a working vicarage and a private family home and this was considered at the very early stage of the design process.

Schematic Cut-away Diagram of Architectural Layout

The design organised principle rooms in a south-facing range over three floors (as shown opposite) with bathrooms and plant to the north to maintain privacy for both the new and the neighbouring old vicarage.

Foremost in the architectural strategy was to design a high-mass, thermal bridge free envelope with significant levels of thermal insulation behind a continuous air-tight line.

Large windows to the principle rooms on the south façade were arranged to maximise daylight penetration and provide useful solar gain.

The selected external brick and render were in sympathy with their surroundings and the blue-black slate roof toned with the solar panels and neighbouring buildings.

6.1 Building Services Planning

The building services planning was initially driven by the need to achieve CfSH Level 6 i.e. True Zero Carbon > 144% improvement over the DER. The strategy was to reduce the inherent energy demand of the building in the first instance, through exemplar envelope design and proficient use of services before decarbonising the electrical energy supply (no gas on site) through the use of renewable technologies.

The use of exacting PassivHaus standards described herein ensured that the space heating demand was kept to an absolute minimum. Low energy eco-fluorescent tubes and LED lighting was used throughout the development. This coupled with high levels of daylight from the large south facing windows and rooflights meant that the electrical lighting load was reduced to the lowest possible level. In addition, all electrical white goods were low energy A+++ or AAA rating.

Solar Photo-voltaic Panels and Solar Thermal Evacuated Tubes

Despite the ultra-low energy design, in total, some 42m^2 of roof mounted solar photo-voltaic panels and 5m^2 of solar thermal evacuated tubes (see above) were still needed to achieve the carbon reduction requirements of CfSH Level 6.

The limitations of the CfSH software (SAP – Standard Assessment Procedure) was such that the benefit of the GAHE system could not be reflected in the SAP calculations, leading to an artificially high quantity of solar photo-voltaic panels being needed to achieve the True Zero Carbon Standard. As the PHPP uses an energy metric, this issue does not arise with PassivHaus design.

7.0 Experience and Monitoring

The Eco-vicarage has been occupied for some 3 years by the local vicar, his wife and 2 children. Temperature and energy data have been recorded throughout this period.

The solar photo-voltaic panels and solar thermal tubes generate some £2,500 per annum through the Feed-in-Tariff (FIT) and Renewable Heat Incentive (RHI) schemes.

The total energy consumption is c. 45kWhr/m^2 per annum which compares favourably with the energy consumption predicted by the PHPP.

8.0 References

The Journal of Ecclesiastical Architect's and Surveyors Association, Spring 2012, pages 26-31.

The Architect's Journal, 31/05/12, pages 44-45.

BBC News: http://www.bbc.co.uk/news/uk-england-hereford-worcester-14069213

Numerous articles in the National Press

9.0 Awards

Winner – Greenbuild Award 2013 – Domestic New Build Category

The judges felt the Passivhaus standard, coupled with the challenging waste and water reduction targets, illustrated what can be done with a holistic green approach.