Dwelling

Low Carbon Research Institute: Low Carbon Built Environment

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Preface

This report is published by Design Research Unit Wales and is the first output of the Low Carbon Research Institute's (LCRI) Low Carbon Built Environment programme work package, 'Design of Low/Zero Carbon Buildings' and is produced to coincide with the conference 'Low Carbon Homes: Lessons from Practice' at the Welsh School of Architecture on 14th October 2011.

The objective of the project is to provide design teams involved in the delivery of low/zero carbon buildings with clear but non-prescriptive design guidance based on current best practice.

The work package aims to examine buildings within the sectors of Housing, Education and Healthcare and this document looks at case studies within the affordable housing sector, analysing procurement and construction techniques and the cost impact of meeting the demands of changing legislation.

Edition 1: October 2011

Contents:

Dwelling

Climate Change: The Need for Action

"Climate change represents a potentially catastrophic threat, but it is within our control to address it – and address it we must"[1]

'The Stern Review: the Economics of Climate Change' demonstrated that there is overwhelming clear evidence of climate change and recommended strong and deliberate policy action in order to motivate carbon emission reduction. The UK emitted 550 million tonnes of CO2 in 2005; energy use in buildings accounted for almost half this total and more than a quarter came from energy used to heat, light and run our homes. Since 2006 the UK has been a net importer of oil and is dependant on imported gas during a period of rising prices and increasing global demand. The UK has agreed to EU targets of a reduction of over 750 million tonnes of CO2 by 2030.[2]

'The Climate Change Act' (2008) set an overall target for net UK carbon account for the year 2050 at a minimum of 80% lower than the 1990 baseline. The Act made the UK the first country in the world to have a legally binding long-term framework to cut carbon emissions and created a framework for building the UK's ability to adapt to climate change. The 'UK Low Carbon Transition Plan' (2009) sets out the government's proposed route to meet the targets. 'Carbon budgets' measure performance and keep the UK on track to meet its goals by setting a binding legal limit on UK greenhouse gas emissions over consecutive five year periods. The first three budgets were announced in December 2008.

The 'UK Low Carbon Transition Plan' includes the aim of 40% of electricity to be generated from low carbon sources by 2020. 30% of electricity must be generated from renewables, a more stringent target than the EU's legally binding target of 15% by the same date. The 'Renewable Energy Strategy' (2009) outlines the government's strategy to achieve this by increasing take up of renewable electricity. The strategy outlines a lead scenario where 30% of electricity, 12% of heat and 10% of transport energy is generated from renewable sources.

Timeline to zero carbon housing

UK Government		Welsh Government
CLG: Building A Greener Future All new housing to be zero carbon by 2016	2007	
English Partnerships Quality Standards All funded housing must achieve Code level 3		
Climate Change Act 80% reduction in CO_2 emissions by 2050. Carbon Budgets introduced; 35% reduction in emissions from housing by 2022	2008	**WAG zero carbon aspiration** WAG announces aspiration for zero carbon homes by 2011
		Code for Sustainable Homes adopted in Wales, all government funded housing to achieve a minimum Code 3
Energy Performance Certificates (EPC's) Modelling of the energy efficiency and carbon emissions from a dwelling, rated A-F	2009	**Planning Policy Wales** 5+ dwellings required to meet CSH Code 3 plus six energy credits (31% improvement over BR2006).
CLG: Definition of zero carbon consultation Zero carbon defined as regulated and unregulated energy (CSH6)		
Building regulations Part L 2010 25% reduction in energy use over BR2006 (CSH3)	2010	**Planning Policy Wales** 1+ dwellings required to meet CSH Code 3 plus six energy credits (31% improvement over BR2006).
The Carbon Plan Coalition policy to achieve Climate Change act targets, introduces the Green Deal and RHI.	2011	
Budget 2011: A revised definition of zero carbon Definition amended to include regulated energy only		**Building Regulations** Devolution of the Building Regulation to Wales
Renewable Heat Incentive (RHI) On site renewable heat generation incentivised	2012	**One Wales Commitment** 3% reduction in greenhouse gasses year-on-year in areas of devolved responsibility
English Building Regulations Part L 2013 44% reduction in energy use over BR2006 expected (CSH4)	2013	**Welsh Building Regulations Part L 2013** First Welsh Building Regulations amendments expected, with a suggested 55% reduction in energy use over BR2006
	2014	**Welsh Building Regulations** A review of Welsh Building Regulations expected
	2015	
English Building Regulations Part L 2016 All new housing expected to be 'zero carbon'. Fabric Energy Efficiency Standard, Carbon Compliance and Allowable Solutions expected to be introduced.	2016	**Welsh Building Regulations Part L 2016** Amended Building regulations to reflect zero carbon expected.

Low Carbon Homes

Housing accounts for 27% of the UK's carbon emissions; these emissions come from energy used for heating, hot water, lighting and appliances.[3] Although new housing accounts for less than 1% of the housing stock every year, by 2050 almost a third of housing stock will have been replaced, making the sector a key target for reducing carbon emissions. As the Barker Review of housing supply suggested new housing provision needs to be increased to meet growing demand and tackle affordability.[4] By setting exacting emissions targets for these new homes and retrofitting existing homes, the government hopes to significantly reduce the energy use in domestic buildings and to create a growing market for sustainable technology.

'Building a Greener Future' outlines the government's policy to achieve the 60% reduction in carbon emissions from housing by 2050 required by the Climate Change Bill. The government has committed to achieving zero carbon standards for all new homes by 2016. Three tools will be used to achieve this goal: National planning policy, which regulates the location and design of development; the Building Regulations Part L covering conservation of fuel and power; and the Code for Sustainable Homes, a measure of sustainability in new build housing. The aim is to use these policies to develop a clear framework in which zero carbon housing can be procured and delivered.

What does 'Zero Carbon' for New Homes mean?

In the 2011 Budget document 'The Plan for Growth' the government amended the definition of zero carbon homes to include only regulated emissions, i.e.: only those emissions covered under the building regulations. This revised definition covers emissions from heating, fixed lighting, hot water and building services. It does not include emissions related to energy use from cooking or plug in electrical appliances such as computers. This will result in a mitigation of around 2/3 of emissions from the typical house. On one hand this change makes the zero carbon goal achievable for a lower cost, but it *"dilutes previously the world-leading low carbon homes policy"*[5] and creates a situation where "*a zero carbon home will no longer do what it says on the tin.*"[6]

The government is suggesting a three tiered approach to achieving 'zero carbon':

- Ensuring an energy efficient fabric-first approach to design of housing
- Reducing CO2 emissions on site through low and zero carbon technologies
- Mitigating remaining carbon emissions through allowable solutions

Fabric Energy Efficiency Standard (FEES)

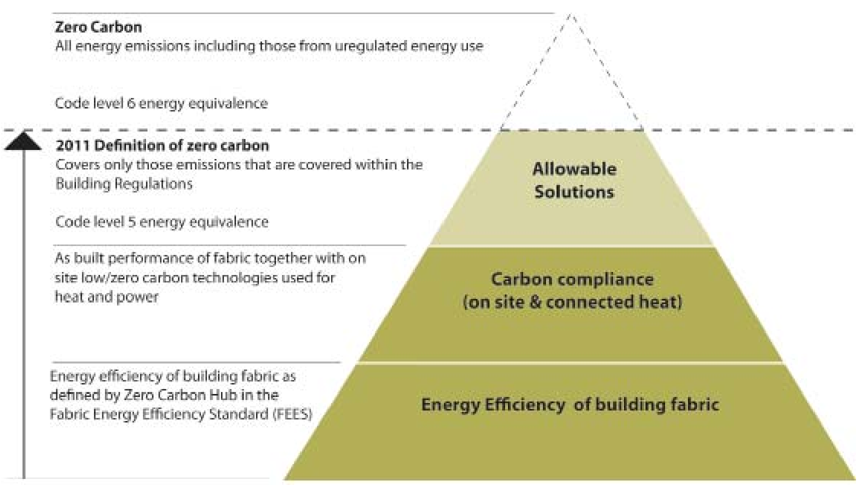
The FEES as defined by the Zero Carbon Hub will set a minimum energy efficiency level for the building fabric. This will be measured at design stage and is a measure of energy demand only, not supply. The FEES will be measured in kwh/m2/yr. This metric has been chosen as it is independent from energy supply. The proposed targets are 30kwh/m2/yr for apartments, 39kwh/m2/yr for mid-terraced houses, and 46kwh/m2/yr for end of terrace houses and semi-detached houses, and 46kwh/m2/yr for detached houses. This is expected to be introduced in the Building Regulations in 2016, with the possibility of an interim step in 2013.

Carbon Compliance

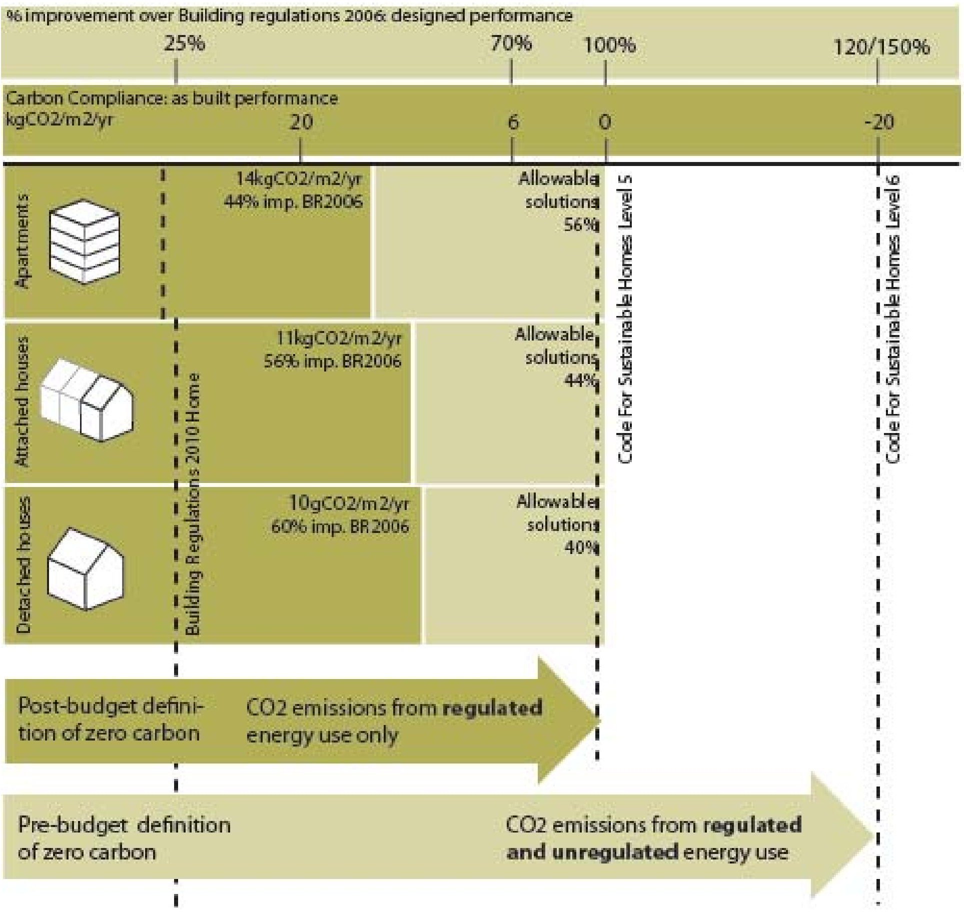
Carbon compliance measures the as built performance of the fabric along with on-site low/zero carbon technologies used for heat and power. This target is measured in CO2/m2/yr and is a measure of the servicing of the fabric demand and supply of energy. 'Budget 2011: The Plan for Growth' confirmed the Zero Carbon Hub's research into 'carbon compliance' will form the basis of future consultation on changes to the Building Regulations up to 2016. The proposed targets are 14kgCO2/m2/yr for apartments up to four storeys, 11kgCO2/m2/yr for attached houses, and 10kgCO2/m2/yr for detached houses. This is expected to be introduced in the Building Regulations in 2016.

Allowable Solutions

Allowable solutions will deliver around half of the carbon savings required to meet the zero carbon goal. The recommended route is that developers will make a payment to an Allowable Solutions provider, who will take responsibility and liability for ensuring that allowable solutions deliver the emissions reductions required. These might include investment in offsite low/zero carbon technologies, advanced carbon compliance on site, exporting heat or electricity, efficient appliances or controls, Section 106 credits, or improvements to the existing building stock. Allowable Solutions are expected to be introduced in the Building Regulations in 2016.



Fabric Energy Efficiency Standards	Suggested U Values to achieve energy efficiency requirements (expected 2016)					
	Wall	Floor	Roof	Window	Air permeability	Thermal bridging
Apartments 39kwh/m2/yr	0.18	0.18	0.13	1.4	3	0.05
Mid-terrace 39kwh/m2/yr	0.18	0.18	0.13	1.4	3	0.05
End terrace/semi-detached 46kwh/m2/yr	0.18	0.18	0.13	1.4	3	0.05
Detached 46kwh/m2/yr	0.18	0.14	0.11	1.3	3	0.04
Building Regulations Part L1 2010	0.3	0.28	0.2	2.0	10	0.08



Zero Carbon Hub (ZCH) Carbon Compliance recomendations

Carbon Compliance is the target carbon emissions from a home, achieved through the as built performance of the fabric together with the performance of on-site low/zero carbon technologies used for heat and power.

In 2009 a target of 70% reduction in carbon emissions compared with Building Regulations 2006 was announced by the Housing Minister.

The ZCH has recommended an appropriate national carbon compliance limit for 2016 to apply to all new homes. This is an 'as built' measure expressed in kgCO2/m2/yr. The suggested targets are:

- 14 kgCO2/m2/yr for low rise apartments up to four storeys
- 11kgCO2/m2/yr for attached houses
- 10kgCO2/m2/yr for detached houses

Achieving Zero Carbon Homes

The government is promoting three linked measures to achieve the zero carbon goal: National planning policy, which regulates the location and design of development; the Building Regulations, particularly Approved Document Part L: Conservation of Fuel and Power covering conservation of fuel and power; and the Code for Sustainable Homes, a measure of sustainability in new build housing. The aim is to use these policies to develop a clear framework in which zero carbon housing can be procured and delivered.

National Planning Policy

The white paper *'Planning for a Sustainable Future'* emphasised the importance of planning in delivering sustainable development, particularly through new housing, employment and infrastructure. '*Planning Policy Statement (PPS) 1: Delivering Sustainable Development*' and its supplement '*Planning and Climate Change*' put sustainability at the heart of planning policy. These outline how regional and local planning can create places with low carbon emissions that are suited to the future climate, promoted through spatial strategies. The PPS places a duty on planning authorities to ensure spatial strategies contribute to the mitigation of and adaptation to climate change. Development plans should consider how development can be delivered to reduce emissions from transport and buildings, create opportunities for decentralised renewable or low carbon technology, minimise future vulnerability to climate change and sustain biodiversity.

Building Regulations

In 2007 '*Building a Greener Future*' set out the government's preferred method of achieving zero carbon by three progressive improvements in energy/carbon performance, to be set through the '*Building Regulations Approved Document Part L1A: Conservation of Fuel and Power in New Dwellings*'. Following the Budget 2011 amendments to the definition of zero carbon, these step changes are expected to be as follows:

2010	25% improvement over BR's 2006	Code Level 3
2013	44% improvement over BR's 2006	Code Level 4
2016	'Zero carbon' (% improvement to be confirmed)	Code Level 5

The first of this series of step changes has been introduced in the 2010 amendments to the Building Regulations Part L1 which aims to reduce carbon emissions by 25% over 2006 Regulations standards. The percentage improvement is measured through the Dwelling Emission Rate (DER), the estimated CO2 emissions per m2 per year (KgCO2/m2/yr) for a dwelling, as calculated by SAP (Standard Assessment Procedure).

The 2013 amendments are expected to reflect the increase in retrofit projects; there is likely to be a recommendation for consequential improvements to energy performance when works are carried out to existing homes. A further 20% reduction of carbon emissions is expected, and the Fabric Energy Efficiency Standard could be introduced. By 2013 Wales is expected to have its own Building Regulations, with a different target likely to be set.

Code for Sustainable Homes

The Code for Sustainable Homes is a national standard prepared by the Government, developed to measure, improve and encourage building of sustainable new homes. The Code became mandatory for all new housing in May 2008. The assessment rates the 'whole home' as a complete package on a rating of 1 to 6 (1 is the entry level and 6 is true zero carbon). Designs are awarded points under nine categories (see table below).

The Code for Sustainable Homes states that 'a Zero Carbon Home is "*where net carbon dioxide emissions resulting from all energy used in the dwelling are zero or better. This includes the energy consumed in the operation of the space heating/ cooling and hot-water systems, ventilation, all internal lighting cooking and all electrical appliances*"[7] It will use no more than 80 litres of water per person per day, of which a minimum 30 percent will be provided by rainwater or grey water harvesting.This is a more stringent target than the current government definition as described in the Budget 2011.

The 2010 update to the Code aims to align the Code with the latest zero carbon homes policy. Lower levels of the Code have been amended to reflect changes to building regulations and upper levels of the code have been amended to match the government definition of zero carbon. Ene2 has been amended to replace the Heat Loss Parameter (HLP) with the Fabric Energy Efficiency Standard (FEES) and the associated metric (kWh/m2/yr). Mandatory FEES levels have been introduced for Code 5&6, set at the target levels for 2016 of 39kwh/m2/yr for apartments and mid-terraced houses, and 46kwh/m2/yr for end of terraced, semi-detached and detached houses.

	Mandatory minimum targets			
Code Category	Code level 3	Code level 4	Code level 5	Code level 6
Energy use	DER 0% improvement over TER 2010 (equivalent to 25% improvement over Psrt L 2006	DER 25% improvement over TER 2010 (equivalent to 44% improvement over Part L 2006	DER 100% improvement over TER 2010	True zero carbon including regulated and unregulated emissions
Fabric performance	none	none	<39kwh/m2/yr for apart-ments and mid terrace, <46kwh/m2/yr for end terraced, detaced and semi-detatched	As Code 5
Water	<105l/ppn/day	<105l/ppn/day	<80l/ppn/day	<80l/ppn/day
Materials	Minimum 3 key elements rated D or above in Green Guide	As Code 3	As Code 3	As Code 3
Surface water run off	Peak rate of run off no greater than before development	As Code 3	As Code 3	As Code 3
Waste	Adequate external space for waste storage (100l for single dwelling, +70l for each additional bedroom	As Code 3	As Code 3	As Code 3
Pollution	No mandatory credits	No mandatory credits	No mandatory credits	No mandatory credits
Health & wellbeing	No mandatory credits	No mandatory credits	No mandatory credits	No mandatory credits
Management	No mandatory credits	No mandatory credits	No mandatory credits	No mandatory credits
Ecology	No mandatory credits	No mandatory credits	No mandatory credits	No mandatory credits

Increasing Awareness of Zero Carbon

The Government has introduced a range of measures which aim to reduce the UK's carbon emissions to meet the target set by the EU, the Climate Change Act and the Energy Bill:

Energy Performance Certificates

Since 2008 Energy Performance Certificates (EPC's) have been compulsory for all dwellings and all non-domestic buildings over 50m2. These are based on design stage modelling of the building performance, rated A (most efficient) to G (least efficient); the more efficient a dwelling is, the lower fuel bills will be. EPC's do not include energy used by appliances. An EPC is accompanied by a report with recommended steps to increase the energy rating of the building.

The Green Deal

The government is exploring how the Green Deal can extend to new homes as well as its current focus on retrofitting existing homes. This would enable house builders to offset the up front cost of building to more demanding emission reduction standards.

Feed in Tariffs (FIT)

Feed in Tariffs are incentives for the generation of renewable electricity. The tariff has three financial benefits: Payment for electricity produced using renewable means; additional bonus payments for any electricity exported to the grid; and a reduction in standard electricity bills from using the energy generated using renewable means. Payment for the tariff comes from energy suppliers, not from the Treasury. Most forms of renewable electricity generation are eligible up to a size of 5 megawatts; payment levels vary depending on the energy source and scale of generation.

Renewable Heat Incentive (RHI)

The RHI is a financial support scheme to encourage uptake of renewable heat installations and encourage use of renewable heat. The scheme pays the installation owner for heat generated through a renewable system that meets the criteria of the scheme; payment is direct from the Treasury. Residential systems will be introduced in 2012. Until then, they are covered by the Renewable Heat Premium Payment. This is a limited £15 million fund for one-off payments for renewable heat systems installed after April 2011, focused on homes not supplied by the gas network.

The Welsh Perspective

Welsh Government (WG) has set its own targets and aspirations for zero carbon building which, in some cases, are more ambitious that those set by UK government. WG has taken a similar approach to the UK in promoting sustainable design through the planning system, Building Regulations and measurement through the Code for Sustainable Homes.

In 2007 WAG announced an aspiration to achieve zero carbon for all government funded homes by 2011, five years ahead of the UK government timeline[8]. '*Planning Policy Wales*' (PPW, 4th edition 2011) sets out Wales' land use policies, and is used to define local planning policy and in deciding the outcome of planning applications. The policy has the aspiration that 'g*ood design should promote the efficient use of resources, including land. It should seek to maximise energy efficiency and the efficient use of other resources, minimise the use of non-renewable resources and minimise the generation of waste and pollution*'[9].

'*Technical Advice Note 22: Planning for Sustainable Buildings*' (TAN 22) provides technical guidance on the implementation of planning policy including guidance on Low and Zero Carbon Design Solutions. This advises a hierarchical approach to the incorporation of low carbon solutions. This reflects the approach set out by UK Government, where the priority should be to reduce energy demand and improve energy efficiency before applying technologies and allowable solutions.

Since 1st September 2010 applications for 1 or more dwellings are required to meet Code for Sustainable Homes Level 3 and obtain 6 credits under issue Ene1 – Dwelling Emission Rate (a reduction of 31% over Building Regulations 2006).

The Building Regulations will be devolved to Wales on 31st December 2011. The first changes in 2013 are expected to include a 55% improvement over 2006 Part L for carbon emissions[10], compared to 44% in England.

Endnotes

1 HM Government, (2005) 'Securing the future: The UK Government Sustainable Development Strategy'.
2 HM Government (2007) 'Building a greener future' p3
3 HM Government (2007) 'Building a greener future' p8
4 Kate Barker (2004) 'Review of Housing Supply'
5 Zero Carbon Hub, http://www.novamedia1999.co.uk/zerocarbonhub/march2011/#news1 accessed 09.06.11
6 UK Green Building Council, http://www.homedesignhub.net/ukgbc-budget-comment-on-zero-carbon-homes/ accessed 09.06.11
7 BRE (2006) 'The Code for Sustainable Homes: A step Change in Sustainable Home Building Practice'
8 Written Statement by the Welsh Assembly Government (2008) 'Towards a Zero Carbon Future for Buildings in Wales
9 Welsh Government PPW4 2011, page 58, section 4.10.5
10 Welsh Government Policy Statement July 2010 – 'Welsh Assembly Government announces target for first changes to Welsh Building Regulations'

Image by Andrew Hazard, courtesy of Leadbitter

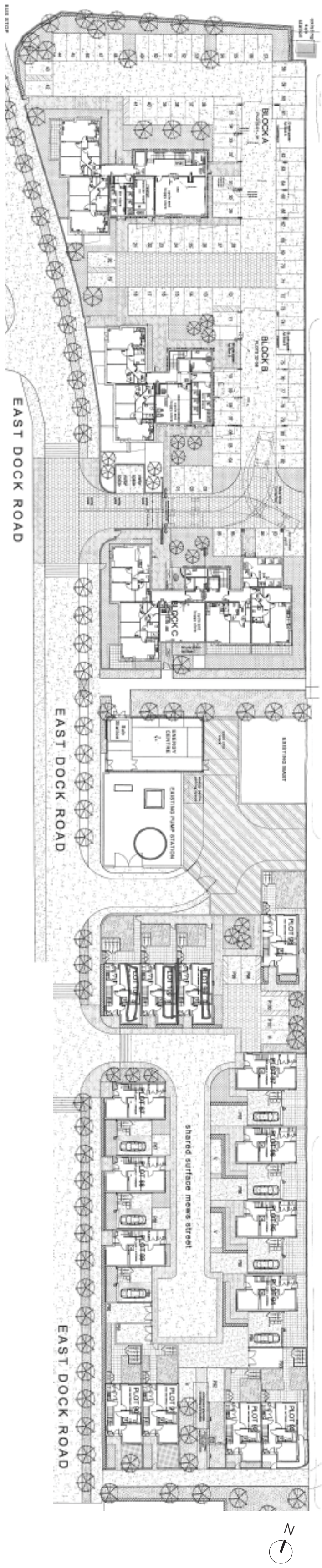
Lessons from Practice: Case Study Houses

- Mariner's Quay, Old Town Dock, Newport
- Chapel Close, St Athan, Vale of Glamorgan
- Future homes Visitor Centre, Ebbw Vale
- Retrofit for the Future, The Turnstiles, Newport

Powell Dobson Architects

Mariners Quay, Old Town Dock, Newport

15 family houses and 3 apartment blocks on a waterfront site in Newport as part of the largest Code 5 social housing development in the UK.



Passive design

South facing compact 'Mews' style houses with living spaces at first floor and roof terraces over car ports. Three apartment blocks with north facing buffer zones and south facing apartments. South facing 'sun boxes' act as solar buffers.

Terraced houses are grouped around a north-west to south-east mews and use passive design strategies to maximise the free aspects of environmental design. Houses have a highly insulated compact form with a south facing monopitch roof. Single storey carports and bike stores link the houses with roof terraces providing south facing outdoor spaces. Sunspaces on the south elevation buffer exposed glazing during winter and absorb heat, radiating it out during cold periods. During summer the sun box can be fully opened as a balcony. A light chimney over the stair brings daylight into the depth of the plan. Houses are designed with living rooms on the first floor to take advantage of views and maximise solar gains into the most frequently occupied areas of the house. Stairs, storage and kitchen create a buffer on the north of the plan, allowing living areas to face south.

Breaking the apartments into three blocks maximises the area of south facing facades. Blocks are accessed from north facing buffer zones containing stairs, lifts and walkways. Designed to meet building regulations standards, this circulation zone helps to minimise heat losses from the apartments by providing a buffer to extremes of climate. Highly insulated apartments face south with high glazing ratios. Each has a sun space, designed as an enclosable balcony with thermal mass floors to take advantage of solar gains and act as a buffer zone in winter.


EAST CLOSE DOCK

Fabric performance - Houses

Wall construction	Timber panel	0.15W/m2K
Floor construction	Hanson Jetfloor	0.15W/m2K
Airtightness	3 m3/m2/hr@50pa.	

The fabric of the houses was designed to meet Energy Saving Trust enhanced construction detail U Values of 0.15 and an airtightness of 3 m3/m2/hr@50pa. The majority of the envelope was designed to be clad in insulated render panels with timber cladding on the light chimneys.

Raised ground floors are constructed use Hanson Jetfloor, a polystyrene based beam and block floor system to maximise insulation in a minimal floor zone. The roof pitch is created using ecojoists, minimising the amount of timber in the joists and creating routes for services within the structural zone.

The houses have triple glazed windows with a U Value of 0.8W/m^{2}K. Windows were chosen to allow bonding of the vapour control layer to the window frame to achieve the required airtightness. Sun spaces are glazed externally and have glazed opening doors between the sun space and the living rooms.

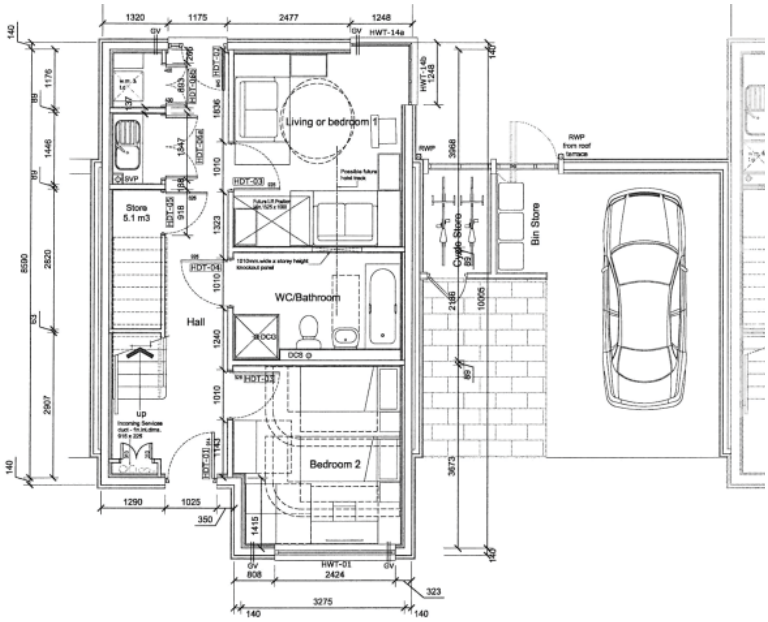
Fabric performance - Apartments

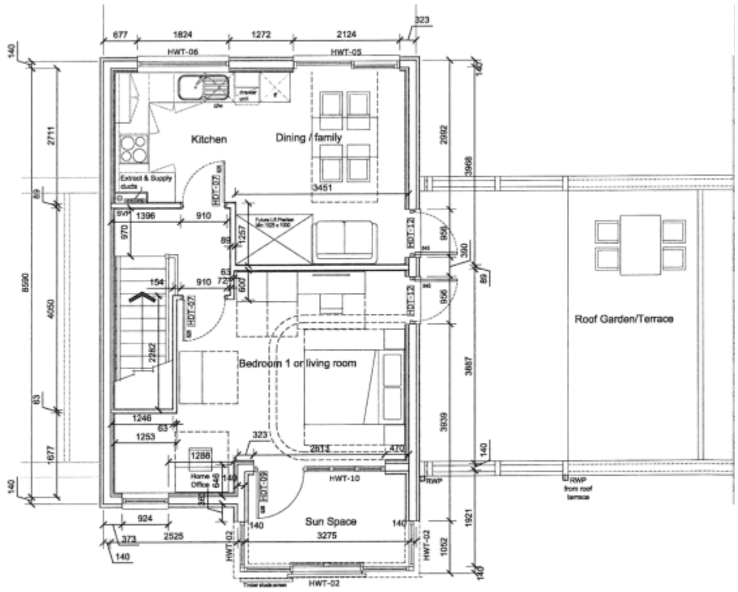
Construction	Metsec Light Steel Frame
U Value	0.15W/m2K
Airtightness	3 m3/m2/hr@50pa.

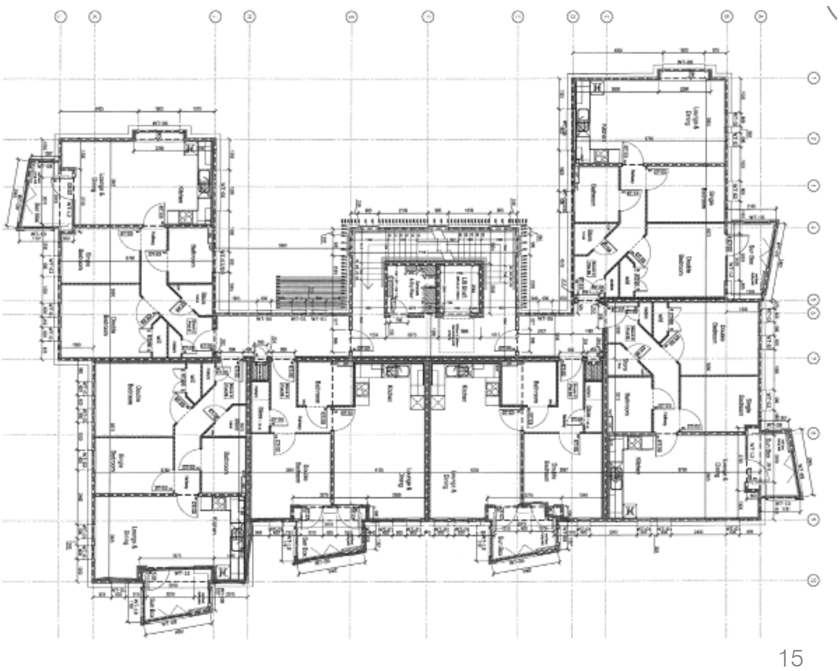
The apartments were designed to the same standards as the houses using a Metsec light steel frame system with composite floors. A 100mm Metsec panel is faced with 150mm EPS insulation, finished with render to achieve the required U value of 0.15W/m2K.

Buffer areas to the north of each block were constructed to building regulations standard only, as these areas are for circulation and access. These buffer the apartments from extremes of weather and offer an additional layer of protection to the north facades. Sun spaces were designed to be TECU copper clad clip-on elements. The majority of the envelope was designed to be clad in insulated render panels, with timber cladding to the north facing buffer zones.

Windows with a U Value of 1.5W/m^{2}K were chosen to allow bonding of vapour control layer to the window frame. This was considered essential for achieving the required airtightness.


Living or bedroom 1
Store
5.1 m3
Hall
WC/Bathroom
Bedroom 2
Cycle Store
Bin Store


Kitchen
Dining / family
Extract & Supply ducts
Bedroom 1 or living room
Home Office
Sun Space
Roof Garden/Terrace



Systems

Hot Water:	Combined Heat and Power system
Heating:	Community biomass woodchip boiler, gas top up and inter-seasonal use, radiators fed by heat exchange
Electrical:	Community Photovoltaic array, combined Heat and Power
Individual systems:	Whole House Mechanical Ventilation and Heat Recovery

A feasibility study assessed methods of energy generation for the site. Wind power was ruled out due to planning restrictions and wind speeds below the required levels, while tidal generation was eliminated on ecological grounds. With these alternatives eliminated, photovoltaic panels were required on all south facing roof slopes and finding the required area that would not be overshadowed was a difficult process. £1.2 million of photovoltaic panels are shared within a community electrical generation strategy, run from a central energy centre. These 1200m2 photovoltaic panels offset carbon associated with gas supply and contributes to electricity demand for lighting, fans and pumps.

Heating load to the development is supplied by different systems depending on season. A woodchip biomass boiler is used only during the peak winter heating season to prevent stopping and starting the system. A thermal store captures excess heat, used once the boiler is deactivated. During intermediate periods gas back-up can be activated on demand to provide heating as required. Heat is pumped around the site on a highly insulated hot water loop, with heat exchangers transferring heat to each house or flat. Radiators in individual rooms supply heat to the dwelling. Long term reliability of supply was a significant issue and required extensive investigation before the final system was agreed. It is estimated that the system requires 23 tonnes of woodchip per year, equating to four deliveries per annum.

Hot water is provided by a Combined Heat and Power (CHP) system. The CHP runs continuously, providing hot water and generating power. Hot water is pumped around the development in a highly insulated closed loop with heat exchangers to each dwelling.

Water use is reduced to 80l/person to maximise credits under the Code. This is achieved by using small volume baths, low flow fittings and grey and rainwater recycling. Recycled rainwater is filtered to bathing standards and used in WC's and washing machines.

High levels of airtightness necessitate mechanical ventilation with heat recovery. Nuaire units are 89% efficient and provide continuous background ventilation.

Procurement

A partnering approach from the outset with the involvement of a full design team led to a collaborative design process with full support from all members of the team. The project was procured using the JCT Constructing Excellence Contract.

Contractors' experience

The contractor had no experience of building to Code 5. While schemes to lower Code levels had been built by Leadbitter, this was the first to this standard. Similarly, none of the subcontractors Leadbitter appointed had experience of Code 5. However, none of the systems used for the scheme were new, all had been used before but not necessarily on housing schemes.

Site management

Leadbitter had in place schemes required under the code such as Considerate Contractors and understood the requirements the Code placed on them before starting on site. This led to good site management practices from the outset.

A well constructed fabric is essential to achieve Code 5. This requires accuracy from the workforce and an understanding of why it is important. Code was included within site inductions, and regular 'Toolbox Talks' ensured that the construction techniques were understood by the workforce. These emphasised the importance of minimisation of waste and accuracy of construction.

The site was large enough for Leadbitters to set up an on site waste sorting and minimisation plant, with compartmented areas for recyclable, timber and waste to landfill. 85% of the construction waste was diverted from landfill.

Supply chain

Materials were specified by the architects to meet Code 5 requirements and had to be sourced from accredited suppliers. All aspects of the supply chain where possible were ISO14001 certified, while materials required chain of custody to accredited sources such as FSC timber. Some conventional materials such as MDF were eliminated from site on sustainability grounds. Demonstrating compliance with the Code demands additional time and paperwork that may not traditionally be included in initial project budgeting.

Buildability

The Metsec steel frame was constructed in the factory and to accurate tolerances before delivery to site stacked on lorries. These were quickly fitted together on site, with each floor taking two weeks to build using cranes and scaffods. Concrete floors were cast in situ using a composite floor system. Once the panels were erected, sheathing, insulation within the panels, external insulation and render were applied. There is in total over 150mm of insulation within the wall build up.

The timber frame system for the houses was delivered from Scotland. While the expectation of the team was for a precise product manufactured under factory conditions, the timber frame was delayed. The accuracy of the panels was less precise than expected; some timber within the panels warped and the system proved slow to construct.

The most difficult detail was the junction between the solar panel stands and the single ply membrane roof. With such a large area of PV panels, Leadbitter were concerned that the large number of penetrations would compromise the waterproof layer. Leadbitter, Powell Dobson, Photon Energy and the roofing subcontractor designed a detail that integrated a flashing on the stands to achieve a lapping of the roof membrane under and over this, preventing water penetration.

M&E coordination

For a residential scheme, Old Town Dock has complex servicing requirements. A central energy centre and community power and heating, combined with whole house MVHR required a highly coordinated services strategy. These complexities included extensive metering of all aspects of the scheme using smart meters. Similarly the plumbing and water distribution was complex due to the centralised storage of rainwater for WC's and washing machines. To reduce use of copper pipes, aluminium cored plastic piping was used with flexible bends for ease of installation.

The density of the scheme meant space on site was at a premium. The volume of cabling and pipework necessitated larger risers and trenches than expected because of additional insulation to pipes, double the volume of electrical cabling and multiple water supply, drainage and recycling systems. There are three separate drainage systems; grey water recycling, rainwater recycling and foul drainage. When combined with four filtration tanks and rainwater attenuation systems, the ground was extremely congested and required careful coordination. The large volume required for rainwater storage necessitated tanks that could have undermined the foundations of the houses, but using a longer tank resolved this problem. Conflicts between landscaping required to achieve ecology credits and this level of services in the ground caused difficulties, as did the need for the Local Authority to adopt roads with private services with the curtilage.

The on site renewable strategy demanded extensive space across the site, which is not always deliverable or cost effective. The need for private energy grids and water collection can conflict with local agencies, particularly Highways Agency who will not normally adopt roads with private services beneath.

Low flow rates dictated by Code water requirements caused difficulties with the heat exchanger supplier. The heat exchangers were designed to activate when the water flow rate was over 8 l/second; as the scheme was aiming to reduce water use, the basin taps were set to 3l/second. This was overcome by the manufacturer altering their standard system to suit the low flow rates.

The community energy strategy has required the housing association to become an energy supplier and metering the development. This has been a steep learning curve and has required the housing association to closely monitor energy use and to purchase software and equipment to enable the correct billing of residents. It is important that the result is affordable for the residents and service charges incurred by this process are minimised. It is also important that monitoring takes place to ensure that the occupants maximise the benefit of renewable energy provision.

Testing

Air tightness tests had to be carried out on each unit. When the first unit was complete, this was tested three times before the required airtightness was achieved. This required an additional level of detail beyond standard construction details and drawings. The tests also showed that it was extremely difficult to predict all the points of air leakage and specify adequate prevention at each point. For example, all recessed plug sockets were fitted with putty pads to ensure no air could escape through the airtightness membrane. This was an additional cost incurred to achieve the airtightness standard. However, once the airtightness details were resolved with this first unit the same could be repeated across the site. Each house had to be individually test to ensure compliance. The apartments all achieved below 3 m3/m2/hr@50pa.

Lessons learnt

Several key findings have emerged from the project:

- In some places DQR, Code for Sustainable Homes and TAN guidance are contradictory; for example, the interpretation of Lifetime Homes against that in the Code, and conflicts in the design of a surface water storage system between the Code and TAN 12 requirements.
- There is a lack of robust or enhanced details suitable for a Code 5 envelope for both thermal and acoustic performance. These details only exist for traditional and timber frame construction; for any other systems details do not exist, leading to over-specification in order to meet BRE approval.
- A full partnering approach and a long lead in time were essential to the success of the scheme. The level of coordination required would be difficult to achieve with a traditional Design & Build approach. The pre-contract phase was intensive and required substantial time commitment. This also meant that design was almost fully complete before starting on site.

Project team

Client: Charter Housing, & Fairlake Properties
Architect: Powell Dobson Architects
Main Contractor: Leadbitter
Structural/civil engineering: RVW Consulting
M&E/Code Assessors: Hoare Lea
Landscape and Ecology: Jellard Associates
Contract Value: £14.7m (£11m SHG) for the entire development including apartments

Image by Andrew Hazard, courtesy of Leadbitter

Powell Dobson Architects & Design Research Unit Wales

Chapel Close, St Athan

16 affordable houses on the outskirts of St Athan in the Vale of Glamorgan achieving Code Level 4 and a 54% reduction in carbon emissions. Designed to rationalise house types to allow use of prefabricated timber frame construction.

Chapel Close is a development of 16 affordable houses and flats on the edge of St Athan in the Vale of Glamorgan. The project brief was to provide:

2 no. 2 bed 3 person flats
6 no. 2 bed 4 person houses
6 no. 3 bed 5 person houses
2 no. 4 bed 6 person houses

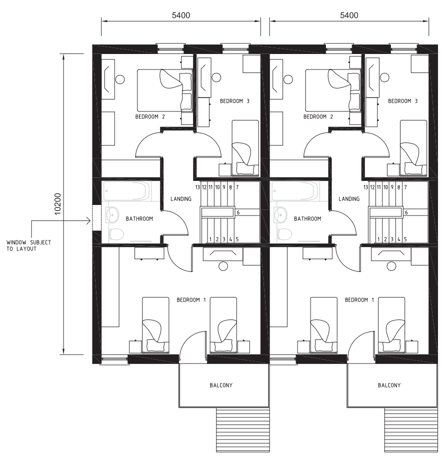
The project was been taken from inception to completion by project architects Powell Dobson Architects in collaboration with Design Research Unit Wales, appointed to advise on rationalisation of the scheme to maximise prefabrication. The project was a case study for MMC Wales, a 21 month research project funded by the Knowledge Exploitation Fund as a Collaborative Industrial Research Project, supported by Welsh Government. The project is a pilot project for Welsh Government to achieve Code level 4.

Passive design

East-west oriented terraces maximise solar gains. South facing pitched roofs maximise solar exposure.

The triangular site is located on the edge of St Athan on the land around a former church. It is bounded on the south by the B4265, to the east by the main route into St Athan and to the north of the site a garage and suburban housing. The site is an exception site, located outside the development boundary.

GROUND FLOOR PLAN



FIRST FLOOR PLAN

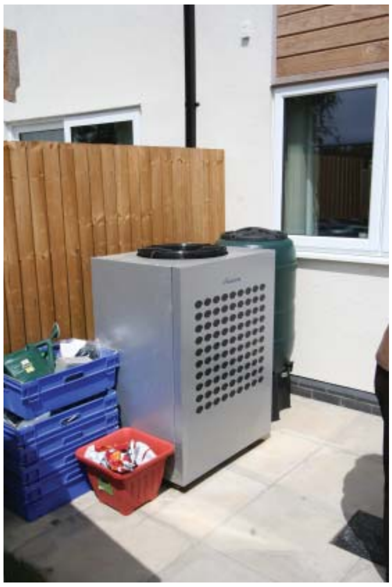
This page: images courtesy of Powell Dobson

From an initial massing study using pattern book house types and footprints, various options were investigated to rationalise the site layout and house type to suit Modern Methods of Construction (MMC). The site layout submitted for planning was based on a concept of lane, court and mews. The majority of the houses line the lane through the site in a terrace form with a southerly aspect. At the east of the site, a mews created a terrace fronting the street while to the west the larger four bed houses look over a hard landscaped court. During the planning process the layout was amended, with the mews court removed and the layout simplified to two terraces abutting the existing building line.

At an early stage the design team investigated the impact of MMC on the house types. From previous experience and consultation with Holbrook Timber Frame, it was decided that as much standardisation as possible would offer the benefits of repetition. House types were developed in close consultation with WAG Housing Directorate in order to meet Development Quality Requirements using innovative house plans.

Houses are designed with a central core containing wet services, risers and the stair. At ground floor the kitchen overlooks the road providing surveillance, while a WC and store inside the building and cycle store externally complete the service areas. A living and dining room spans the width of the house and opens onto the garden. The house types developed for St Athan use a narrow aspect plan for all the house types and a wide aspect flat type. The houses are designed to be standardised across all house types; the difference between a 2B3P and a 3B5P is only 300mm in width. However, this means that the area of houses does not adhere to DQR pattern book areas, but is in most cases higher than the standards recommend. In the 4B6P house, the roof space is used to provide two bedrooms made possible by the use of a timber panel roof rather than a trussed roof. Previously unused space can be inhabited for a minimum cost increase, a significant cost saving over extending the house.

Air source heat pump located in garden



Fabric performance

Closed timber frame with integrated insulation, U Value 0.15, roof U Value 0.13, air tightness below 3m3/m2/hr.

A fabric first approach was applied to maximise energy savings from the building fabric. Using a factory finished product delivered to site in panellised form ensured accurate tolerances to minimise thermal bridges. The 195mm closed timber panel by Wave consists of 145mm Kingspan Therma insulation between studs, with 9mm OSB sheathing. Externally, the panels are finished with a ventilated render or timber cladding, and internally a 40mm service void is battened out and finished with wallboard.

A reinforced concrete slab is insulated with 75mm Kingspan rigid insulation, with underfloor heating pipes secured to the upper face, and 75mm screed above.
The roof is constructed using prefabricated trusses by Wave with140mm Kingspan Thermapitch rigid insulation between trusses and a further 50mm below. The roof finish is a Euroclad standing seam roof in dark grey.

Systems

Heating:	Air source heat pump to each house, underfloor heating and radiators. MVHR system.
Electrical:	Mains

Each house has an air source heat pump located in the back garden. Under floor heating provides background heating throughout the house. The heating system has been designed to be future proof and have built in flexibility to allow new technologies to be incorporated as required. A Mechanical Ventilation and Heat Recovery unit collects waste heat from the kitchen and bathrooms which is reused to heat incoming fresh air. This was required due to the high level of airtightness in the building fabric. Water saving to achieve Code credits was important; low flow fittings were used throughout the development.

The specification of the heating system was modified to combine underfloor heating at ground floor with radiators at first floor. This was due to a concern with using underfloor heating with a carpet finish, as this could effectively act as insulation and affect the performance of the heating system.

Code Assessor and team appointment

A full design team and Code assessor were not appointed until after planning (RIBA Workstage E).The adoption of the Code at this stage, replacing the earlier EcoHomes assessment method, lead to modifications to the design of the scheme at a late stage. The design approved for planning had to be modified to create sufficient space within the dwelling for distribution of services and large cylinders to serve underfloor heating. The involvement of a Code assessor early in the process removes the potential for late changes and ensures Code requirements are integrated with design and not a late addition.

Construction

Design & Build, negotiated contract

The project was the first Lovells had carried out to high Code levels, and as such was a learning experience for all involved. Decisions regarding Code credits had be made prior to the appointment of the contractor. With a design and build route, the impact of variations on credits was a constant problem.

The use of a prefabricated system with a factory built product that had to be delivered to site necessitated a long lead in time and up front design period.

Code assessment

The site itself proved problematic under Code, as the site was classified as greenfield. This made ecology credits difficult to achieve as proving an improvement in ecological value is difficult in this situation. The difficulties encountered with the site added cost to the project and were a financial burden that could not be avoided. This led to cost savings being required elsewhere in the design.

The houses have integrated bin and bike stores at the front of the house, a home office in the living room, A rated materials where possible, and low water use appliances.

Site management

Using a prefabricated system reduced the amount of waste on site and the number of trades required to complete the project. Wet trades were limited and water use reduced by 60% compared to traditional build projects; only the lightweight render system required water.

86% of waste generated on site was recycled or reused. Some materials such as timber pallets were reused by the local community, businesses and schools. 90% of the workforce came from within a 15 mile radius of the site, directly supporting the local economy.

Cost control

The project underwent continual value engineering during the construction phase to retain the viability of the project despite WG support and funding as a pilot. A key decision was the specification of the window to meet DQR, Secured by Design and maintenance requirements and achieve Code credits. The initial specification of tilt and turn windows were non-compliant; this necessitated a change in the window system, which due to changes in frame size affected the daylight factors within the house, particularly the home office area. This required careful balance to ensure the window met the requirements of both DQR and Code.

Buildings in use

As with all low carbon projects, it was important that the end users were educated about the technologies installed in their homes. Detailed information packs were prepared for residents to explain the technology in each home. Post occupancy monitoring for energy use is taking place, but as yet no results have been published. Similarly, informal post-occupancy reviews with residents will take place.

Findings

- The scheme has shown that a high performing building fabric could reach the expected WG reduction in emissions in the Building Regulations amendments in 2013. The scheme achieves between 49-54% reduction in emissions (TER over DER), 1% short of the 2013 target, for £1228sqm.
- Using the WAVE system allowed a factory quality product to be delivered to site and be quickly assembled. Using prefabrication has the benefit of tighter tolerances and therefore increased airtightness. However, a longer lead-in time is required as locations for cabling runs and penetrations for ducting need to be decided earlier in the design process.
- Achieving materials and sourcing credits was a time consuming process; the contractor did not fully appreciate the work involved in chasing credits and providing evidence to confirm credits had been achieved. In many projects this can be a long and arduous process, especially where products do not have a readily available chain of custody or ISO certification.
- The separation of design and construction team was problematic. Unlike other case studies, where close relationships between designers, contractors, assessors and so forth were beneficial, in this case the construction team suffered as a result of the late introduction of the code and the higher level Code requirements. From this it seems that partnering is essential to successful low carbon projects.

Project team:

Client: Wales & West Housing Association
Architect: Powell Dobson Architects & Design Research Unit Wales
Main Contractor: Lovells
Engineers: Blackurn Griffiths
Contract Value: £2.25 million

Design Research Unit Wales

Future Homes Visitor Centre, Ebbw Vale

A visitor centre on the Future Homes Exhibition site to be retrofitted as a two-bed house. The centre is a reinterpretation of a traditional Welsh Longhouse using the Ty Unnos construction system.

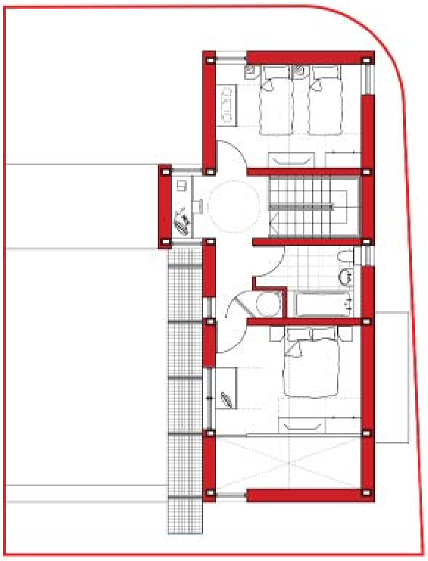
The Future Works Visitor Centre was designed to meet PassivHaus standards using Welsh products and materials. The house is a development of Design Research Unit Wales' third-placed Future Homes competition entry. The three bed house designed for the competition was developed into a visitor centre that can be retrofitted as a two bed house once its exhibition role is complete. The aim for the project was to target PassivHaus equivalence and Code for Sustainable Homes level 5.

PassivHaus

PassivHaus is a voluntary construction standard created in Germany in 1996. It is suitable for dwellings and non-domestic buildings and aims to provide excellent comfort conditions and reduce energy needed for space heating and cooling. A typical PassivHaus features:

- very good levels of insulation with minimal thermal bridges
- well thought out use of solar and internal gains
- excellent level of airtightness
- good indoor air quality

To achieve PassivHaus, the energy requirement for space heating must not exceed 15 kWh/m2/yr and total primary energy use for all appliances, domestic hot water and space heating and cooling must be less than 120 kWh/m2/yr.



This requires the following:

- Super-insulation: opaque U-values must be less than 0.15 W/m2K
U-values for windows and doors need to be 0.8 W/m2K or less (for both the frame and glazing). This requires the window frame to be insulated and glazing to be triple glazed
- Thermal bridging needs to be minimised, and ideally eliminated
- Airtightness: n50 of 0.6 h-1 @ 50 Pa or less
- Whole house mechanical ventilation with heat recovery (75% efficient or better, with a low specific fan power).

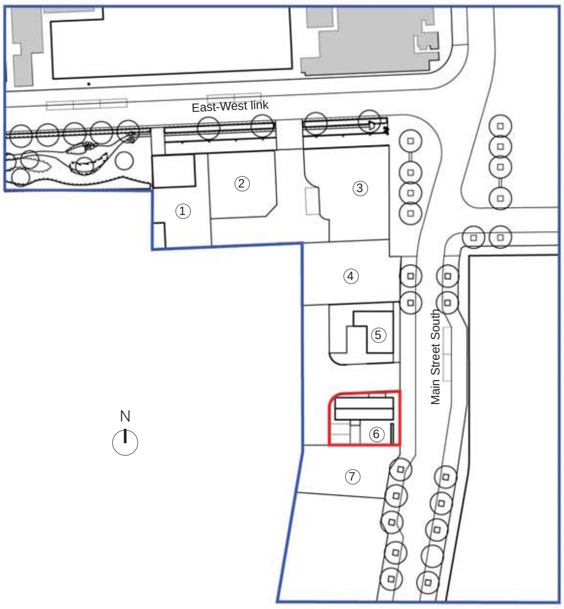
The *PassivHaus Planning Package* (PHPP) is a modelling package and energy calculation tool used to verify PassivHaus standards have been met. In the UK, BRE is certified to register PassivHaus buildings. In order to achieve certification, materials and systems used have to be accredited by the German PassivHaus Institut.

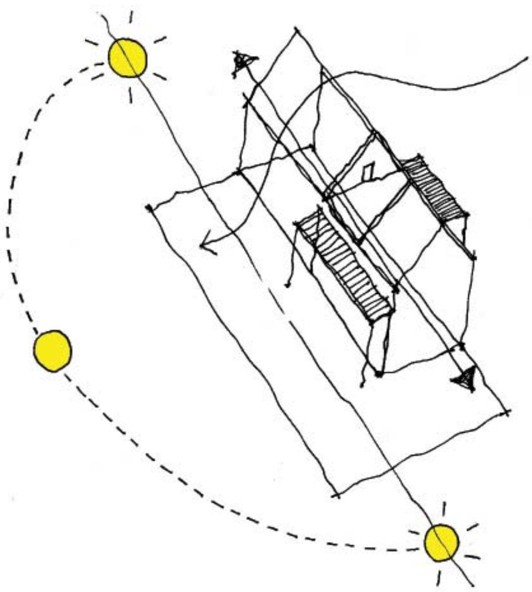
The Future Homes visitor centre aimed to achieve PassivHaus equivalence using Welsh products and materials, as the majority of systems accredited by the Institut have to be imported from the continent.

Siting and passive design

East-west longhouse design with heavily glazed south facing living areas, roof and garden; service areas facing north.

The site is one of several case study house sites located at The Works, the former steelworks site in Ebbw Vale (see below). The re-development of the steelworks site aims to create a new vision of a sustainable community; the £300 million project includes 720 new homes, a community hospital, learning campus and a business hub.





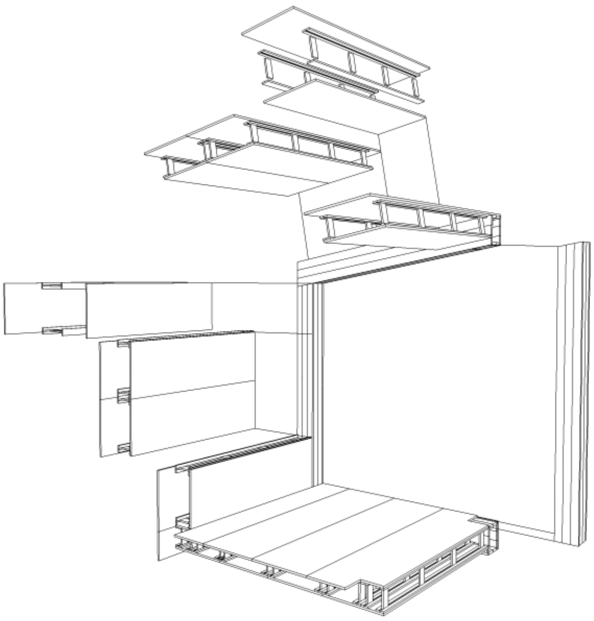
The site provides near optimal conditions for passive design. When aiming for PassivHaus the orientation of glazing is critical in maximising 'free' passive warmth to the house. The design maximises south facing glazing to the living room, with further punched windows to the bedrooms and kitchen. The north elevation has few windows to minimise heat loss.

The design of the house is a re-interpretation of the traditional Welsh longhouse vernacular for the 21st century. A linear access route runs along the southern edge of the site, giving access to the longhouse and garden. The linear house looks south across its garden along the valley, while the first floor offers views up and down the valley to north and south. A restrained palette of vertical timber cladding, white render and standing seam roof are used to develop a contemporary interpretation of traditional vernacular buildings. The house uses colour to add personalisation, in this case coloured panels on the elevations of the dwelling and on pop-out bays.

Fabric performance

Ty Unnos timber frame with Warmcell-filled Sitka Spruce infill panels; Intello membrane and external insulation to achieve a U Value of 0.1 and airtightness of 0.3 m3/m2/hr

The building fabric is designed to meet PassivHaus standards using Welsh products where practically possible. The house uses a Ty Unnos frame; Ty Unnos is a Welsh tradition of building 'a house in one night'. This tradition has been developed by Coed Cymru and Design Research Unit Wales as a construction system using local expertise to use low value local softwoods for sustainable housing. The Welsh tradition of Ty Unnos is fitting for the Ebbw Vale area, as several 20th century Ty Unnos houses exist around the Vale. The design of the house has been driven by an understanding of the constraints and opportunities Ty Unnos offers, such as the limits of the portal frame. The system is perfectly suited to a simple longhouse form, allowing an optimum configuration of Sitka Spruce frames to create a linear 'tube'.



The frame sits on a concrete raft foundation with 250mm Yelofoam insulation below the slab and 100mm Rockfloor below the screed to achieve a U Value of 0.07W/m2K.

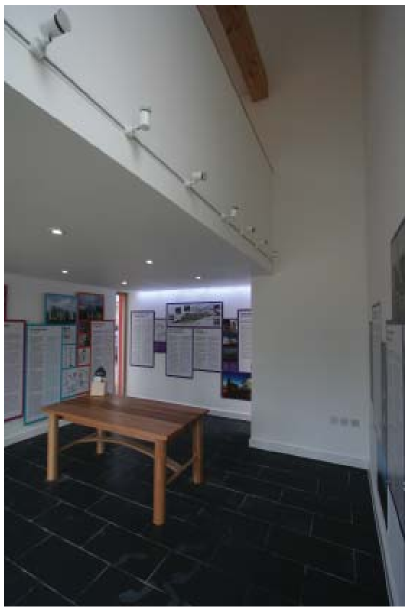
Ty Unnos portals at 3.6m intervals are filled with Warmcell insulation. Sitka Spruce ladder beam panels with OSB sheathing infill the frame and are insulated with blown Warmcell once installed. An Intello membrane provides high levels of airtightness throughout. At ground floor, an insulated render system with 120mm rigid insulation board provides external finish, while at first floor drained and back ventilated sweet chestnut vertical cladding is fixed to Gutex wood fibre insulation board. All walls achieve a U Value of 0.11W/m2K. Roof panels are the same Ty Unnos frame and infill as the wall; as at first floor, Gutex woodfibre boards provide external insualtion with weather protection provided by a Corus Colourcoat Urban seam roof system.

Airtightness is provided by a Pro Clima Intello Plus membrane. This product is a vapour barrier and airtightness membrane that offers high diffusion tightness in winter, protecting against condensation, and a high level of diffusion openness in summer, allowing rapid drying.

Systems

Hot Water:	4m2 Solar Hot Water panels
Heating:	Mechanical Ventilation and Heat Recovery with gas back up system
Electrical:	Photovoltaic array to be installed once converted to house

The PassivHaus method aims to reduce heating loads through a highly efficient and airtight building fabric. Heating requirements in a true PassivHaus are provided by solar gains and a Mechanical Ventilation and Heat Recovery system. This recovers warmth from exhaust air in the kitchen and bathrooms to warm incoming air, which is circulated around the house.

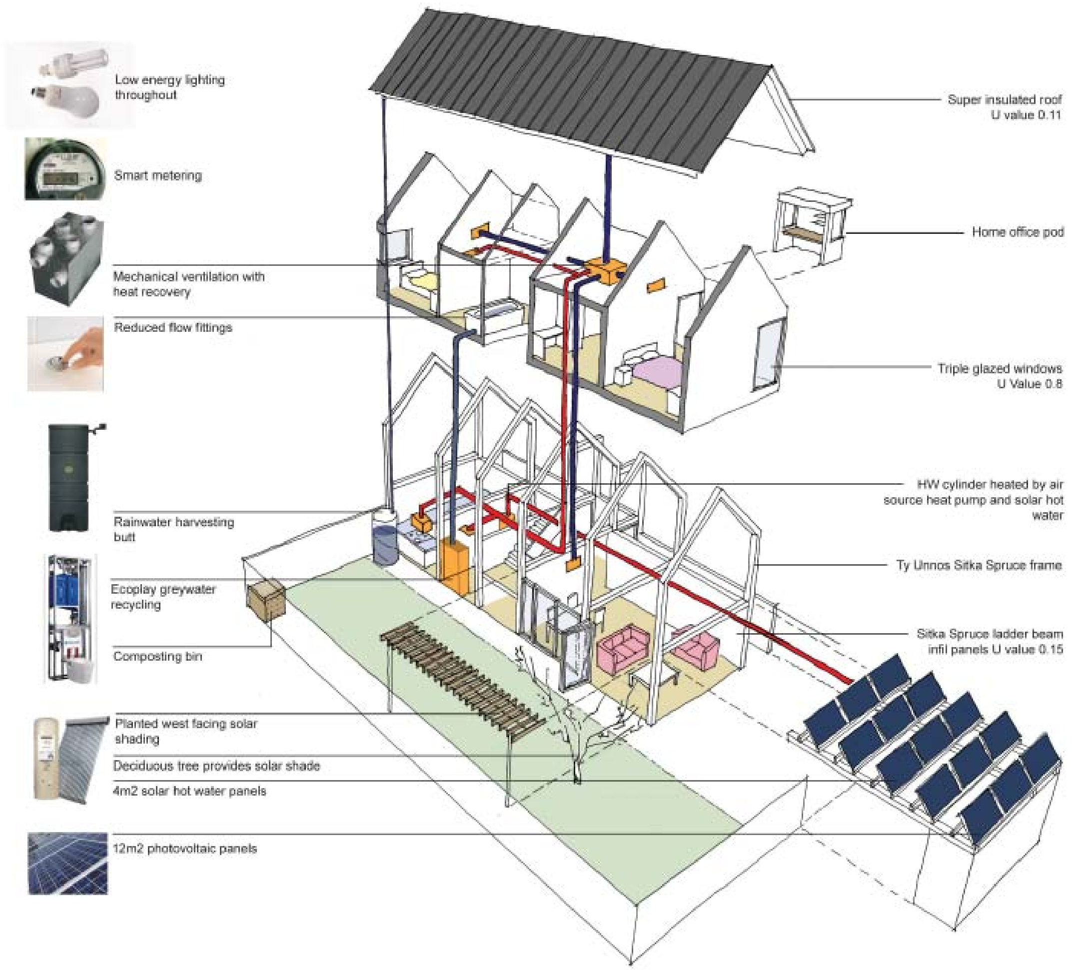


The Future Homes Visitor Centre follows these principles. However, as PassivHaus is still relatively new in the UK, a back up system was installed; the house effectively has two heating systems, increasing cost and complexity:

- A whole house MVHR system provides primary heat and ventilation. Housed in the first floor bathroom it recovers heat from the kitchen and bathrooms to warm incoming air.

- A triple coil 250 litre insulated tank (100mm insulation) is linked to 4m2 flat plate solar hot water panels on the south facing roof. This provides hot water to the house.
A gas condensing boiler provides back up heat. This feeds low temperature underfloor heating at ground floor and radiators and towel rails at first floor. The boiler has a feed to the MVHR post heater to provide additional heat if required in winter.

The house was assessed using PHPP, the PassivHaus assessment tool. Despite meeting the U Value and airtightness requirements and using an MVHR system, the house does not meet the Space Heating Demand target of 15 kWh/(m2a). This could be attributed to several factors; the overall size and proportion of the house, which is less compact than many PassivHaus dwellings; the length of the north elevation; the U Value of the windows not being as high as a similar German system; and insufficient thermal bridging data.



Code pre-assessment has been carried out on the visitor centre, but a full assessment cannot be completed until it is converted into a house. In its Visitor Centre form, the building is a Code Level 4 home, but it is incomplete as there are several items to be added when converted into a house. These include bin and bike stores, home office fit out, a composting bin and photovoltaic panels.

Construction

The competition phase of the project was completed in October 2009. The entry came in third place, and in January 2010 the design team was appointed for the visitor centre. Delivery of the Visitor Centre was required by the Eisteddfod Festival in July 2010. As the project was a prototype for the Ty Unnos system, a traditional contract route was preferred. A contractor with experience of the system was chosen; G Adams Construction Ltd had experience using Ty Unnos on an Environmental Resource Centre on The Works site. The contractor had no experience of building to high Code levels or PassivHaus standards.

Site practice and construction

The site management strategy was influenced by the prototypical nature of the project. A very close working relationship between the contractor, Ty Unnos supplier, and architect developed. The project architect was on site to guide the construction process as the building was erected.

Site waste and management processes were not documented sufficiently to gain additional code credits. Unlike some of the other case studies, no formalised training of the workforce was carried out on site, although additional training for the contractor included installation methods for TATA Steel's Urban Roof system.

Time lapse images showing frame construction over a period of just over 2 months

Supply chain

An aim of the project was to construct the Visitor Centre to PassivHaus equivalence using local materials and suppliers. The contractor and design team used approximately 80% of the building materials, suppliers and sub-contractors from within Wales.

The use of local suppliers and SME's has meant that there is no chain of custody in place for materials. Many of the suppliers use sustainable materials, but the 'paper chase' to document this through supply, processing, manufacture and construction is a time consuming process. As the Ty Unnos system is designed to use timber that is not typically considered suitable for construction, there is no FSC certification for this despite being from sustainably managed forests overseen by Coed Cymru.

Buildability

The nature of Ty Unnos is that it is a simple system to construct with low-tech construction techniques. The frame and infill panels were prefabricated by Kenton Jones in Welshpool and delivered in phases to site. Once the concrete slab was in place, the ground floor frame and infill took one day to complete and the first floor two days.

Products, suppliers and manufacturers within Wales:
steel standing seam roof
internal/external slate
Ty Unnos structure,
Warmcell insulation,
airtightness membranes
and pressure testing
Coed Cymru

50mile radius:
slate
plant hire
ironmongery

40mile radius:
Rockwool insulation
flashings
radiators
ironmongery
solar water panels
timber suppliers
architects
engineers

30mile radius:
Woodfibre insulation
fencing
welfare and stores
MVHR installation

20mile radius:
fencing
scaffolding
External render
Blaenau Gwent CBC
main contractor
electrical contractor
window, stair and floor joinery
tiling
general building supplies
Plant/ equipment
concrete
screed

M&E coordination

The aim with the M&E systems was to incorporate as much as possible within designated spaces in the loft, two airing cupboard spaces in the bathrooms, and within the wall and intermediate floor zones. The MVHR unit is located in the loft space with straight duct runs for hot air exhaust and cool air intake. However, routes around the house were more complex. Ty Unnos box beams at each portal location meant that ducts could not run continuously within the depth of the floor, and at ground floor a suspended ceiling was required to carry the extract pipes. A similar issue was encountered with routing of extract ducts to the kitchen.

Testing

Air permeability tests were undetaken at three points in the construction period; firstly, when the intello membrane was installed to test for failures in the membrane; secondly, after plasterboard was installed, and finally when completed. The first two tests achieved good results, but the third test highlighted an installation problem in the airtightness seal around the flue. This was resolved and airtightness of 0.3 m3/m2/hr @ 50pa achieved.

Finishing the visitor centre

The house will be finished once the Future Homes exhibition closes. At this point the house will be assessed under the Code for Sustainable Homes; at present the rating is provisional. In order to complete the house, bathrooms and a full kitchen will be installed. Additional requirements to achieve Code credits will also be added; these include a bin and bike store, composting bin, water butt and a photovoltaic array with a minimum of 2.75kWp.

One issue that needs to be overcome is to resolve thermal bridging calculations. Without these for the bespoke Ty Unnos system, the SAP assessment has to use default values, significantly reducing fabric performance. The Fabric Energy Efficiency without these values is 56.75kWh/m2/yr; if the bridging values were reduced the house would achieve beyond the mandatory 46kWh/m2/yr.

Building in use

The house is currently not occupied and monitoring has not taken place, although the performance of the heating system will be monitored during winter 2012.

A major problem encountered with the heating and ventilation system has been the dryness of the internal environment. As the building has an extremely airtight fabric, there are no occupants, and the MVHR system removes moisture from the air, the internal conditions have caused the timber floor to dry out and shrink. This could have been avoided by installing drier timber.

Project team:

Client: Blaenau Gwent CBC
Architect: Design Research Unit Wales
Main Contractor: G Adams
Ty Unnos system: Coed Cymru, Kenton Jones, Design Research Unit Wales, Burroughs, Pontrilas Timber, Technology Strategy Board
Structural/civil engineering: Burroughs
M&E/Code Assessors: BRE Wales, Welsh School of Architecture
Contract Value: £250,000

Design Research Unit Wales & Welsh School of Architecture

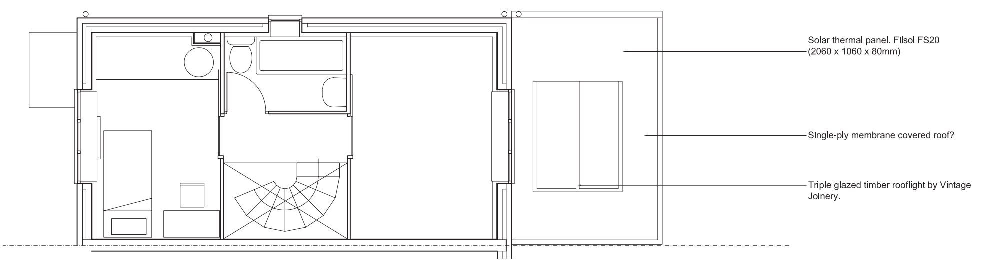
Retrofit for the Future, The Turnstiles, Newport

A carbon cutting retrofit of a two-bedroom, brick and block end of terrace house in Newport. The retrofit includes improvement of the building fabric, a single storey extension, and installation of renewable energy systems, cutting carbon emissions to 17 kg/m^2 per year.

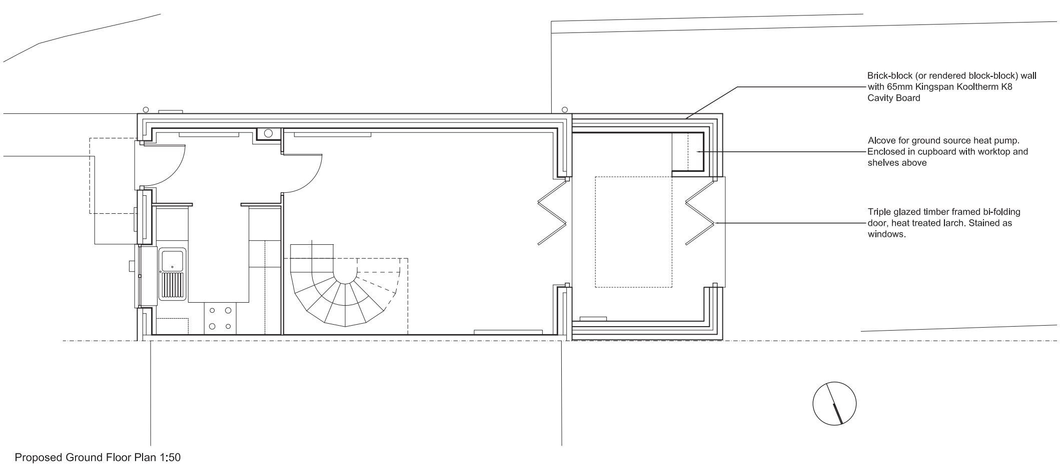
Funded by the Technology Strategy Board as part of its Retrofit for the Future scheme, this retrofit aimed to dramatically cut the energy use and carbon emission of a 1980s urban semi-detached (end terrace) two bedroom three person house in Newport, South Wales.

The property had a small entrance hall open to the kitchen, and lounge with door direct to the garden on the ground floor. The first floor accommodated 1 double bedroom, 1 single bedroom and a bathroom. The total internal floor area was 56m2.
Construction was brick-block cavity wall with subsequent blown cavity insulation, concrete slab floor, tiled timber truss roof, loft insulation in poor condition, timber double-glazed windows in poor condition, with gas central heating.

Purchased as part of housing stock from private developers by Charter housing association during a previous recession - the house did not meet space standards usually required of new-build social housing. It was lacking in living and amenity space, presenting an additional challenge to the retrofit team. The solution and design method adopted are particularly useful for properties where amenity and space standards are an issue.



Proposed First Floor Plan 1:50



Proposed Ground Floor Plan 1:50

The team set out to achieve a successful carbon cutting retrofit which was integrative, technologically robust, holistic and people focused. Meeting the energy and carbon targets was a top priority. The measures adopted were to be agreed by all stakeholders including landlord and tenant, and to fit in with existing maintenance practices. It was agreed that energy efficiency measures would be a first step to achieve the deep carbon cuts aimed for as a preface to the application of appropriate renewable technologies. For replication purposes, it was important that proposals caused minimal disruption to the household as decantation was to be avoided. A scheme that did not involve the requirement of planning permission was also favourable. The project is therefore based on the involvement of a real 'maintenance supply chain' including tenant liaison officers; tenant interviews and satisfaction surveys and value for money design interventions.

Four aspects of the property were considered:

Form and space	to reduce energy demand, improve daylighting and address lack of living space and amenity.
Fabric	to reduce heat losses and draughts and improve occupant comfort.
Appliances	to reduce energy demand from white goods and lighting.
Systems	to provide energy from renewable sources.

To achieve the objectives a decision making matrix was developed and used by the project team to identify the optimal, practical and replicable low carbon solution for this property. Each proposal was valued against carbon savings, whole life costs, buildability, locality of suppliers, replicability and comfort conditions. Property survey and analysis, modelling results and expertise of the various team members all contributed to this collaborative process. Relative costs and future cost savings were analysed for each of the options proposed. Costs per Kg CO^2 saved were also modelled and considered. Future maintenance costs were important to the client. The tenants (user clients) were consulted regularly throughout the design stages so that their opinions and concerns could be taken on board, and so that they better understood why and how their home was being retrofitted.

Retrofit

	U-value	Description
Walls	0.19	Internal insulating drylin-ing, 72.5mm (32.5mm at reveals) added to existing
Party walls	-	No modifications to fabric
Roof	0.16	Original loft insulation replaced with 100mm Warmcel between joists, 2 layers 52.5mm thick Knauf Space Board, 18mm chipboard
Floor	0.35	No modifications to fabric
Windows	0.9	Replaced with triple-glazed, heat treated larch framed windows by Vintage Joinery
Doors	0.9	Replaced with triple-glazed, insulated, heat treated larch doors by Vin-tage Joinery

Extension

	U-value	Description
Walls	0.22	86mm SIPs with 100mm EPS insulated over
Party walls	-	NA
Roof	0.18	Steel cassette with 130mm Kingspan insula-tion
Floor	0.15	Reinforced concrete raft, with 100mm insulation (30mm at perimeter) with 50mm screed over
Windows	0.9	Triple-glazed, heat treated larch framed roof light by Vintage Joinery
Doors	0.9	Triple-glazed, heat treated larch framed bi-fold door by Vintage Joinery

Passive design

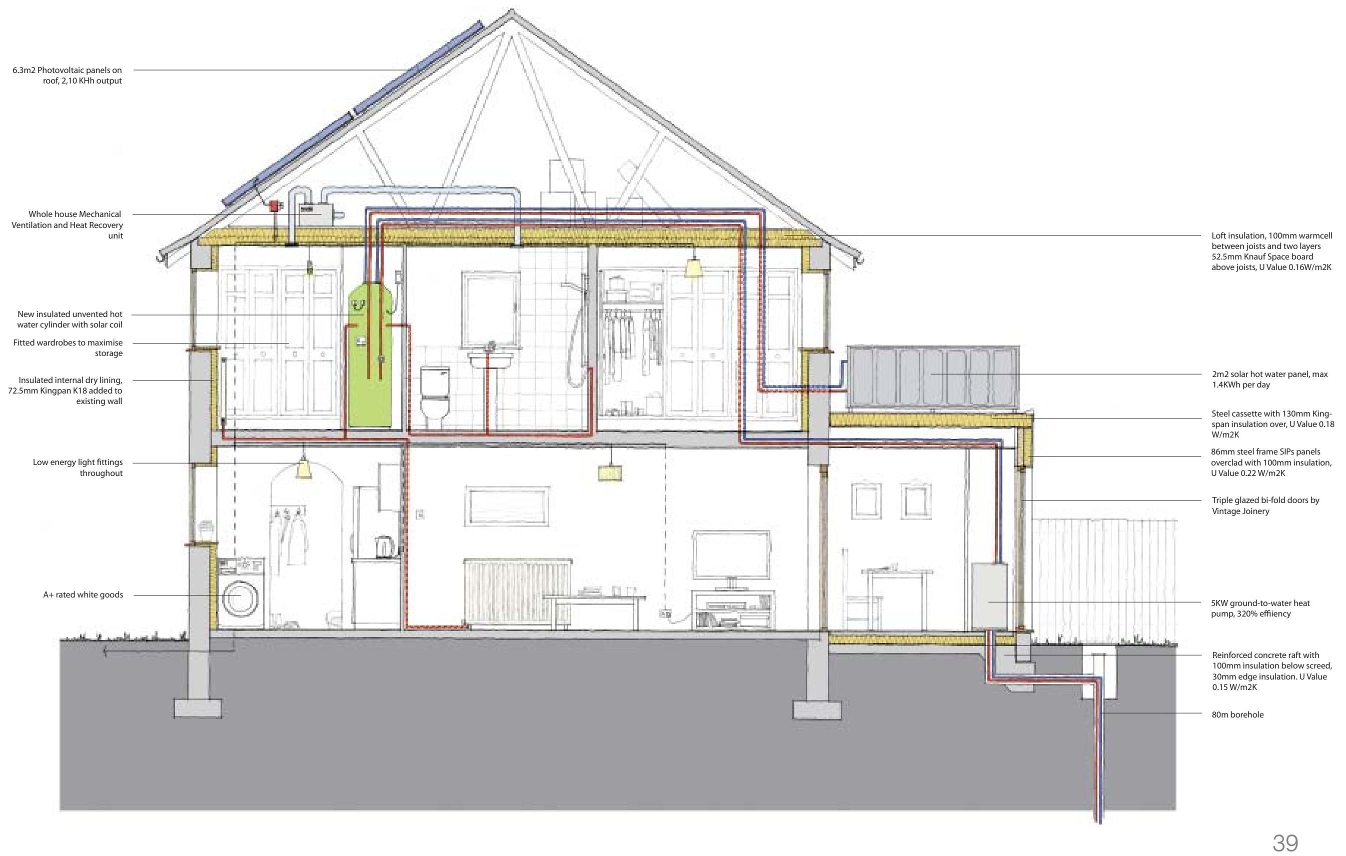
Oportunities for passive design are limited in retrofit projects as the siting, orientation and form of the building have already been decided. This project made use of natural daylighting by incorporating a large rooflight in the extension and a light pipe over the landing which previously had no source of daylight.

Fabric performance

With high levels of insulation the SIPs construction extension acts as a buffer to the living room. Insulating dry-lining has been installed internally, and loft insulation replaced and improved. Triple-glazed windows were fitted throughout.

72.5mm thick Kingspan K17 insulated dry-lining was fitted internally over the existing wall finish, with 32.5mm used on the reveal returns. All windows and doors were replaced with triple-glazed timber frame units to improve thermal performance and air-tightness. In the loft, the existing insulation, which was in a poor condition, was replaced with 100mm deep Warmcel recycled paper between the joists and two layers of 52.5mm thick Knauf Space board insulation above. Boarding allows for additional storage space in the loft.

The new extension is insulated above Building Regulations requirements. 86mm thick SIPs panels are over-clad with 100mm insulation to give a U-value of 0.22. The extension houses the ground source heat pump, and gives the tenants additional space to replace that compromised by the internal insulation and extra equipment associated with the retrofit. Built-in storage was added in the bedrooms to make storage space more efficient for the same reason.



Systems

Hot Water:	2m2 solar thermal panel, max 1.4KWh per day for hot water on extension roof.
Heating:	5KW ground source heat pump with 80m deep borehole Whole House Mechanical Ventilation and Heat Recovery
Electrical:	6.3m2 Photovoltaic array, 2.1KWh

To reduce energy use and carbon emissions to the levels required, a number of systems were installed in the house as part of the retrofit. A ground-to-water heat pump (electric) with 320.0 % efficiency, using radiators on a standard tariff has been installed. The controls include time and temperature zone control. The hot water system has evacuated tube collectors (2m2) mounted on the building which feed into an unvented cylinder with Solar Coil. Whole house ventilation is provided by an MVHR system which extracts stale warm air from the bathroom and kitchen and inputs warmed fresh air to the living rooms and bedrooms. 2KWhp Photovoltaic panels are fitted on the front roof.

Environmental modelling

Modelling using SAP plus 'whole house extension' was used from the outset. Modelling was used to predict the carbon savings and fuel cost savings of different options compared to the base case. Each option was modelled individually
The carbon savings calculations were made for each individual option considered using Builddesk Energy Design 3.4.

The total carbon savings made as a result of this suite of retrofit measures has been calculated using SAP with the extension to be a reduction from 103 kg/m^2 per year to 17 kg/m^2 per year. This equates to a 83% CO_2 kg/m^2 savings. This is much higher than that predicted in the original proposal.
The space heating demand is reduced from 224kwh/m^2/yr to 64kwh/m^2/yr.
The fuel cost for the householder will reduce from £598 to £212 per year therefore saving £386 per year.
Total CO_2 emissions will reduce from 6071 kg/yr to 1304kg/yr, making a saving of 4767 kg/yr.

Construction

Materials and supply chain

Materials were chosen which could meet the performance levels required to reach the targets. Where possible, local, low-impact materials and local trades were specified. Maintenance and durability were also concerns. The project builds on established supply chains and frameworks in place at Charter Housing to allow continuity and familiarity in supply, installation and maintenance. All manufacturers, suppliers and contractors are UK based and local to Newport where possible, promoting local economy and reducing carbon emissions related to transport.

Micaul provided all the renewable energy technology and were involved at a later stage when major design decisions had been made. Using one company for all the renewables made coordination easier. Some alterations had to be made to the design to accommodate the products they could supply.

Building in use

The house will be monitored for 24 months to assess its performance. Power consumption of the MVHR unit will be monitored in conjunction with input and output airflows and temperatures. The opening of windows will also be monitored in order to identify when occupants deem internal conditions unsatisfactory and whether this dissatisfaction occurs while comfort technologies are operating. An envelope air tightness test will also be carried out. The integrated solar thermal and ground source heat pump, will be fitted with heat meters to monitor the DHW, heating and solar thermal outputs. Parasitic loads associated with the system will also be monitored.

Temperature and relative humidity will be monitored at 4 different locations (including externally) and CO_2 will be monitored in the main living area. The contribution of the photovoltaic array will be monitored using a kWh meter, and Pyranometers will be situated on the roof to collect data on solar intensity.

Project team:

Client: Charter Housing
Architect: Design Research Unit Wales
Main Contractor: Charter Housing
Sub-Contractors: CWE Electrical,
Micaul Renewable Energy Systems
Structural engineering: WL2 Ltd
M&E: Welsh School of Architecture
Contract Value: £122,942

The work reported here has been funded by the Technology Strategy Board under the Small Business Research Initiative (SBRI) under the Retrofit for the Future programme. This project is one of nearly 90 projects funded under the programme. Further information on the programme can be found at:

www.innovateuk.org/retrofit
http://www.retrofitforthefuture.org/viewproject.php?id=96#figures

Summary of findings

Fabric first and passive design

All the case studies examined started with passive design principles from the outset, except for The Turnstiles where the building form and orientation were given. The use of passive design considerations, such as building, glazing and roof orientation can maximise the benefit of 'free' elements of sustainable design, such as access to sunlight, natural ventilation, and optimum orientation for technology.

Delivering a high performance fabric creates a strong foundation to maximise the efficiency of low and zero carbon technologies. By designing to a high performance level means homes will be less likely to require expensive fabric refurbishment in the future. In all cases, fabric performance far outperformed Building Regulations, with Old Town Dock, St Athan and the Future Homes Visitor Centre meeting the expected U-Value requirements in the Fabric Energy Efficiency Standard.

Balancing regulatory demands

Social housing is Wales is required to meet a range of different standards, including Welsh Government Development Quality Standards, The Code for Sustainable Homes, Lifetime Homes, RNIB accreditation, Building Regulations and Secured by Design standards. Meeting this range of accreditations can add to cost, as different measures are required for each. A revised regulatory system or guidance document that incorporates all these standards and resolves conflicts between them might make provision of social housing simpler and easier. The draft consultation document '*The London Housing Design Guide*' is a good example of how this might be delivered.

Working with a team

All the projects were delivered by strong partnerships between contractor, architects, sub-contractors, code assessor and client. This can result in an integrated solution with all parties understanding and feeling ownership of the project.

Air tightness and thermal bridging

All the case studies achieved a high level of airtightness, between 3m3/m2/yr and 0.3m3/m2/yr. All projects required numerous airtightness tests to achieve these levels, adding additional costs to the projects. On larger schemes such as Old Town Dock the details required to achieve the airtightness can be fine tuned on a single unit and repeated across the site. On this project the first completed unit required three tests to achieve an airtightness of 3m3/m2/yr, but all others required only one.

The use of prefabrication, or Modern Methods of Construction (MMC), can help to improve airtightness. Lower tolerances and factory finished quality and detailing result in reduced air leakage. MMC has further benefits of a predictable delivery timescale and reduction in site waste.

Three of the case studies were assessed under Building Regulations 2006, before thermal bridging calculations became a requirement in 2010. The experience of the Future Homes Visitor Centre demonstrates the complications of using non-standard details to calculate thermal bridges. The Ty Unnos system had no modelled details, resulting in the default values being used. This affected the SAP calculation and reduced the reported expected performance of the fabric.

Cost

At present a major barrier to wider adoption of low carbon design is the additional cost of development. While the cost of achieving Code levels has been documented, predicted costs of meeting the latest definition of 'zero carbon' have not yet been published.

At present, the average cost of mixed new build housing developments is £851 sqm.[1] All the case studies cost approximately 150% or more than this figure. While to some extent the larger footprint and more stringent regulatory requirements (Lifetime Homes, DQR standards, etc) contribute to this increase, the need to meet higher levels of the Code for Sustainable Homes results in a large proportion of this additional cost.

Social housing grant in Wales is distributed using Acceptable Cost Guidelines (ACG). The cost of Chapel Close was 128% ACG. 8% over the acceptable limit at the time. The acceptable limit of ACG has since been amended to £1250 sqm for a Code 3 house and £1350 sqm for a Code 4 house.[2] Overall cost was therefore well within these revised guidelines. However, there remain few Code 5 or 6 developments in Wales, making it difficult to predict an average cost increase to reach these levels.

A report published in 2011 by Element Energy and Davis Langdon, based on market tested industry data, concludes that there is significant variation in extra over cost at each Code level. Typical percentage increases over 2006 Building Regulations baseline are 3-4% at Code 1, 3.5-4.5% at Code 2, 4-5.6% at Code 3, 8.7-10% at Code 4, 27.7-30.8% at Code 5 and from 45.7-53.4% at Code 6.[3] At lower Code levels (1-3), fabric improvements are enough to meet the mandatory energy credits, but for Code 4 and above in most cases some form of low/zero carbon technology is required. These costs start to dominate the expense of meeting the required code level, particularly when photovoltaic panels are required to meet Code level 5&6.

Other reviews suggest higher uplift costs. Lee Wakemans' '*Cost Report*'[4] suggests a uplift of 5-10% for Code 3, 14-28% for Code 4, and 59-64% for Code 5. The basis for comparison was a 2006 Building Regulations standard home; the house was modelled with different construction techniques (cavity wall, timber frame, thin joint blockwork and Durisol) and costed accordingly. The report notes the impact of the recession on cost predication at the present, suggesting there is very little cost data that has been derived from true competitive tendering. As such the costing in the report is based on cost planning or trials, and there is an element of uncertainty in the predictions. Emerging construction strategies and labour skills requirements will also impact on future costs.

Consumer attitudes toward low carbon homes

Related to cost is the need to convince the market that zero carbon homes represent a valuable investment and drive demand for low carbon homes. While the case studies are all social housing, increasingly volume housebuilders will be required to deliver more sustainable homes to more demanding standards. The Zero Carbon Hub in the report '*Marketing Tomorrow's New Homes*' identify that most consumers do not see low carbon as a benefit, but see it as a potential lifestyle sacrifice driven by legislation. Instead, ZCH suggest that 'zero carbon homes' should be remarketed so as to appeal to the consumer. Rather than talking of zero carbon homes, a notion that many consumers do not understand, zero carbon should be marketed as a benefit. Rather than a niche market, low or zero carbon should be seen as an important and integral part of the future development of housing, and not an isolated issue.

Household management

Alongside issues of demand are the requirements for running a low carbon home. New technologies may require a different management strategy for the home, particularly systems supplying lower levels of heat, such as underfloor heating. If Passivhaus principles are followed then in order to maximise performance a change in lifestyle may be required to minimise loss of gains through opening windows and doors for extended periods.

This will require a change in lifestyle from home owners and customer education for the benefits of low carbon housing to be maximised. At Old Town Dock residents were given a DVD explaining their new home and a comprehensive and clear user manual. Charter Housing have revisited each resident to ensure they are comfortable running their homes and make the most of the systems installed.

With the gradual adoption of low energy solutions by volume house builders it will be important that this message is passed on between consecutive owners. Unlike the case study examples, where properties are managed by one landlord, in the private market the housebuilder will have no role once the house is sold which could lead to future owners lacking an understanding of how to run their house efficiently.

Endnotes to case studies

1 BCIS (Building construction information service) 30.07.11 update, based on Q3 2011 prices and mean UK location. Accessed 11.08.11
2 Constructing Excellence, 'Exemplar Pilot Case Study: St Athan Housing Development' p3
3 CLG, 'Code for Sustainable Homes: A Cost Review', August 2011
4 REF Lee Wakemans, 'Cost Report on the Code for Sustainable Homes: An independent report by Lee Wakemans for the promotion of discussion and understanding within the industry', February 2010

Further information:

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CLG (2007) 'Building a Greener Future: Policy Statement'.
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HM Government (2011) Low Carbon Construction Action Plan: Government Response to the Low Carbon Construction Innovation & Growth Team Report'.
Lee Wakemans (2010) 'Cost Report on the Code for Sustainable Homes'
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This report is the first output of the Low Carbon Research Institute's (LCRI) Low Carbon Built Environment programme work package, 'Design of Low/Zero Carbon Buildings.' The objective of the project is to provide design teams involved in the delivery of low/zero carbon buildings with clear but non-prescriptive design guidance based on current best practice.

The LCRI was set up to unite and promote energy research in Wales, UK to help deliver a low carbon future. The multidisciplinary LCRI aims to support the energy sector, UK and globally, to develop low carbon generation, storage, distribution and end use technologies, and to offer policy advice.

The Higher Education Funding Council For Wales (HEFCW) granted £5.1 million to develop the LCRI for 5 years from April 2008. LCRI's research is also supported by contracts from the Research Councils, Industry and Government.

In 2010 LCRI secured £15 million from the Welsh European Funding Office, a contribution to a £34 million programme to enable Wales and its industry partners to lead the way in research to cut carbon emissions, as part of the European Research Development Fund's Convergence, Regional Competitiveness and Employment programmes.

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