INFORMATION PAPER IP 3/09

LESSONS LEARNED FROM THE BARRATT GREEN HOUSE

Delivering a zero carbon home using innovative concrete systems

Gavin Hodgson

This Information Paper is intended for housing professionals interested in the challenge of delivering housing to zero carbon standards. The Barratt Green House, built on the BRE Innovation Park, utilises innovative concrete products to achieve this aspiration, with the key design and construction stages involving the application of concrete products in the building fabric. This publication discusses how zero CO_2 emissions were achieved through the adoption of low carbon and renewable energy technologies. Finally, the Paper also brings together key conclusions and the wider lessons learned.

INTRODUCTION

In response to the fact that 27% of the UK's CO_2 emissions are produced by housing stock, the British Homes Awards launched a competition for the Home for the Future in 2007. This gave architectural practices an opportunity to showcase their design capabilities in a home which incorporated design qualities that were attractive to prospective purchasers and had excellent environmental performance. Nine designs were shortlisted.

Streetscape of terraced 'Green Houses'

The Barratt Green House

Project team

Client	Barratt Developments plc
Architect	Gaunt Francis Architects
Structure/M&E/acoustics	Arup (Newcastle)
SAP/sustainability consultant	BRE
Code assessor	Arup (London)
Main contractor	Barratt North London

IHS bre press The Concrete Centre™ bre

Shortlisted designs for the British Homes Awards – Home for the Future 2007
From top left: Comfort Haus by Bere Architects; Blink House by Paul Archer Design; F222 by Higgs Young Architects
From centre left: HomeZED by Bill Dunster Architects; Green House by Gaunt Francis Architects; Tree House by SW Architects
From bottom left: Life House by Cartwright Pickard Architects; Home Works by FKDA Architecture; Light House by HTA Architects

The Mail on Sunday BHA British Homes Awards 07 NHBC

BARRATT DEVELOPMENTS PLC

The winning design – Green House

The shortlisted entries were voted on by readers of *The Mail on Sunday*, and the competition generated awareness of excellence in design and at the same time gauged the public's perception of what is desirable for a home for the future.

The Green House design by Gaunt Francis Architects won the 2007 Home for the Future competition, receiving more than 22,000 votes.

The house is designed as a 130 m^2 (1400 sq ft) three-storey, three-/four-bedroom family home. It incorporates novel automatic window shutters, a roof terrace and a distinctive area of green pre-weathered copper cladding. The design was the only entry that used heavyweight construction – with innovative concrete components providing thermal mass. This smoothes out the peaks and troughs of temperature within the building.

The role of Barratt

Barratt's role as the build partner allowed them to use the winning design as a realistic test bed and gauge if the innovative approaches used could form the basis for mainstream homes in the future. Barratt were particularly interested in seeing if zero carbon technologies used could be adopted affordably in other housing schemes.

DESIGN BRIEF

The designer's ambition was to prove that a range of construction technologies and products could be used to achieve an aesthetically pleasing design that also complied with the highest level of sustainability set by the Code for Sustainable Homes – Level 6.

Inspiration for the Barratt Green House was drawn from contemporary and historical housing in the UK and continental Europe, resulting in a house type suitable for high-density urban and suburban living.

The Barratt Green House on the BRE Innovation Park, between the Hanson EcoHouse™ and Stewart Milne Group's Sigma Home™

Illustration of the design incorporated into a row of terraced houses

The layout and design of the interior incorporate familiar features and spaces – living-dining-kitchen space, downstairs cloakroom, games/play room, home office, family bathroom and ensuite bathroom to the main bedroom. The rooms are serviced from a central hallway, which starts from the front door and a covered car port area and terminates at the second-floor external terrace. Although it achieves high levels of sustainability, the design does not try to convert people to a different style of living.

The architect's aspirations went beyond the key requirements of the Home for the Future brief, and considered the following aspects:

- Flexible design to allow a range of standard house types to be created. The core design can be easily adjusted between a two-bed terraced house and a four-bed detached house.
- Comfortable indoor temperatures all year round by using concrete to provide thermal mass.
- Confirmation that the whole-life costs of the project are affordable, including construction, operation and maintenance throughout its service life.
- Provision of a contemporary living space that can be adapted to meet changing lifestyle needs, including disability access.
- Integration of an intelligent infrastructure, including a computer server with CAT 5 networking (which would allow the installation of internet cameras for assisted living/telecare).
- A quality of the indoor environment (lighting, acoustics, heating and ventilation) that enhances occupancy comfort and health.

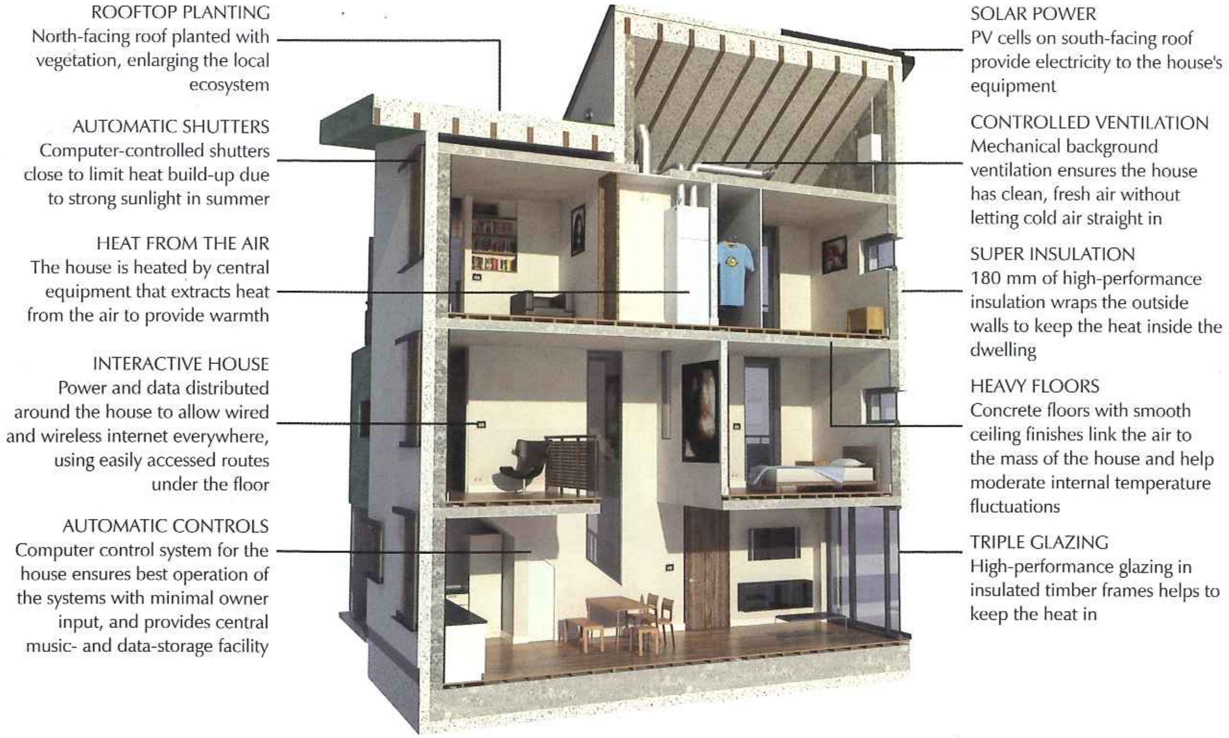
The designers also paid close attention to providing ample space for low carbon and renewable energy technologies – a large south-facing roof area for photovoltaic (PV) panels, and a loft space within the thermal envelope of the building for the building services.

The philosophy of the building design was first to reduce energy demand as much as possible by using passive measures and then to provide energy-efficient devices where passive measures alone were not deemed adequate to maintain comfortable conditions within the house.

Water-saving devices and fittings were specified to minimise water use to meet the requirements of the Code for Sustainable Homes. A large rainwater harvesting tank was included underneath the drive-port in the original design.

Site constraints mean that not all the credits are achievable. Therefore, obtaining the 90 percentage points for Level 6 requires that all possible credits are sought. The Barratt Green House has 92 percentage points. Aiming over the minimum Code requirements gives some buffer against credit slippage occurring during construction or post-construction review.

Architect's visualisation of a 'Green House' street



Visualisation of a prototype Barratt Green House

FABRIC

Great care was taken with the design, specification and construction of the building fabric in order to meet the demanding heat loss parameter (HLP) of 0.8 W/m²K (Ene. 2 credit) for Level 6 of the Code.

The design team found this difficult to achieve and early designs after the competition were above the 0.8 W/m²K limit. A variety of options were considered, including replacing the glazing leading onto the external roof terrace with a Kalwall walling system (a semi-translucent wall that has very low thermal conductivity).

A HLP value of 0.72 W/m²K was finally achieved by improving the design specification and reviewing the 1:20 scale construction details to reduce thermal bridging. This was achieved in one area by extending the external cross-lapped phenolic insulation and render across the insulated timber window sub-frames.

The Home for the Future competition required a car port to be included within the design. This made it difficult to achieve the HLP requirement. The design team would have preferred to provide an external parking area as this would have allowed a more compact build form with less exposed elements, potentially allowing the thermal insulation requirements to be relaxed.

Floors

The Barratt Green House is built on a raft foundation on top of EPS insulation; this allows a continuous external layer of insulation to be created. The original intention was that foundations would incorporate recycled aggregate to reduce embodied energy, but this proved difficult to source.

Hollow-core concrete floor slabs were used for the intermediate floors to provide high thermal mass. This smoothes out the peaks and troughs of temperature change within the building.

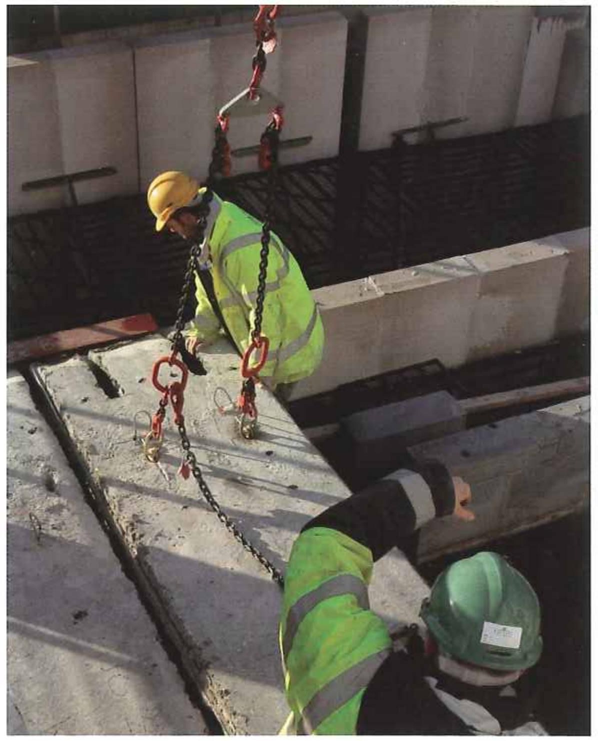
The exposed soffit over the car port posed a particular challenge with regard to the thickness of insulation that could be installed. A combination of 25 mm of Kingspan K10 soffit board (thermal conductivity 0.023 W/mK) and two 30 mm layers of va-Q-tecB vacuum insulated panels (VIP) (thermal conductivity 0.008 W/mK) were used.

Table 1: **Design specification summary**

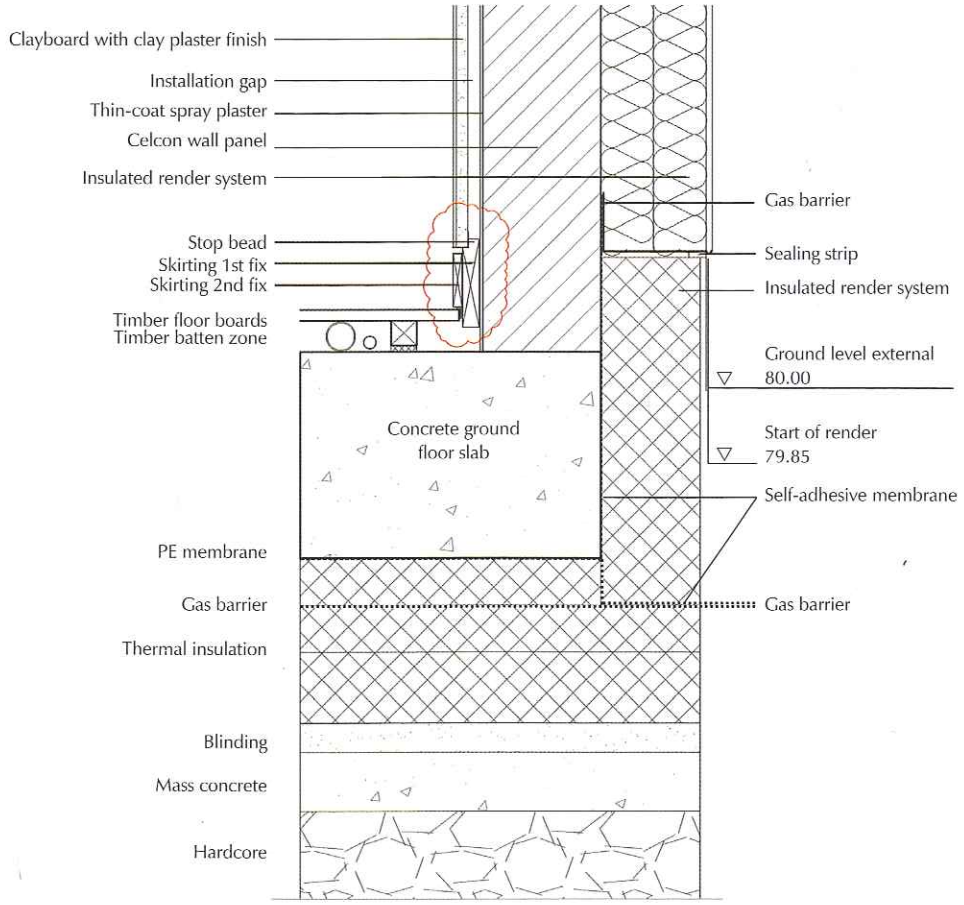
	Initial specification	Final specification
U-values (W/m²K)		
Roof	0.15	0.09
Walls	0.12	0.11
Ground floor	0.12	0.09
Exposed floor to car port	0.15	0.11
Glazing	0.80	0.70
Doors	1.00	0.68
Thermal bridging (psi-value)	0.08 (Accredited construction details)	0.04 (Energy Saving Trust enhanced construction details)
Ventilation	Standard MVHR* unit	91% efficiency SAP appendix Q MVHR* unit
Airtightness	1.0 m³/(hr.m²)@50 Pa	1.0 m³/(hr.m²)@50 Pa
HLP	1.03	0.72

* Mechanical ventilation heat recovery

Laying ground floor insulation



Hollow-core concrete floor slab being positioned for the intermediate floor

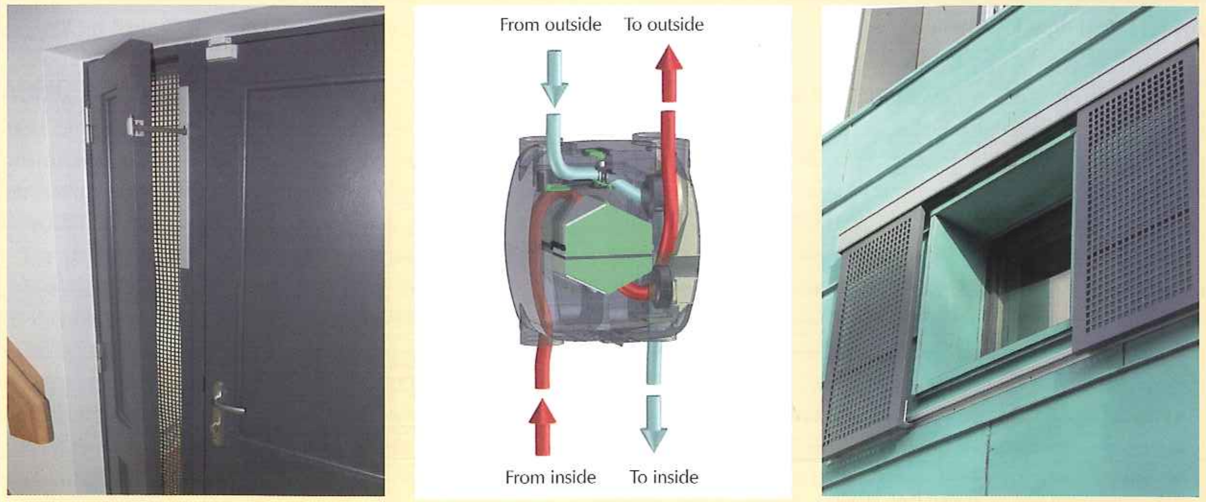


Construction detail of the ground floor-to-wall junctions. The concrete slab is formed on top of the insulation so a continuous external layer of insulation is achieved and thermal bridges avoided. Internally, the dry-lining has been installed on 50 mm timber battens to create a service void.

Box 1: Avoiding overheating

Realising that the inclusion of mechanical cooling would increase the CO$_2$ emissions, the design team worked with Arup to develop a combination of strategies which helped reduce the design peak temperatures in summer by 4–6°C.

- **Thermal mass**
  The internal walls are battened out with clayboard to form a service void. As a result, the thermal mass of the walls is not exposed. (The incorporation of the service void helps prevent accidental damage to the inner leaf of the building, which forms the airtight barrier.) Calculations indicated that the area of exposed thermal mass needed to provide comfortable temperatures turned out to be the same as the floor area. Hollow-core concrete slabs in the intermediate floors provided the required thermal mass. The concrete ceiling was permanently exposed to the indoor environment and unlikely to be covered by wall fixtures and fittings (such as kitchen cupboards).
- **Dual ventilation strategy**
  When the second floor windows are opened, the insulated shutter next to the front door opens automatically to provide stack ventilation to the hallway. Because the shutter is adjacent to the shaded car port it draws in cooler air. The occupants can also open windows in other rooms to help with cross ventilation. In addition, the mechanical ventilation heat recovery (MVHR) unit incorporates a 'summer bypass', so that when the user selects a cooler temperature the MVHR unit bypasses the fresh incoming air away from the heat exchanger to provide unheated fresh air. As a result of this ventilation strategy, the heat stored in the thermal mass can be removed during the night.
- **External shading**
  The automatic shutters (by Häfele/Hawa) play a crucial part in the technical design. They are linked to a central computerised building management system that automatically opens and closes the individual shutters. This allows the solar gain to be carefully managed, reducing fuel consumption for heating and minimising solar overheating during the summer. Occupants can also manually over-ride the automatic function of each shutter.



Left: The insulated shutter next to the main entrance door can be opened to allow secure ventilation
Centre: The summer bypass ensures that adequate ventilation is achieved without recovering heat
Right: Automated external shutters

Walls

The walls of the Barratt Green House are constructed from innovative storey-height H+H Celcon Vertical Element 200 aircrete lightweight concrete panels 600 mm wide, 200 mm thick and up to 3000 mm high. They were quickly erected on site by crane, and because they have flat edges they are joined using a thin layer of mortar (Celfix). The joint area is much smaller than in a conventional block wall so there are fewer paths for air leakage. More complex details and junctions in the external walls were constructed using conventional aircrete blocks. The aircrete panels have a thermal conductivity of 0.11 W/mK, which assists in achieving the required U-value.

A thin-coat, spray-applied polymer plaster (Alltek UK) just a couple of millimetres thick was also applied internally to seal the joints.

The walls are externally insulated with 180 mm of high-performance phenolic insulation (weber.therm XM), which is cross-lapped to reduce thermal bridging and held in place using mechanical fixings. A woven glass reinforcing mesh was applied and rendered with mortar before an acrylic-based textured finish was applied.

Some areas of the house such as the balcony and roof terrace areas have been finished with clayboard (Trespa) as a design feature.

Internally, the walls are dry-lined to allow services including MVHR ducting to run in the void between the wall and the plasterboard.

Non-load-bearing partition walls are 75 mm timber studs infilled with sheep's wool – the use of non-load-bearing partitions facilitates adaptability in the future and the sheep's wool also helps in achieving good credits in the Materials (Mat 1) category of the Code.

Aircrete panels being positioned

Box 2: Why build an airtight home?

Achieving a HLP value of 0.8 W/mK is very difficult in a large detached house such as the Barratt Green House.

The HLP value is calculated in SAP[1] and takes into account the thermal performance of the building fabric, the amount of thermal bridging and the amount of heat lost due to ventilation.

The construction method has a significant impact on airtightness[2] and hence heat loss and achieving the HLP. In the Barratt Green House, spray plaster was applied to the inner surfaces of the walls to ensure a continuous airtight seal. Careful consideration was also given to the incorporation of the vertical ductwork and sealing around windows.

Throughout the build, regular visits by the airtightness tester helped to ensure that the targets were achieved.

This strategy resulted in a final airtightness value of 0.97 $m^3/(h.m^2)$@50Pa. This is 10 times better than current Building Regulation requirements.

Polyurethane foam was used to create an airtight seal around the windows and doors

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[1] SAP is the government's 'Standard Assessment Procedure' for the energy rating of dwellings. See www.bre.co.uk/SAP2005

[2] For further information on airtightness and the testing procedure, see the Energy Saving Trust guide 'Improving airtightness in dwellings' (CE137), www.energysavingtrust.org.uk/housing

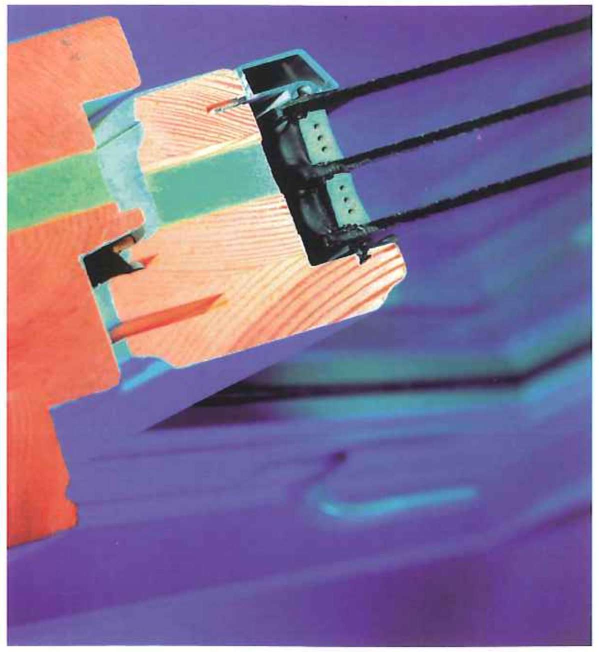
Weber external wall insulation

Roof

The roof is a 'butterfly' design (two pitches falling to a central gutter) trimmed with copper. The south-facing aspect is covered with PV cells and the north with vegetation (sedum).

The choice of a pre-fabricated timber Structural Insulated Panel roof (by Smartroof) enabled the whole roof to be erected in less than three hours and all of the roof space to be habitable. The roof was pre-insulated to achieve a U-value of 0.09 W/m^2K. The use of this roofing system helped to maximise the number of credits awarded in the Materials category of the Code.

North-facing roof that has been covered in sedum



NTech PassivHaus window

Insulated ductwork to the MVHR unit (by Vortice). The 'post-heater' (small radiator) is located in the metal box and fed by the thermal store (not shown).

Windows and doors

By using high-performance PassivHaus windows with triple glazing and thermally-broken wooden frames (achieving U-values of 0.7 W/m^2K for both the window and frame areas), the house could be built with a good proportion of glazing (25% of floor area).

The external doors are also insulated and achieve a U-value of 0.68 W/m^2K at the centre of the door.

Once the HLP value was achieved, the design team discussed how to achieve zero CO$_2$ emissions by specifying low carbon and renewable technologies. These items are covered in the next sections.

Materials (Mat 1)

For materials, an overall score of 15 out of 24 points available in the Code was achieved. A higher score could not be achieved as recycled concrete was not available, due to a national shortage of recycled aggregate, which resulted in a poor rating for the pre-cast concrete floors. To overcome this, materials with very low environmental impact were specified elsewhere. Also in some instances, due to poor availability from UK sources, products were sourced from overseas. For example, the high-performance triple-glazed windows were imported from Norway.

CO$_2$ EMISSIONS AND ENERGY USE

To achieve zero carbon, it is important that energy demand is reduced, with efficient building services then being specified to minimise CO$_2$ emissions. This approach was adopted in the Barratt Green House, which reduced the amount of renewable energy technologies incorporated.

The original design incorporated underfloor heating, but due to the very low heating demand this was virtually unnecessary as the heating requirement had been practically eliminated. An additional heating system was therefore seen by the design team as an unnecessary expense so they examined the possibility of using the MVHR unit as the heating distribution system.

The principle of this is based on the PassivHaus approach[3], whereby the fresh incoming air is pre-heated in the heat exchanger in the MVHR unit by the warm air extracted from the bathrooms and kitchen. Top-up heat is provided by a small 'post-heater' located in the fresh air ducting (see diagram on page 10).

The incorporation of a best-of-class SAP Appendix Q MVHR system[4] in an airtight house helps to reduce CO$_2$ emissions, because it has a low electricity requirement and can recover up to 90% of the heat from the stale exhaust air.

Ventilation

The MVHR unit also provides the required ventilation which would not be satisfied by a natural ventilation system due to the high levels of airtightness specified. However, the strategy does not completely neglect the need for passive ventilation and incorporates a dual ventilation strategy for warmer periods (see Box 1 on page 6).

Heating

The small 'post-heater' could be a small electric resistance heater (1–1.5 kW) to provide the top-up heating, but to facilitate compliance with the Code for Sustainable Homes (and further reduce CO$_2$ emissions) an air-to-water heat pump was used.

This pump feeds into a large thermal store, which also receives heat input from two solar hot water panels. When the panels are not contributing heat in winter, the air-to-water heat pump is the primary source of heating. A small wet heating circuit to a radiator located within the fresh air inlet forms the basis of the 'post-heater'.

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[3] *An introduction to PassivHaus: a guide for UK application*. BRE Information Paper IP 12/08.

[4] SAP Appendix Q allows the energy performance of new technologies and advanced versions of existing technologies to be evaluated for inclusion in SAP assessments. See www.sap-appendixq.org.uk

The warmed fresh air is supplied to every habitable room (living room, dining room, bedrooms, study) using insulated ductwork. Insulated ductwork is used so that the rooms furthest from the heating source can still receive the required amount of heat. As is common in PassivHaus designs, the heating is supplemented by a warm towel rail in each bathroom where slightly higher temperatures are desirable. There is also a radiator underneath the stairs in the hallway to provide boost heating to the lobby when required.

The heat pump unit allows heating periods to be controlled like a conventional boiler using a conventional programmer.

The heat pump also provides hot water when the two external solar hot water collectors are not generating enough heat (an electric immersion heater is also present as an emergency back-up).

Box 3: Other alternatives

The design team believe that a community heating system has the potential to work well for larger schemes. However, there were concerns that, while the zero carbon targets may be readily achieved, difficulties might have been encountered in finding a suitable energy services company that could cost-effectively implement and operate a viable scheme while still providing good value to the house owners.

For individual properties, the strategy adopted for the Barratt Green House seems to be a viable approach. However, the separate units (MVHR, heat pump and thermal store) take up valuable space and add to the construction cost. The same functionality can be achieved by the specification of a 'compact services unit', but it was not possible to source one for this project. Companies such as Drexel and Weiss can now provide this in the UK.

A compact services unit incorporates a hot water cylinder, MVHR and a small heat pump. While only suitable for use in very low energy buildings, this can provide all of the heating, hot water and ventilation requirements.

Daikin air-to-water heat pump achieves a Coefficient of Performance (COP) of 2.5 when modelled in SAP

RENEWABLE ENERGY TECHNOLOGY

For a home to achieve the zero carbon standard within the Code and qualify for stamp duty land tax relief, it is necessary to offset the electrical energy use of the house (inclusive of appliances and cooking) against a renewable resource. To achieve this, the Barratt Green House incorporates two PV arrays – one roof-mounted and one private-wire PV array. Two separate arrays are needed because the SAP calculations showed that 7.2 kWp of PV would be required to achieve zero carbon. Because this is such a large PV array, only 4.1 kWp could be incorporated onto the southern façade of the butterfly roof.

The SAP calculations also formed part of the feasibility study to allow credits to be achieved for the provision of renewable energy (Ene. 7)[5].

The PV array is connected to an electricity meter, which allows a home owner to be paid within their utility bill for each kWh of electricity generated. There is no form of local electricity storage (eg batteries/fuel cell) in the Barratt Green House and the mains connection is used as the 'store'. So when the electricity being generated cannot be used locally, it is fed back into the mains grid and credited appropriately. During the night, electricity is sourced from the national grid. The combination of the low energy demand of the house, the solar hot water units and the two PV arrays means that the house is designed to achieve net zero carbon over the course of the year.

Simulations based on local conditions at the BRE Innovation Park indicate that the combined PV system will generate 6003 kWh/year. However, it is expected that actual output may exceed this by up to 900 kWh/year depending upon the yearly solar contribution.

Without the inclusion of the solar hot water panels, there would still be a significant proportion of electricity

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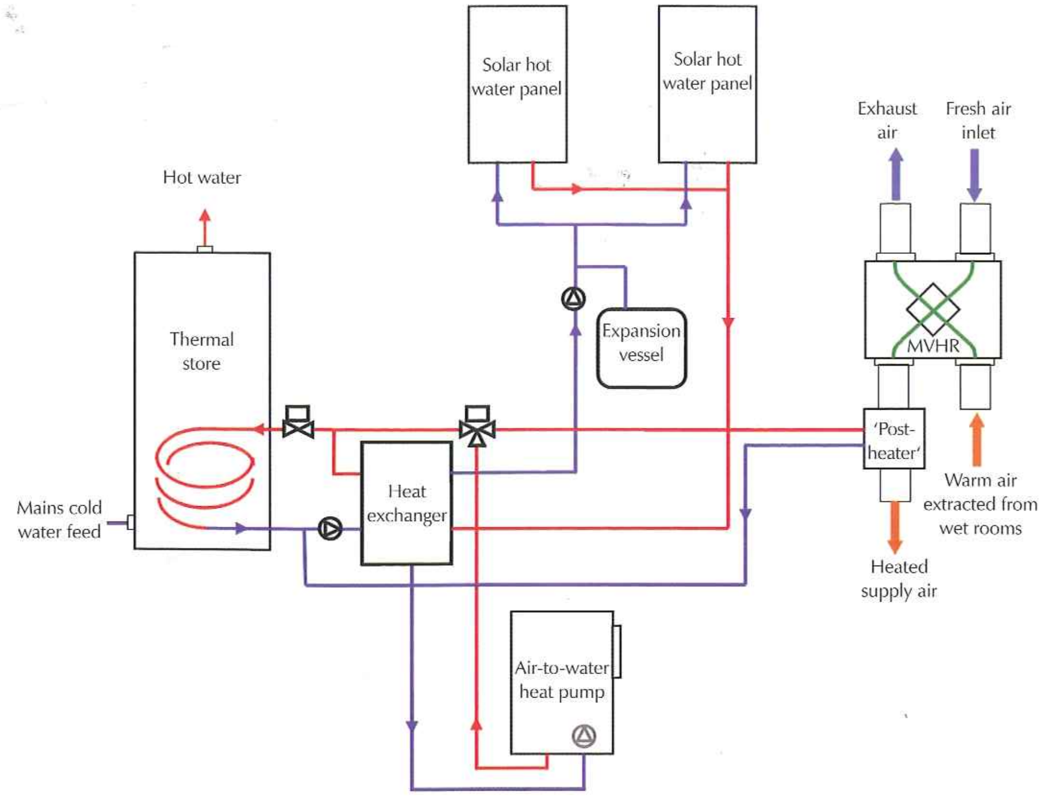
[5] See the Code Technical Guidance at www.communities.gov.uk/thecode



Schematic of services in the Barratt Green House

used by the air-to-water heat pump to generate hot water. If the solar hot water had not been provided, the size of the PV array would have had to be increased. The two solar hot water panels can provide the bulk of the hot water in the summer and avoid the need to run the air-to-water heat pump.

The two solar hot water panels are located on the south-facing wall above the roof terrace and become over-shadowed at some times of the day, which reduces their potential output. It would have been optimal for the solar hot water panels to have been installed at an angle of approximately 30° facing south to maximise the amount of solar gain. However, limited roof space (due to the incorporation of PV) meant that this could not be achieved. Changing the design to a large south-facing mono-pitch roof would have facilitated this and could have removed the need for the private-wire PV array located away from the building.

SWEPCO PV installation on purpose-built mounting frame and SIPS panel roof

Two solar hot water panels are incorporated in the design

LESSONS LEARNED

Superstructure

The basic H+H Celcon aerated concrete panel wall construction was simple to erect and provides improved air permeability values and reduced build times. The high-performance external wall insulation also reduced the wall thickness and helped to reduce thermal bridging. The amount of external wall insulation can also be easily adjusted to meet the required standard.

Consider mixing construction technologies

Incorporating a pre-fabricated roof reduced construction programme times and provided another offsite fabrication element to this system build. It was craned into place as a complete item.

Concrete floors allow flexibility for relocation of partitions; in this case, timber studwork partition walls in-filled with sheep's wool were chosen. Enough thermal mass is provided by the exposed hollow-core intermediate floors.

Airtightness

The early design decision to include a service void in the walls behind the dry-lining meant that the concrete structure was not breached. The inner leaf of the aerated concrete panels was sprayed with a thin layer of plaster to ensure that no air leakage occurred between the panels. At other junctions (eg at the wall-to-roof junction), spray foam was used to ensure an airtight seal, and window sealing tapes were also used. Grouping the service penetrations together also limited the risk of air leakage.

This strategy proved very successful, with no major problems and reduced supervision required on site. An exceptionally good pressure test result of just under 1.0 $m^3/(h.m^2)$@50Pa was achieved.

Heating, hot water and ventilation

The house uses separate units to provide space heating, hot water and ventilation. This adds to the expense of the build and uses extra space. Smaller house types would benefit from a compact services unit in a central location to provide supplementary heating when required, hot water and ventilation. Currently, there is a shortage of manufacturers capable of supplying such units.

Insulation materials

Improving the performance of insulation materials could reduce the thickness of the exposed areas of the building fabric and hence the footprint area. Manufacturers need to invest in this. One particular success in the Barratt Green House was the use of VIP as insulation in the soffits of the car port. VIP insulation is ideally suited to applications within soffits and floors as it can reduce the thickness of the element, and is at little or no risk of being punctured in these locations.

Using a variety of insulation materials according to their location, performance, cost and Green Guide rating can also help to achieve Code compliance.

Comfort in winter and summer

Extremely high levels of insulation, triple glazing and excellent airtightness have resulted in an indoor environment where all surfaces are warm and no draughts can be felt (ie localised discomfort has been eradicated). However, summer overheating can be a problem if not considered. To counter this, the automated external shutters ensure that solar gains in summer are not excessive, and the thermal mass is an effective means of keeping the indoor temperature within a comfortable range without resorting to mechanical cooling. The use of the stairwell to provide secure summertime purge ventilation also assists with this and with clothes drying. This combination of strategies has proved very successful.

Sourcing of products

While most products required to achieve Level 6 of the Code for Sustainable Homes are available, windows with low U-values (such as PassivHaus windows) often need to be imported – they can also be one of the larger extra costs incurred for a Level 6 building. UK manufacturers are starting to respond, but it may be some time before these windows become readily available and the premium charged for PassivHaus windows is reduced.

Procurement of sustainable building products

To meet the requirements of the material section of the Code, responsible sourcing should be a prerequisite of procurement and suppliers must be accredited if drawn-out investigation exercises are to be avoided. Many suppliers are beginning to provide this information.

Developer aspirations

When designing and delivering a development to meet the Code for Sustainable Homes, set realistic targets and go for 2–3 points more than needed, as a contingency.

Heat loss parameter (HLP)

A HLP of 0.8 W/m^2K is mandatory for a Code Level 6 dwelling. The use of SAP and early design decisions are essential.

Talk to your supply chain

They may have new products to consider that can facilitate compliance with the Code. Talk to the technical and sales people to get different opinions.

Consider employing a clerk of works

A clerk of works (if appropriate to the form of procurement) is permanently on site, so that if they are briefed before construction starts they can highlight the areas in the construction that need to be considered by contractors. This helps to ensure that the design strategy is understood and airtightness and thermal bridging requirements have been achieved.

Material substitutions

Beware of agreeing to changes in specification throughout the contract. Substitute materials and finishes may not allow the same credits as indicated in preliminary design assessments.

Materials and components used in the Barratt Green House

Floors

Pre-cast concrete hollow-core intermediate floors with high GGBS content. www.milbank-floors.co.uk

Walls

Concrete wall panels: H+H Celcon Vertical Element 200. www.hhcelcon.co.uk

External insulation: 180 mm cross-lapped weber.therm XM (phenolic) insulation with Ejot Ejotherm insulating fixings. www.netweber.co.uk

Render: weber.plast TF150 2000-N. www.netweber.co.uk

Rainscreen cladding panels: Trespa. www.trespa.com/uk

Copper cladding: KME Tecu patina. www.tecu.com

Kingspan Kooltherm K15 used behind rainscreen cladding (both copper and Trespa). www.insulation.kingspan.com

Roofs and exposed floor to car port

SIP roof panel: www.smartroof.co.uk

Green roof: XF301 sedum blanket. www.bauder.co.uk

Insulation in exposed floor: Kingspan K10. www.insulation.kingspan.com

Vacuum insulated panels: va-Q-tecB. www.passivehouse.co.uk

Windows and doors

External windows and glazed doors: NorDan NTech triple-glazed windows (U-value 0.7 W/m^2K). www.nordan.co.uk

Window actuators: CDC 200 chain drive. www.dyerenvironmental.co.uk

Main entrance door and door to roof terrace: Russell Door tech. www.russelltimbertech.co.uk

Automated sliding shutters and controls: www.Hafele.com and www.hawa.ch

Airtightness solutions

Airtightness foam: Hilti CF812. www.hilti.co.uk

Spray plaster: www.alltekuk.com

Window sealing: Tremco illlbruck window foil, elastic foam and compraband. www.tremco-illbruck.co.uk

Heating, hot water and ventilation

Air-to-water heat pump: Altherm system by Daikin. www.daikin.co.uk

MVHR: Vortice HRU ECO 3 RF unit. www.vortice.ltd.co.uk

Renewables

Photovoltaic panels: www.swepco.co.uk

Solar hot water panels: Kingspan evacuated tube panels (CLS 1808). www.kingspan-renewables.com

Living space in the Barratt Green House

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