Homes of today for tomorrow: Decarbonising Welsh Housing between 2020 and 2050

appendix A.
case studies

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CS#	PROJECT TITLE	LOCATION	COUNTRY	Newbuild or retrofit	Number dwellings	Date completed
CS01	Zero Carbon House	Birmingham	England	both	1	2009
CS02	Maes yr Onn Farmhouse	Caerphilly County	Wales	retrofit	1	2013
CS03	TSB Shorhouse	Newport	Wales	retrofit	1	2010
CS04	SOLCER retrofit - Galltcwm Terrace	Bryn, Port Talbot	Wales	retrofit	1	2014
CS05	SOLCER retrofit - Cricklewood Close	Bridgend	Wales	retrofit	1	2014
CS06	SOLCER retrofit - Tyn y Waun	Bettws	Wales	retrofit	1	2014
CS07	SOLCER retrofit - King Street	Gelli	Wales	retrofit	1	2014
CS08	SOLCER retrofit - Poppy Close	Sandfields	Wales	retrofit	1	2014
CS09	SOLCER house	Pyle	Wales	new build	1	2015
CS10	Pentre Solar	Pembrokeshire	Wales	new build	group	2016
CS11	Milford Way Passivhaus	Swansea	Wales	new build	group	2017
CS12	LCBE retrofit - Taff Street	Gelli	Wales	retroft	1	2018
CS13	Energy Efficient Scotland	Stirling, various	Scotland	retrofit	3,700	ongoing
CS14	BRE park victorian terrace	Watford	England	retrofit	4	2011
CS15	Retrofit for the Future house #1	North Belfast	N Ireland	retrofit	1	2001
CS16	Retrofit for the Future house #8	London	England	retrofit	1	2001
CS17	Retrofit for the Future house #35	Norfolk	England	retrofit	1	2010
CS18	Retrofit for the Future house #109	West London	England	retrofit	1	
CS19	Residential Retrofit - Grove Cottage	Hereford	England	retrofit	1	2010
CS20	Residential Retrofit - TSB#57 Highfields	Leicester	England	retrofit	1	
CS21	Residential Retrofit - TSB#57 Hawthorn Road	North London	England	retrofit	1	
CS22	Residential Retrofit - TSB#51Shaftesbury Park Terrace	Wandsworth, London	England	retrofit	1	
CS23	Residential Retrofit - TSB#98 Easton Road	Bristol	England	retrofit	1	
CS24	CarbonLight Homes	Kettering (Northhamptonshire)	England	new build	2	2011
CS25	Reno2020 - Rue Molinay	Liege	Belgium	retrofit	1	2012

CS26	Retrofit for the Future house (Cambridge)	Cambridge	England	retrofit	1	2010
CS27	Retrofit and Replicate	South London	England	retrofit	1	2009
CS28	Low Carbon Adaptable Home	Dublin	Ireland	new build	1	2013
CS29	Salford Energy House - Saint-Gobain whole house retrofit	Salford	England	retrofit	1	2015
CS30	Salford Energy House - BEAMA Heating Controls Group	Salford	England	retrofit	1	2013
CS31	Heathcott Road, Leicester	Leicester	England	new built	68	2017
CS32	Greylingwell district heating and CHP	Chichester	England	retrofit and new built	780	
CS33	West Bridge Mill CHP	Kircaldy	Scotland	retrofit	16	
CS34	Edinburgh social housing CHP	Edinburgh	Scotland	new built	192	
CS35	Flat retrofit in Serbia	Belgrade	Serbia	retrofit	1	2011
CS36	Cymdeithas Tai Eryri's ARBED 1 scheme	Norht Wales	Wales	retrofit	410	2011
CS37	Retrofit for the Future house (Oxford)	Oxford	England	retrofit	1	2010
CS38	Cymdeithas Tai Eryri improvement of 'hard to heat' homes in Gwynedd	South Gwynedd	Wales	retrofit	24	2012
CS39	Trem y Môr Terrace renovation pilot scheme	Trefor	Wales	retrofit	5	2010

Case study: CS 01

Project title:	Zero Carbon Home
Location:	Birmingham
Project size:	1 dwelling, 204sqm
Project type:	retrofit and newbuild
Dwelling type:	end of terrace
Dwelling age:	pre 1919 (1896)
Construction type:	masonry - solid wall
Date of works:	2008-2009
End user:	private single household
Funding source:	private
Contact:	John Christophers
Project team:	John Christophers (architect) * *

Key words: **zero carbon | active house**

Summary:

(source: Low Energy Buildings Database)

"Half the scheme retrofits a 170-year old terraced house - the other half is new - all working to AECB Gold standards and roughly PassivHaus insulation and energy levels.

Solar thermal and PV on the roof with other measures take the project to certified Code for Sustainable Homes level 6, using "true zero carbon" - ie 100% renewable energy is generated. 3-storey load-bearing earth block structure, rammed clay floors, reclaimed timber, and other very low embodied energy materials.

RIBA Architecture Award 2010; RIBA Manser Medal Finalist 2010; Retrofit Award 2011; Considerate Constructors Award 2010; Constructing Excellence Award 2011."

Believed to be the first UK retrofit to achieve CfSH level 6 and true zero carbon.

Headlines:

Primary energy requirement 38kWh/sqm.year (measured)
Annual CO2 emissions 7kg CO2/sqm.year (measured)
Electricity generation (PV) 4030kWh/year (measured)
Cost £1700/sqm (2009)

Related literature:

Own website: http://zerocarbonhousebirmingham.org.uk/
Low energy buildings database
http://www.lowenergybuildings.org.uk/projectPDF.php?id=214
Designing Zero Carbon Buildings Using Dynamic Simulation Methods by Dr Ljubomir Jankovic
The Zero-Carbon House by Martin Cook
New York Times article:
https://www.nytimes.com/2010/12/16/greathomesanddestinations/16location.html?ref=greathomesanddestinations&_r=0

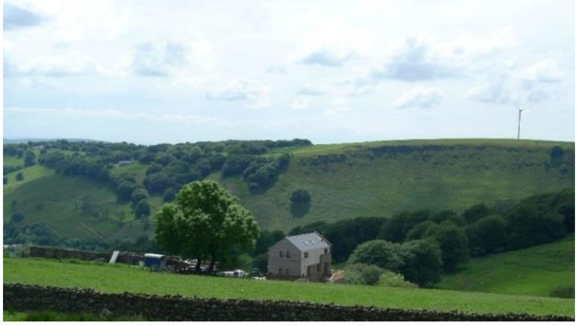
reference	action theme*	details	evidence
action 01	Strategic	The client set out explicitly to design and build a zero carbon home. They decided from the outset to maximise passive solar gains (oriented 30degrees west of south), high thermal mass and natural ventilation.	
action 02	Strategic	They spent time living in the property to fully understand its operating characteristics and optimise the design. Top lighting / mirrors to reduce electric lighting demand.	Modelling undertaken using PHPP and THERM
action 03	Fabric	Existing front elevation is internally dry-lined. Walls U=0.11: existing and new blockwork rear/sides externally lime rendered Neopor insulation. Roofs U=0.08: existing slate roof internally insulated. Unfired rammed earth floors insulated from below. Triple glazed windows and doors. Airtightness achieved through installation of vapour permeable membranes to all roofs, and front elevation. Wet plaster to existing and new walls elsewhere, linked to membranes. Final airtightness 0.9 m^3/m^2.hr @ 50 Pa	
action 04	Services	Gas fired boiler removed and replaced with wood burning stove. Wood burning stove and solar hot water rated to provide 80% of output to hot water cylinder. Occasional fuel for the stove comes from the garden. Two towel radiators in bathrooms also run from hot water cylinder. MVHR (winter only) with supplementary heater battery.	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and CO_2 calculated.
action 05	Renewables	5kWp roof-mounted PV. Solar hot water, also on roof, with electric immersion heater backstop.	
action 06	People	The occupants, as both design team and client, were fully invested in the project, and designed it around their needs.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	the character of the street constrained the form nature and detailing of the refurb.	action 03
challenge 02	Existing building	Planning constraints meant that external insulation could not be used	action 03
challenge 03	Financial	Capital cost is high (bearing in mind this is partially a new-build project) – total costs of £350,000	all actions

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 02



Project title:	Maes yr Onn Farmhouse
Location:	Caerphilly County
Project size:	1 dwelling
Project type:	newbuild
Dwelling type:	detached
Dwelling age:	2013
Construction type:	Choose an item.
Date of works:	2013
End user:	private
Funding source:	Self / SSE
Contact:	Simon Lannon
Project team:	Arthur Davies, Self Build/ SSE for services, BRE Andy Sutton, CCBC RDP Energy team

Key words: **Battery | off-grid**

Summary:

The Manmoel area comprises a small upland village with surrounding hill farms in the county borough of Caerphilly in South East Wales. The remote rural community's activity is largely based on agriculture.

The farm, established in 1825, comprises of 84 Ha and has been farmed on a commercial basis for over 30 years. Unfortunately, the original farmhouse fell into disrepair many years ago and the family lived off-site. Their efforts to re-establish a presence on the farm were hampered by a lack of electricity, gas, water or sewerage services at this upland site.

Their restrictions are not unique however as, in Wales, 19% of the population is considered off grid (from mains gas, electricity, or water), a figure of 253,000 households. However, with the support of a number of organisations, the client, after a lengthy period of consultation, gained outline planning permission to construct a farmhouse on the former site in April 2012. The construction of the new farmhouse ensures effective day-to-day management of the farm and stock and will enable further expansion of the business.

Related literature:

PLEA 2015 papers http://orca.cf.ac.uk/78377 and http://orca.cf.ac.uk/78380
CEW leaflet http://www.cewales.org.uk/files/4114/4319/2722/Maes-Yr-Onn-CASE-STUDY.pdf

reference	action theme*	details	evidence
action 01	Strategic	Worked with Council rural development team to get the help require	
action 02	Fabric	Self build, achieved good standards	monitoring
action 03	Services	On site water purification, battery storage, PV, biomass. All work well	monitoring
action 04	Renewables	PV 2.6kWp	monitoring
Action 05	People	Occupants rely on top of electricity usage, used the renewable sources when available. Ran the batteries manually	monitoring

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	Wouldn't allow solar thermal as well as PV, not in keeping.	
challenge 02	Strategic	Services us the vast majority of the electricity. Freezer is in efficient, don't see the point in changing it.	
challenge 03	Supply chain	When the PV invertor failed, didn't know who to turn to. In emergency got a contractor from 80 miles away.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 03

Project title:	TSB SHOR house
Location:	Newport County
Project size:	1 dwelling, 58 sqm
Project type:	retrofit
Dwelling type:	end of terrace
Dwelling age:	1989
Construction type:	masonry - cavity
Date of works:	2010
End user:	Social housing
Funding source:	TSB Retrofit for the Future project
Contact:	Joanne Patterson
Project team:	Welsh School of Architecture, Charter Homes, TSB

Key words: **Fabric | heat pump**

Summary: The project takes a team-based approach aiming to develop an integrated, technologically robust, people focussed approach to the retrofit. The house is owned by Charter Housing Association and was built in 1989. It is located within the city of Newport in South Wales and is an end of a terrace 2 storey house with a lounge, kitchen, two bedrooms, bathroom and a garden. Three adults live in the house. Energy savings have been made through modifications to the form and space, fabric and systems in order to achieve 80% carbon reductions required. The works were undertaken during the summer of 2010 and the tenants remained in situ.

Headlines:

Primary energy requirement 120 kWh/sqm.year (80% savings, calculated)
Annual CO2 emissions 28 kg CO2/sqm.year (75% savings, calculated)
Electricity generation (PV) 774 Wh/year (calculated)
Cost £923/sqm (2010)

Related literature:

PLEA 2011 paper http://orca.cf.ac.uk/41943
Project website http://www.lowenergybuildings.org.uk/viewproject.php?id=96
Residential Retrofit: 20 case studies book by Marion Baeli
Forster, Wayne Peter and Heal, Amanda 2009. Low carbon retrofit: Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s urban semi-detached house. http://orca.cf.ac.uk/52413/

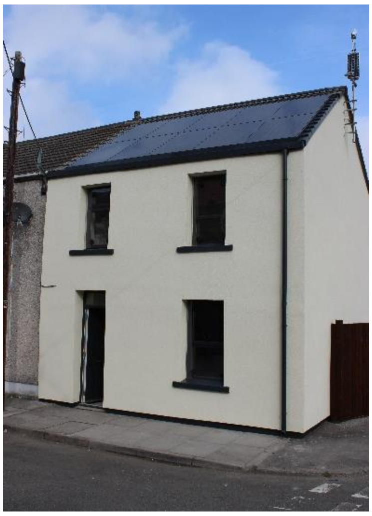
reference	action theme*	details	evidence
action 01	strategic	Worked with HA to develop holistic approach, built on long term relationships	
action 02	fabric	Work done when in situ. Internal insulation. External wall – existing cavity walls treated with internal dry lining and insulation (U = 0.19 W/m^{2}K) Roof - loft insulation (U = 0.19 W/m^{2}K) Windows – new triple-glazed non-PVC windows (U = 0.90 W/m^{2}K) Improved airtightness to 2 m^2/(m^{2}h)	
action 03	services	Ground source heat pump, PV, solar thermal. All work well	Monitoring
action 04	renewables	2 kWhp PV panels and solar thermal panels	Monitoring
action 05	people	The occupants were really happy to be part of the work as long as the dog could benefit. Lack of amenity and living and storage space has been addressed through the retrofit.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Supply chain	All manufacturers, suppliers and contractors wee UK based and local to Newport where possible. Vintage joinery were happy to develop the triple glazing units, long term relationship with WSA	
challenge 02	strategic	There was confusion about the installation of the smart meters, no one would give a simple answer.	
Challenge 03	Financial	The total cost of the retrofit measures (£53,541) was considered too high to be replicated by private homeowners	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 04



Project title:	SOLCER retrofit - Galltcwm Terrace
Location:	Bryn, Port Talbot
Project size:	1 dwelling, 67 sqm
Project type:	retrofit
Dwelling type:	end of terrace
Dwelling age:	Pre-1919
Construction type:	masonry - solid wall
Date of works:	2014
End user:	Social housing, owner occupiers
Funding source:	WEFO – Low Carbon Research Institute (LCRI) Low Carbon Built Environment/SOLCER projects
Contact:	Jo Patterson
Project team:	Welsh School of Architecture, NPT Homes (now Tai Tarian), Warm Wales, GB Sol

Key words: **Insulation | battery | behaviour | cost**

Summary: A holistic retrofit of an end terrace solid wall house where modelling was used to identify appropriate and affordable low carbon measures relating to energy demand reduction, renewable energy supply and energy storage. Stakeholders were involved in selection of appropriate measures. Whole house retrofit cost £30,452. The house was vacant before the works were undertaken and is now being rented at the mid-range rentable level. Retrofit was designed to not require planning.

Headlines:

Primary energy requirement 185 kWh/sqm.year (savings 40%, measured)
Annual CO2 emissions reduced by 64% (measured)
Electricity generation (PV) 2150 kWh/year (measured)
Cost £455/sqm (2014)

Related literature: Jones, Phillip, Li, Xiaojun, Perisoglou, Emmanouil and Patterson, Joanne 2017. Five energy retrofit houses in South Wales. Energy and Buildings 154 , pp. 335-342. 10.1016/j.enbuild.2017.08.032

Related case studies: CS05,CS06, CS07, CS08, CS09

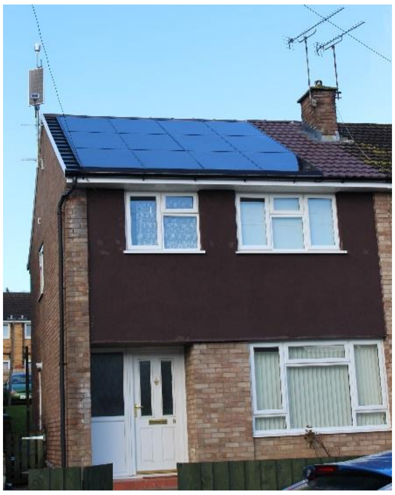
reference	action theme*	details	evidence
action 01	strategic	Work with RSL and supply chain to help develop confidence in applying technologies and the supply chain to combine technologies.	RSL increase retrofit work and fully supported the project.
action 02	strategic	Affordable low bills	Energy bill reduction 62%.
action 03	strategic	Moving homes from unlettable back into the market	The property was empty before and during the retrofit. Lettable at mid-range rent following retrofit.
action 04	Fabric	External Wall Insulation (100mm) Loft insulation 300mm Low e double glazing	Energy and carbon savings, more comfortable environment. Gas reduction 56%
action 05	services	MVHR, LED lighting, new gas boiler with hot water tank, controls, 4.8kWh lead acid battery to feed LEDs and hot water.	Energy and carbon savings, more comfortable environment.
action 06	renewables	2.5kWp integrated renewables PV roof	Energy generated on site – carbon savings. Electricity reduction 37%. CO_2 reduction 64%

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	People	When the occupant moved in they did not change their behaviour patterns, leaving windows open all year round and heating hot water 24 hours a day. They then complained that their bills were still high.	Advice was given but this had no impact.
challenge 02	Strategic	The battery system was very basic. The research team held little knowledge about the complexities of selecting appropriate batteries for dwellings.	As more retrofits were carried out more advanced battery systems were applied
challenge 03	financial	The cost of the retrofit as a whole is still beyond what is considered by the research team to be of affordable.	Monitoring of the occupants and the building have been undertaken to provide evidence of the impact of the Actions

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 05



Project title:	SOLCER retrofit – Cricklewood Close
Location:	Cricklewood Close, Bridgend
Project size:	1 dwelling, 70 sqm
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1960s
Construction type:	masonry - cavity
Date of works:	2014
End user:	Social housing, owner occupiers
Funding source:	WEFO – Low Carbon Research Institute (LCRI) Low Carbon Built Environment/SOLCER projects
Contact:	Jo Patterson
Project team:	Welsh School of Architecture, Wales and West Housing, Warm Wales, GB Sol

Key words: **Insulation | MVHR | cost**

Summary: A holistic retrofit of 1960s semi-detached cavity wall house where modelling was used to identify appropriate and affordable low carbon measures relating to energy demand reduction, renewable energy supply and energy storage. Stakeholders were involved in selection of appropriate measures. Whole house retrofit cost £27,438. The house was occupied during the works were undertaken. Retrofit was designed to not require planning.

Headlines:
Annual CO2 emissions reduced by 42% (measured)
Electricity generation (PV) 2395 kWh/year (measured)
Cost £391/sqm (2014)

Related literature: Jones, Phillip, Li, Xiaojun, Perisoglou, Emmanouil and Patterson, Joanne 2017. Five energy retrofit houses in South Wales. Energy and Buildings 154 , pp. 335-342. 10.1016/j.enbuild.2017.08.032

Related case studies: CS04,CS06, CS07, CS08, CS09

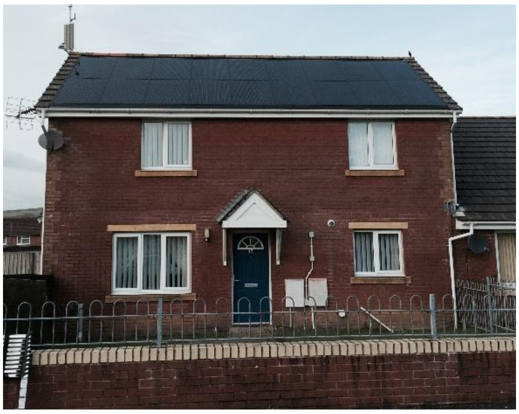
reference	action theme*	details	evidence
action 01	strategic	Work with RSL and supply chain to help develop confidence in applying technologies and the supply chain to combine technologies.	RSL continuing to trial retrofit solutions.
action 02	Strategic	Affordable low energy bills	Energy bill reduction 52%
action 03	Fabric	External Wall Insulation to front (50mm), Loft insulation 300mm, cavity wall insulation to gable wall.	Energy and carbon savings, more comfortable environment. Gas reduction 23%
action 04	services	MVHR, LED lighting, new gas combi boiler, controls, 8.5kWh lead acid battery to feed LEDs and fridge.	Energy and carbon savings, more comfortable environment.
action 05	renewables	2.7kWp integrated renewables PV roof	Energy generated on site – carbon savings. Electricity reduction 41%. CO_2 reduction 42%
action 06	strategic	Work with RSL and supply chain to help develop confidence in applying technologies and the supply chain to combine technologies.	RSL continuing to trial retrofit solutions.

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	The battery system was very basic. The research team held little knowledge about the complexities of selecting appropriate batteries for dwellings.	As more retrofits were carried out more advanced battery systems were applied which
challenge 02	Financial	The cost of the retrofit as a whole is still beyond what is considered by the research team to be of affordable.	Opportunities to reduce the costs of the retrofits are being investigated.

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 06



Project title:	SOLCER retrofit – Tyn y Waun
Location:	Tyn Y Waun, Bettws, Bridgend
Project size:	1 dwelling, 86 sqm
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	2000
Construction type:	masonry - cavity
Date of works:	2014
End user:	Social housing, owner occupiers
Funding source:	WEFO – Low Carbon Research Institute (LCRI) Low Carbon Built Environment/SOLCER projects
Contact:	Jo Patterson
Project team:	Welsh School of Architecture, Wales and West Housing, Warm Wales, GB Sol

Key words: **Insulation | battery | cost**

Summary: A holistic retrofit of semi-detached cavity wall house where modelling was used to identify appropriate and affordable low carbon measures relating to energy demand reduction, renewable energy supply and energy storage. Stakeholders were involved in selection of appropriate measures. Whole house retrofit cost £30,446. The house was occupied whilst the works were undertaken. Retrofit was designed to not require planning.

Headlines:
Annual CO2 emissions reduced by 54% (measured)
Electricity generation (PV) 3439 kWh/year (measured)
Cost £354/sqm (2014)

Related literature: Jones, Phillip, Li, Xiaojun, Perisoglou, Emmanouil and Patterson, Joanne 2017. Five energy retrofit houses in South Wales. Energy and Buildings 154 , pp. 335-342. 10.1016/j.enbuild.2017.08.032

Related case studies: CS04,CS05, CS07, CS08, CS09

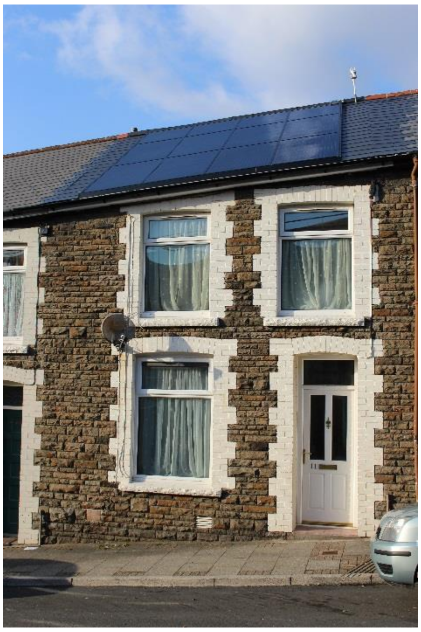
reference	action theme*	details	evidence
action 01	strategic	Work with RSL and supply chain to help develop confidence in applying technologies and the supply chain to combine technologies.	RSL continuing to trial retrofit solutions.
action 02	Strategic	Affordable low bills	Energy bill reduction 85%
action 03	Fabric	Loft insulation 300mm, positive pressure ventilation system.	
action 04	services	LED lighting, new gas boiler and hot water tank, controls, 18kWh lead acid battery to feed whole house.	Energy and carbon savings, more comfortable environment.
action 05	renewables	4.5kWp integrated renewables PV roof	Energy generated on site – carbon savings. Electricity reduction 79%. CO2 reduction 54%

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	strategic	The battery system was very basic. The research team held little knowledge about the complexities of selecting appropriate batteries for dwellings.	As more retrofits were carried out, more advanced battery systems were applied which connected to more appliances within the homes.
challenge 02	financial	The cost of the retrofit as a whole is still beyond what is considered by the research team to be of affordable.	Opportunities to reduce the costs of the retrofits are being investigated.

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 07



Project title:	SOLCER retrofit – King Street
Location:	King Street, Gelli, Pentre,
Project size:	1 dwelling, 74 sqm
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	Pre-1919
Construction type:	masonry - solid wall
Date of works:	2014
End user:	Social housing, owner occupiers
Funding source:	WEFO – Low Carbon Research Institute (LCRI) Low Carbon Built Environment/SOLCER projects
Contact:	Jo Patterson
Project team:	Welsh School of Architecture, Wales and West Housing, Warm Wales, GB Sol

Key words: **Insulation | battery | cost**

Summary: A holistic retrofit of a mid-terrace solid wall house where modelling was used to identify appropriate and affordable low carbon measures relating to energy demand reduction, renewable energy supply and energy storage. Stakeholders were involved in selection of appropriate measures. Whole house retrofit cost £23,852. The house was occupied whilst the works were undertaken. The child occupying the house was suffering from asthma before work was undertaken. Her health has vastly improved since. Retrofit was designed to not require planning.

Headlines:
Annual CO2 emissions reduced by 74% (measured)
Electricity generation (PV) 2007 kWh/year (measured)
Cost £322/sqm (2014)

Related literature: Jones, Phillip, Li, Xiaojun, Perisoglou, Emmanouil and Patterson, Joanne 2017. Five energy retrofit houses in South Wales. Energy and Buildings 154 , pp. 335-342. 10.1016/j.enbuild.2017.08.032

Related case studies: CS04, CS05, CS06, CS08, CS09

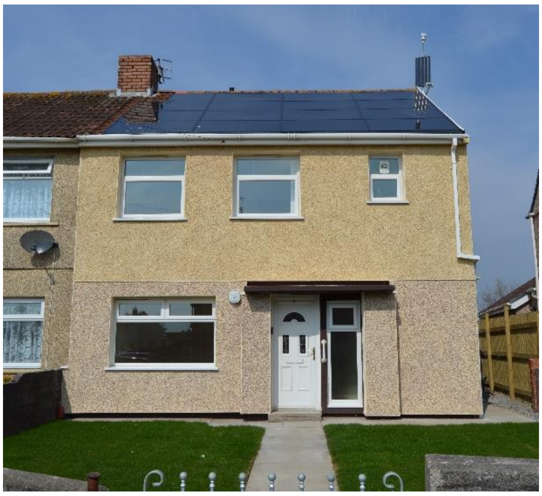
reference	action theme*	details	evidence
action 01	strategic	Work with RSL and supply chain to help develop confidence in applying technologies and the supply chain to combine technologies.	RSL continuing to trial retrofit solutions.
action 02	Strategic	Affordable low bills	Energy bill reduction 81%
action 03	Fabric	Rear EWI (100mm), Front internal wall insulation, loft insulation 300mm, floor and roof insulation to rear extension.	Reduced gas bills 35%
action 04	services	LED lighting, controls, 2kWh lithium ion battery to feed whole house.	Energy and carbon savings, more comfortable environment.
action 05	renewables	2.0 kWp integrated renewables PV roof	Energy generated on site – carbon savings. Electricity reduction 72%. CO_2 reduction 74%

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	strategic	The battery system was very basic. The research team held little knowledge about the complexities of selecting appropriate batteries for dwellings.	As more retrofits were carried out, more advanced battery systems were applied which connected to more appliances within the homes.
challenge 02	financial	The cost of the retrofit as a whole is still beyond what is considered by the research team to be of affordable.	Opportunities to reduce the costs of the retrofits are being investigated.

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 08



Project title:	SOLCER retrofit – Poppy Close
Location:	Sandfields, Port Talbot
Project size:	1 dwelling, 80sqm
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1950
Construction type:	masonry - cavity
Date of works:	2014
End user:	Social housing, owner occupiers
Funding source:	WEFO – Low Carbon Research Institute (LCRI) Low Carbon Built Environment/SOLCER projects
Contact:	Jo Patterson
Project team:	Welsh School of Architecture, Wales and West Housing, Warm Wales, GB Sol

Key words: **Fabric | battery**

Summary:

A holistic retrofit of a semi-detached post war cavity wall house where modelling was used to identify appropriate and affordable low carbon measures relating to energy demand reduction, renewable energy supply and energy storage. Stakeholders were involved in selection of appropriate measures. Whole house retrofit cost £30,510. The house was occupied whilst the works were undertaken. Retrofit was designed to not require planning.

Headlines:

Annual CO2 emissions reduced by 61% (measured)
Electricity generation (PV) 3458 kWh/year (measured)
Cost £381/sqm (2014)

Related literature:

Jones, Phillip, Li, Xiaojun, Perisoglou, Emmanouil and Patterson, Joanne 2017. Five energy retrofit houses in South Wales. Energy and Buildings 154 , pp. 335-342. 10.1016/j.enbuild.2017.08.032

Related case studies: CS04, CS05, CS06, CS07, CS09

reference	action theme*	details	evidence
action 01	strategic	Work with RSL and supply chain to help develop confidence in applying technologies and the supply chain to combine technologies.	RSL continuing to trial retrofit solutions.
action 02	Strategic	Affordable low bills	Energy bill reduction 84%
action 03	Fabric	EWI (100mm) overclad to existing cavity wall insulation, loft insulation 300mm.	Reduced gas bills 6%
action 04	services	LED lighting, controls, 10kWh lithium ion battery to feed whole house.	Energy and carbon savings, more comfortable environment.
action 05	renewables	3.97 kWp integrated renewables PV roof	Energy generated on site – carbon savings. Electricity reduction 84%. CO2 reduction 61%

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	strategic	A lithium ion battery was implemented to feed the whole house. There were some safety concerns expressed by the RSL but these were overcome by the installation of some fireboards and IR detectors.	As more retrofits were carried out, more advanced battery systems were applied which connected to more appliances within the homes.
challenge 02	financial	The cost of the retrofit as a whole is still beyond what is considered by the research team to be of affordable.	Opportunities to reduce the costs of the retrofits are being investigated.

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 09

Project title:	Solcer House
Location:	Pyle, Bridgend
Project size:	1 dwelling, 100 sqm
Project type:	newbuild
Dwelling type:	detached
Dwelling age:	2015
Construction type:	SIPs
Date of works:	2014-2015
End user:	Private (office and demonstration centre)
Funding source:	Public (ERDF Wales/LCRI WEFO)
Contact:	Dr Jo Patterson
Project team:	Welsh School of Architecture (Cardiff University), Swansea University, Glyndwr University and University of South Wales

Key words: **Energy positive | TSC**

Summary:

(source: Patterson et al., 2017)

"Staff at the Welsh School of Architecture at Cardiff University in the UK have designed and built Wales' first low carbon energy-positive house. The Solcer House is capable, over an annual period, of exporting more energy to the national electricity grid than its uses. The overall aim of the Solcer House is to optimise a whole building energy system by combining building integrated renewable energy supply, energy storage and reduced energy demand for both thermal and electrical energy."

Headlines: **Cost £1,000/sqm (2015)**

Related literature:

Jones, Phillip, Li, Xiaojun, Coma Bassas, Ester and Patterson, Joanne 2017. The SOLCER energy positive house: whole system simulation. Presented at: *Building Simulation 2017: 15th Conference of International Building Performance Simulation Association*, San Francisco, CA, USA, 7-9 August 2017. *Proceedings of Building Simulation 2017: 15th Conference of International Building Performance Simulation Association, San Francisco, USA, August 7-9, 2017.*

Patterson, Joanne Louise, Coma Bassas, Ester and Varriale, Fabrizio 2016. *Systems based approach to replicable low cost housing: renewable energy supply, storage and demand reduction.* In: Roset Calzada, Jaume, Kaltenegge, Ingrid, Patterson, Joanne Louise and Varriale, Fabrizio eds. *Smart Energy Regions - Skills, knowledge, training and supply chains*, [Smart Energy Regions - Skills, knowledge, training and supply chains]. Cardiff: Welsh School of Architecture, pp. 239-245.

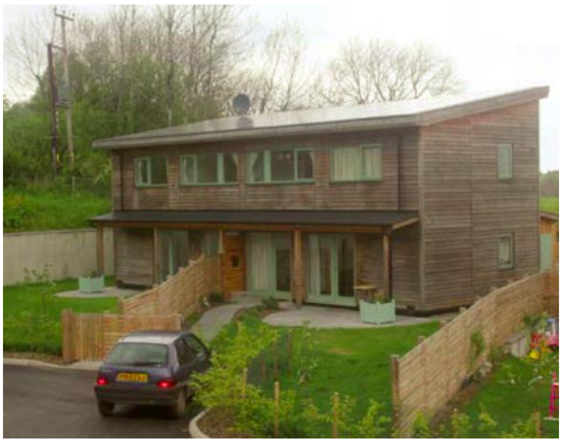
reference	action theme*	details	evidence
action 01	Strategic	The Solcer team set out to develop a model of a replicable energy-positive social housing unit for Wales. The building was designed to be constructed with readily available technologies, using local supply chains, and to meet social housing standards with the layout and specifications of a typical UK dwelling. The built prototype is a detached unit, but the house is designed to be replicated as a terraced unit. The built prototype is certified as ‘BREEAM Excellent’ and is currently used as office space and demonstration and training centre.	
action 02	Strategic	The electric and heating services were designed with a systems approach to use as much of the renewable energy generated in the building, before exporting the surplus to the grid. The renewable energy systems (PV and TSC) are integrated into the architectural components.	
action 03	Fabric	External walls – Structural Insulated Panels (SIPS) with XPS core (total SIP thickness = 19 cm) with external insulated render (total U = 0.13 W/m^2K). Part of the south-facing façade integrates the TSC. Roof – SIPs on the north-facing roof; integrated PV panels on the south-facing roof. Floor – Low-carbon concrete ground floor; SIP loft floor. Windows – aluminium-clad timber frames with Pilkington energiKareTM glazing	
action 04	Services	In the heating season, outside air is heated up and collected by the TSC and passed through a MVHR unit. A 585W electric air-source heat pump (COP of 3.2) uses the heat from the exhaust air (after it has passed though the MVHR) to top up the air temperature and to heat a DHW storage unit as required. A 6.9kWh lithium-ion-phosphate battery storage system (located in the loft) is used to as a buffer store for the electricity generated by the PV array. Excess electricity from the PV panels is also used to heat the DHW storage, if suitable.	
action 05	Renewables	The shouth-facin roof integrates a 4.3kWp solar PV array of 34m2. The south-facing external wall of the first floor Integrates a 17 sqm Transpired Solar (air) collector (TSC).	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Financial	The Solcer team believes that, by building several units, economies of scale can reduce the construction cost of the house to around £1,000/sqm. For comparison, the construction cost of typical UK social housing units is between £800/sqm and £1,000/sqm.	
challenge 02	Supply chains	The Solcer team strived to use local supply chains, when possible, to engage local industries and stimulate the regional economy. 16 out of 20 companies involved in the manufacture and supply of the house materials were Small and Medium Enterprises (SMEs). 4 out of 9 manufacturers and 12 out of 13 suppliers/installers were companies based in Wales.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 10



Project title:	Pentre Solar
Location:	Glanrhyd, Pembrokeshire
Project size:	6 dwellings, 100 sqm each
Project type:	newbuild
Dwelling type:	detached
Dwelling age:	2016
Construction type:	timber frame
Date of works:	2016
End user:	Private (affordable rental)
Funding source:	Western Solar
Contact:	Dr Glen Peters
Project team:	Western Solar

Key words: **Passivhaus | heating storage**

Summary:

(source: CEERA Response 04)

The six houses repeat the form of the Ty Solar prototype maximising the use of solar energy through a monopitch roof and south facing orientation. They are made of locally sourced timber at the company's eco factory in Pembrokeshire. With eleven inches of insulation and south-facing windows they use 12% of the energy of a traditional home.
The company has taken advantage of the Welsh Government's apprentice training scheme to recruit and train its workforce in the manufacture of all modular timber components. The timber frames are made from trees from a local forest, kiln-dried, processed and manufactured in the company's own factory near to the project site, supported by a growing network of local suppliers.
It takes approximately three days to erect the structural wall, first floor and roof panels, and to achieve a weatherproof envelope. This compressed programme saves considerable time on site, and results in lower overall costs.
Residents are also offered a subsidized electric car sharing scheme, powered by on-site PV, to cut the cost of short distance commuting to nearby Cardigan and Newport.

Headlines: **Cost £1,290/sqm (2016)**

Related literature: *CEERA Response 04*

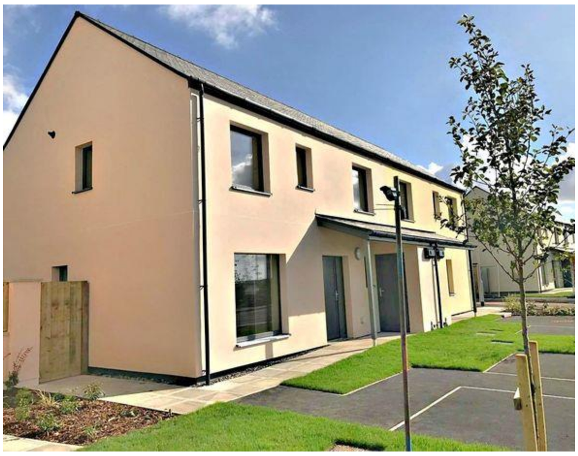
reference	action theme*	details	evidence
action 01	Strategic	The developer set out to build an example of low carbon social housing with multiple environmental and social benefits. This includes low carbon and local materials, low energy bills and integrated electric vehicles. The 3-bedroom units are rented for £620 per month, the 2-bedroom units are rented for £480 per month. This gives about 3.5-4% Return On Investment to the developer.	
action 02	Fabric	External walls - timber frame insulated with 27 cm of blown recycled cellulose (total U = 0.13 W/m^2K) Roof - timber frame insulated with blown recycled cellulose (U = 0.13 W/m^2K) Ground floor – insulate concrete slab (U = 0.14 W/m^2K) Windows – Double-glazed (U = 1.34 W/m^2K) The construction has low embodied carbon, due to the carbon capture in timber and the very limited use of cement.	
action 03	services	Electric room heaters using electricity from PV array. This a conventional technology adapted with an innovative approach. The energy produced by the PV panels at day is used to heat a high thermal mass element, which releases gradually the heat during the night. Mains electricity is used in the coldest times of winter.	
action 04	Renewables	Large PV array integrated on the roof: 6.5kW (for the semi-detached units) and 10.5kW (for the detached units) of PV panels per dwelling	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	Although technically feasible, most large developers are not interested in building this type of social housing due to the smaller margin of profit. Local authorities and housing associations have reacted positively to the Pentre Solar development, but the regulative framework focuses excessively on capital cost and does not acknowledge benefits to the tenants and the local community.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 11



Project title:	Milford Way Passivhauses
Location:	Swansea
Project size:	18 dwellings
Project type:	newbuild
Dwelling type:	semi-detached
Dwelling age:	2017
Construction type:	timber frame
Date of works:	2017
End user:	Social housing for LA
Funding source:	City and County of Swansea
Contact:	Carol Morgan, City and County of Swansea
Project team:	City and County of Swansea, Architype

Key words: **Passivhaus |**

Summary:

This development consists of 10 houses with 2 bedrooms and 8 apartments with 1 bedroom. It is part of a larger development located on two suburban sites for a total of 30 new homes. This is the first new built social housing in the area since the 80's.
The project approach is described as 'eco-minimalist' and employs a Fabric First strategy, focussing on building elements such as insulation and windows – those that would be expensive to upgrade at a later date - to deliver high performance without relying on expensive add-ons or complicated technology. The wide use of timber in the construction 'stores' carbon dioxide in the building's fabric - this is often called CO_2 sequestration.

Headlines:

Primary energy requirement < 120 kWh/m2.y
Annual CO2 emissions kg CO2/sqm.year
Cost £/sqm (2017)

Related literature:

Architect webpage http://www.architype.co.uk/blog/new-passivhaus-social-housing-completes-for-swansea-residents/
Web articles https://www.swansea.gov.uk/article/37815/Milford-Way-council-home-scheme-complete-by-Christmas
https://www.walesonline.co.uk/news/wales-news/state-art-homes-first-council-13696277

Related case studies:

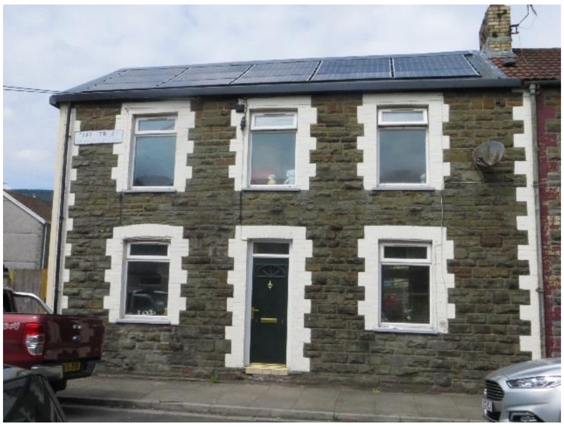
reference	action theme*	details	evidence
action 01	Strategic	The planning process lasted only 8 weeks. The rent for 2 bedroom units is £88 per week, the rent for the 1 bedroom units is £79 per week. The new tenants are being trained to manage the house services, which could reduce the energy bills up to £70 per year.	
action 02	Fabric	Highly insulated building fabric with low U-values (W/m^2k): walls (0.127), roof (0.095), floor (0.131) and glazing (0.8). Highly airtight building, target of 0.6ach@50Pa	
action 03	services	MVHR and gas combi boiler with radiators	
action 04	Renewables	None	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	The pilot scheme is being constructed to the rigorous Passivhaus standard.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 12



Project title:	LCBE Taff Street
Location:	
Project size:	1 dwelling, 72 sqm
Project type:	retrofit
Dwelling type:	end of terrace
Dwelling age:	Pre 1919
Construction type:	masonry - solid wall
Date of works:	2018
End user:	Social housing
Funding source:	SPECIFIC 2 LCBE
Contact:	Joanne Patterson
Project team:	Welsh School of Architecture, Cardiff University and Wales and West Housing

Key words: **Fabric | MVHR | TSC | PV | battery**

Summary:

The project takes a systems-based approach aiming to combine appropriate renewable energy supply, energy storage and energy demand reduction technologies to create a low carbon retrofit that is both replicable and affordable. This project involves the retrofit of a typical solid wall end of a terrace house, which is owned by Wales and West Housing Association. The dwelling is a pre-1919, located in Gelli, South Wales. The house has two-storeys with a footprint of 36 m2 (total floor area of 72m2). The living room and kitchen are on the ground floor and the two bedrooms and bathroom are on the first floor. The house has a garden accessed from the rear façade plus a side gate from the street. Two adults and two kids under 5 live in the house. Energy savings have been made through modifications to the fabric and systems in order to achieve 80% carbon reductions required. The works were undertaken during the winter of 2017 and the tenants remained in situ.

Headlines:

Predicted annual heating demand: 3,475 kWh/y (before intervention) and 1,946 (after intervention).
Predicted annual CO2 emissions: 49 kgCO2/m^{2}y (before intervention) and -20 kgCO2/m^{2}y (after intervention).
Predicted electricity generation from PV: 9,146 kWh/y

reference	action theme*	details	evidence
action 01	strategic	Worked with HA to develop holistic approach, built on long term relationships	
action 02	fabric	External walls: Front stone wall - Internal insulation and aerogel to windows reveals. Side and rear pebble dash rendered wall – External wall insulation with rendered finish and aerogel to windows reveals. Roof: 300 mm mineral wool insulation in the loft floor.	
action 03	services	Mechanical ventilation with heat recovery (MVHR), transpired solar collectors (TSC), roof integrated PV, lithium-ion battery and LED lighting.	Monitoring
action 04	renewables	6.9 kWp PV panels and TSC	Monitoring
action 05	people	The occupants were really happy to be part of the work, especially because one of the kids was suffering from asthma which was worstened by the high humidity levels inside the house.	

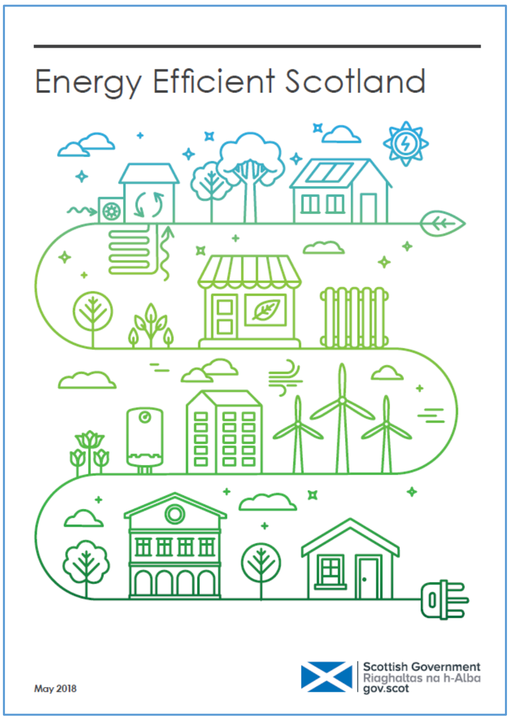
*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Supply chain	All manufacturers, suppliers and contractors were UK based and local to South Wales area.	
challenge 02	strategic	There was confusion about the installation of the TSC in connection with the MVHR system. MVHR filters blocked due to running the system while decorating.	
Challenge 03	Financial	The total cost of the retrofit measures approx. £60,000 was considered too high to be replicated by private homeowners.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 13

Project title:	Various (reported in Energy Efficient Scotland)
Location:	Stirling, Scotland
Project size:	3700 dwellings, various sizes (2400 completed)
Project type:	retrofit
Dwelling type:	various
Dwelling age:	various
Construction type:	other
Date of works:	2015-2019
End user:	Stirling Council housing stock
Funding source:	Public (Scottish Government)
Contact:	
Project team:	



Key words:	**Photovoltaics | energy efficiency | route map**
Summary: (source: Energy Efficient Scotland Route Map 2018)	Over the next period to 2040 we will transform Scotland's buildings to be warmer, greener and more efficient. Doing so will have substantial economic, social and health benefits, and this Route Map sets out how the Energy Efficient Scotland Programme will achieve that ambition.
Headlines:	**Depending on the size of system installed and the orientation, solar PV increases the energy efficiency rating by between 10 to 20 RdSAP (2012) points.**
Related literature:	Energy Efficient Scotland http://www.gov.scot/Publications/2018/05/1462

reference	action theme*	details	evidence
action 01	renewables	**Stirling Council – Solar Photovoltaics / Battery Storage** 2,400 installations were completed (42% of the Stirling Council housing stock) with a further 1,300 installations planned for 2018/19. The average size of system installed is 3.0kWp at an average cost of £4,200 (ex VAT) generating on average 2,330kWh per annum per property. In order to maximise the "self-consumption" benefit to tenants, the solar PV installations are being complimented with solar diverters in the "off-gas" stock and piloting battery storage across the solar PV portfolio. Depending on the size of system installed and the orientation, solar PV increases the energy efficiency rating by between 10 to 20 RdSAP (2012) points. Battery storage has been installed in over 100 properties to date and a further 200 installations planned for 2018/19. Systems range from an internally mounted system providing 2kWh storage to an externally mounted system that can provide 13.5kWh of storage. Data is showing that battery storage can provide the householder with a "self-consumption" rate of 25% during winter months to over 90% during summer months. The cost of a 13.5kWh battery storage system is currently around £5,600 (ex VAT) but costs are starting to fall as the technology starts to mature in the UK. Battery storage is starting to open up other opportunities including sharing microgeneration power over connected homes and the ability to import Economy 7 power in to the battery to time shift consumption out with Economy 7 time bands. Feedback from tenants has been very positive. They have cited the reduction in their electricity bills and that they are secure in the knowledge that Stirling Council's Housing Service remotely monitors the performance and maintenance across the entire portfolio of both PV systems and battery storage units.	2400 installations completed. The average size of system installed is 3.0kWp at an average cost of £4,200 (ex VAT) generating on average 2,330kWh per annum per property. Battery self-consumption" rate of 25% during winter months to over 90% during summer months. The cost of a 13.5kWh battery storage system is currently around £5,600 (ex VAT)

*action themes: strategic / fabric / renewables / services / people

Case study: CS 14

Project title:	Victorian terrace at BRE Park
Location:	Watford, England
Project size:	4 dwellings
Project type:	retrofit
Dwelling type:	various
Dwelling age:	1885
Construction type:	masonry - solid wall
Date of works:	2008-2010
End user:	Building Research Establishment (BRE)
Funding source:	DECC , EEDA, BRE TRUST
Contact:	BRE
Project team:	BRE, Wates Living Space, PRP Architects, Mason Navarro Pledge, EC Harris, BASF, St Gobain, EDF, CRH, British Gas & Mears, Megaman

Key words: **Solid wall**

Summary:

BRE retrofitted 4 terraced units into a demonstration centre and knowledge hub. The project was an opportunity to test different measures and to closely monitor the construction process.

Headlines: **Annual CO_2 emissions reduced by 80% (calculated)**

Related literature:

Web page https://bregroup.com/ipark/parks/england/buildings/the-victorian-terrace/
BRE Information paper 12/11 part 1 – Design philosophy
BRE Information paper 12/11 part 2 – The construction process
BRE Information paper 12/11 part 3 – Lessons learned

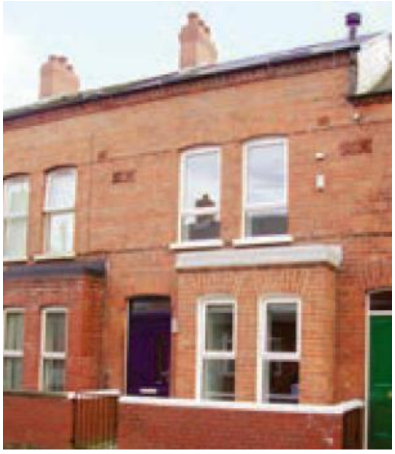
reference	action theme*	details	evidence
action 01	Strategic	The project aimed to change the EPC rating of the units from ‘F’ to ‘B’, and achieve 80% carbon reductions. The dwellings were heavily reworked to transform them in to a demonstration centre with a small conference room. Due to differences in the existing constructions and in the measures applied in the retrofit, the four units achieved different performances.	
action 03	Fabric	For unit C (achieving the best performance) the following measures were applied External walls – Grey EPS used for external insulation (U = 0.17 W/m^{2}K): aerogels used for internal insulation () Roof – Insulation between rafters with grey EPS (U = 0.16 W/m^{2}K) Floors – Insulated (U = 0.18 W/m^{2}K) Windows – new double-glazed argon windows (U = 1 W/m^{2}K), and triple-glazed rooflights	
action 04	Services	Heat pumps and condensing gas boilers were installed in different units. Heat pumps were used in combination with MVHR.	
action 05	Renewables	PV and Solar thermal panels installed on roofs.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Existing building	Despite the retrofit works, two of the units did not reach the minimum airtightness requirement of 10 m3/h/m2 at 50 Pa for new dwellings.	
challenge 01	Supply chain	The ‘BRE Information paper 12/11 part 2 – The construction process’ contains a detailed breakdown of the time and cost required for the retrofit works.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 15



Project title:	Retrofit for the Future case study 1 house #1
Location:	North Belfast
Project size:	1 dwelling
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	1896
Construction type:	masonry - solid wall
Date of works:	2001
End user:	Grove Housing Association
Funding source:	
Contact:	Grove Housing Association
Project team:	Eco-Energy (NI) Ltd with Hugh Green (architect)

Key words: **IWI | MVHR | behaviour**

Summary: A holistic retrofit of a mid-terrace solid wall house.

Headlines:
Primary energy requirement reduced by 85% (measured)
Annual CO2 emissions reduced by 83% (measured)

Related literature: LR01
Related case studies: CS16,CS17, CS18

reference	action theme*	details	evidence
action 01	Fabric: Holistic package	Phenolic internal wall insulation bonded to 18mm OSB, phenolic insulation to the solid ground floor and a combination of insulation types to attic ceiling. Highly insulated pre-fabricated roof. Passivhaus certified windows.	
action 02	Services	An efficient gas boiler with flue gas heat recovery, PV and MVHR. The boiler has an interlock that prevents operation unless the MVHR is running and windows are closed. A user-friendly, hybrid ventilation system was designed, combining active ventilation from the MVHR with passive ventilation via automatically opening roof windows. The only controls were a simple on/off switch for all services and two room thermostats.	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and co2 calculated.
action 03	Renewables	Roof mounted photovoltaic panels	
action 04	Strategic	The project team spent time living in the property to fully understand its operating characteristics and optimise the systems.	Modelling undertaken using PHPP and THERM
action 05	People	The design team worked to a solution that prioritised the resident. They sought appropriate technologies with straightforward controls that would provide a comfortable and easily controlled environment.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	The nature of the street meant external insulation could not be used	01
challenge 02	Financial	During the systematic destruction before the retrofit, the team encountered numerous structural and safety concerns that needed to be addressed. This added unforeseen time and cost.	01

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 16

Project title:	Retrofit for the Future case study 2 house #8
Location:	London
Project size:	1 dwelling
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	1992
Construction type:	masonry - cavity
Date of works:	2001

Key words: **IWI | MVHR | behaviour**

Summary: Mid-terrace two-storey house with three bedrooms built in 1992. It had masonry unfilled cavity walls, double glazing and a pitched roof with a limited amount of loft insulation

Related literature: LR01
Related case studies: CS15,CS17, CS18

reference	action theme*	details	evidence
action 01	Fabric: Holistic package	Phenolic internal wall insulation bonded to 18mm OSB, phenolic insulation to the solid ground floor and a combination of insulation types to attic ceiling. Highly insulated pre-fabricated roof. Passivhaus certified windows.	
action 02	Services: MVHR	An efficient gas boiler with flue gas heat recovery, PV and MVHR. The boiler has an interlock that prevents operation unless the MVHR is running and windows are closed. A user-friendly, hybrid ventilation system was designed, combining active ventilation from the MVHR with passive ventilation via automatically opening roof windows. The only controls were a simple on/off switch for all services and two room thermostats.	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and CO2 calculated.
action 03	renewables	Roof mounted photovoltaic panels	
action 04	Strategic	The project team spent time living in the property to fully understand its operating characteristics and optimise the systems.	
action 05	people	The design team worked to a solution that prioritised the residents, who remained in situ during the works. They sought appropriate technologies with straightforward controls that would provide a comfortable and easily controlled environment.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Fabric – unanticipated costs	During the systematic destruction before the retrofit, the team encountered numerous structural and safety concerns that needed to be addressed. This added unforeseen time and cost.	01

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 17

Project title:	Retrofit for the Future case study 3 house #35 ref. ZA233U
Location:	Norfolk, England
Project size:	1 dwelling, 51sqm
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1948
Construction type:	masonry - solid wall
Date of works:	2010
End user:	Hastoe Housing Association Ltd. Social housing client
Contact:	Hastoe Housing Association Ltd.
Project team:	Energy Conscious Design (architects) 1st Saxon-Clenmay (contractor)

Key words: **IWI | heat pump**

Summary:

One of a four-bungalow terrace built in 1948. Before retrofit, it had little insulation, poor airtightness and was reliant on electric heating and a coal fire. It had an EPC rating of ‘G’.

“Our approach to energy saving and CO_2 reduction is to follow a lean-clean-green hierarchy: seeking to minimise heat losses from the property thermal fabric and ventilation method; to supply residual space and water heating using replicable, low carbon technology; to minimise lighting and appliance energy loads; and finally to consider micro-generation using proven, renewable energy systems.”

Headlines:

Primary energy requirement reduced by 93% (calculated)
Annual CO_2 emissions reduced by 93% (calculated)

Related literature: LR01
Related case studies: CS15,CS16, CS18

reference	action theme*	details	evidence
action 01	Fabric: Holistic package	Focus on loft space (bungalow): Blown fibre insulation was added to a depth of 420mm. The loft entrance was built up by 500mm and a deck was created to allow ease of access to the MVHR unit and PV inverter. The existing solid ground floor was overlaid using 18mm chipboard with aerogel blanket backing. Aerogel laminated board was installed to interior of external walls throughout. Secondary glazing was provided to Crittal windows. Unfortunately, the subsequent installation of an electricity meter required the insulation to be cut away behind a kitchen cupboard, which breached the air barrier; some evidence that this may be causing a cold spot is visible in thermal imaging.	PHPP calculations, measured data not yet available
action 02	Services: MVHR	Reduced space heating demand is met by an air source heat pump with newly installed radiators and MVHR. The summer bypass was not installed on the MVHR. Monitored data shows temperature peaks of 25-26°C and relative humidity in the region of 55% during the summer months, which could be a source of discomfort.	
action 03	Energy: Solar thermal, PV	Hot water is partially met by solar thermal and a 2.1kWp PV array offsets some of the electricity needed for the house which is not on the gas grid.	
action 04	strategic	Whole house modelling in PHPP	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	planning	Planning requirement that the appearance of the dwelling be unchanged by the works.	01,
challenge 02	Form fabric	Size of the dwelling (51sqm) made space saving a priority, necessitating expensive insulation	01

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 18

Project title:	Retrofit for the Future case study 4 house #109
Location:	West London
Project size:	1 dwelling
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1950s
Construction type:	masonry - solid wall
End user:	HA CLIENT
Project team:	housing association as both client and lead contractor

Key words: **Passivhaus | MVHR**

Summary: Semi-detached 3-bedroom dwelling built in the 1950s. This solid wall house needed new windows, a heating upgrade, re-wiring, and a new kitchen and bathroom. End user kept in situ during works.

Related literature: LR01
Related case studies: CS15, CS16, CS17

reference	action theme*	details	evidence
action 01	Strategic: clear targets	Clear, well-communicated performance targets led to robust, well-engineered details that were drafted early in the design process, ensuring insulation continuity and a high level of airtightness.	
action 02	Fabric: Holistic package based on EnerPHit	This project adopted a fabric first approach based on Passivhaus EnerPHit principles, comprised of 240mm EPS external wall insulation, 100mm mineral wool + 300mm cellulose loft insulation, 150mm mineral wool between ground floor joists and triple glazed 0.8 W/m2K windows and doors. By paying attention to the thermal envelope, details and airtightness, the specific space heating demand was reduced by approx. 95% (as modelled by PHPP). External insulation was extended 1m below ground, creating a thermal apron around the perimeter of the property that helps eliminate thermal bridging at the ground floor and reduce floor heat loss. An airtight membrane from the attic bonded into a parge coat underneath the external wall insulation, and continuous membranes and tapes fitted around window and door openings have helped improve airtightness from 7.06 down to 1.39 m3/h/m2.	Monitoring of the occupants and the building have been undertaken, predicted and actual energy use monitored and co2 calculated.
action 03	Services: MVHR	MVHR, with a new (resized) gas combination boiler and a new hot water cylinder.	
action 04	Energy	Evacuated tube solar thermal collector feeding into hot water cylinder.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Fabric – existing ground level	While below ground insulation is considered good practice, a common issue is how to work with services that are close to the house. In this instance, the foul drain was too close to the below ground insulation, so a new drain run was dug.	02
challenge 02	Occupancy	The only airtightness weaknesses are within the intermediate floors which couldn't be accessed with residents in situ.	02

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 19

Project title:	Residential Retro Fit: Grove Cottage
Location:	Hereford
Project size:	1 dwelling, 135sqm (after extension)
Project type:	retrofit
Dwelling type:	detached
Dwelling age:	1869
Construction type:	masonry - solid wall
Date of works:	2009-2010
End user:	Private
Funding source:	Private
Contact:	Andrew Simmonds (private client)
Project team:	Simmonds Mills Architects, Eco-DC contractor, Alan Clarke (PHPP)

Key words: **MVHR | cold bridge | cost**

Summary: Two bedroom detached cottage built in 1869. It had solid masonry exterior walls and a timber ground floor, with a 30sqm unheated basement and a pre-existing extension.

Headlines:
Primary energy requirement reduced by 58% (measured)
Annual CO2 emissions reduced by 92% (measured)

Related literature: LR02
Related case studies: CS15 - CS22

reference	action theme*	details	evidence
action 01	Fabric: Holistic package	Comprehensive external wrap including: 250mm rendered EPS to exterior of walls Reconstructed roof from 400mm I-joist rafters fully filled with mineral wool. 175mm sheep wool between ground floor timber joists, underlined with 50mm of the same. Passivhaus certified triple glazed windows. Achieved airtightness of $0.8m^3/m^2h$ @ 50Pa (better than EnerPHit standard / target of $1m^3/m^2h$)	First EnerPHit certified project in UK, modelled, built, tested and certified.
action 02	Services: MVHR	An MVHR system was installed, along with new gas boiler and hot water system. All pipework well insulated.	.
action 03	Energy	Roof mounted solar thermal hot water was designed but not installed due to perceived marginal benefit.	
action 04	Strategic	THERM and WUFI cold bridge modelling was used to ensure cold-bridge-free construction.	Thermographic testing

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Fabric	Difficult to resolve cold bridge at base of external wall with timber joists. Insulated loadbearing blocks retrofitted into existing masonry to resolve..	01
challenge 02	Cost	Total budget of £140k, of which £45k was budget for actions listed above. This does not include VAT, prelims, design fees (designer was client) or MVHR installation (carried out by client).	Cost breakdown

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 20

Project title:	Residential Retro Fit: TSB #57: Highfields
Location:	Leicester
Project size:	1 dwelling, 70sqm
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	Pre-1919
Construction type:	masonry - solid wall
End user:	Social housing (East Midlands HA)
Funding source:	Technology Strategy Board
Contact:	East Midlands HA
Project team:	Gordon White Hood (architect), Aqua Interiors (contractor), DeMontford university

Key words: **MVHR | behaviour | cost**

Summary: Modest mid-terrace two-storey house with three bedrooms. It had solid masonry walls and a pitched roof with a limited amount of loft insulation. Factory prefabrication of replacement roof volume including MVHR, PV and new insulated roof space.

Headlines:

Primary energy requirement reduced by 76% (measured)
Annual CO2 emissions reduced by 80% (measured)
Cost £800/sqm

Related literature: LR02 pp.52-55
Related case studies: C1S15 – CS23

reference	action theme*	details	evidence
action 01	Fabric: Holistic package, negligible impact on exterior	150mm PIR insulation plus 50mm rockwool to inside face of exterior walls for services zone. Insulated loft pod (150mm mineral wool + insulated 'floor') replaces existing roof, replicating form and providing additional bedroom. Installed in one day, minimising risk / impact on project as a whole. Replacement triple glazed sash / casement windows mirror original windows. Achieved airtightness of $2.8m^3/m^2h$ @ 50Pa (above target of $1m^3/m^2h$) due to windows and complex junctions.	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and CO2 calculated.
action 02	Services: MVHR	A small MVHR unit located in the roof pod. Location is designed to minimise duct run lengths.	
action 03	Low Zero C: Solar thermal	Roof mounted solar thermal panels top up the condensing mains gas boiler.	
action 04	Occupants	Smart 'Wattbox' observes and adapts to occupant behaviour. Simple controls deliver a controllable system with quick response times. Estimated 10-15% saving on heating energy for typical useage.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	costs	The team encountered unanticipated problems, causing budget overrun of £18k. Cost of energy saving measures £56k.	all
challenge 02	fabric	Space lost internally due to internal wall insulation. Loft pod considered successful, but required more time for development.	01

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 21

Project title:	Residential Retro Fit: TSB #59: Hawthorn Road
Location:	North London
Project size:	1 dwelling, 109sqm
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	Pre-1919
Construction type:	masonry - solid wall
End user:	Private housing provider (Metropolitan)
Funding source:	Technology Strategy Board, Neighbourhood Investment Unit (NIU)
Contact:	Dr Ben Croxford, UCL Bartlett
Project team:	Anne Thorne Architects, Sandwood Design and Build (contractor)

Key words: **Insulation | MVHR**

Summary: Edwardian mid-terrace two-storey building, restored from subdivision into 2no. 1bed apartments, back to a single 3 bedroom dwelling to meet family housing need in the area. Targeted an 80% CO_2 reduction.

Headlines:

Primary energy requirement reduced by 70% (measured)
Annual CO_2 emissions reduced by 72% (measured)
Cost £825/sqm

Related literature: LR02 pp.44-47

Related case studies: CS15 – CS22

reference	action theme*	details	evidence
action 01	Strategic: Setting targets / Natural materials	Detailed modelling using PHPP software revealed limitations of the project (esp airtightness) and enabled reasonable targets to be set. Decision to use breathing/natural materials for carbon sequestering + moisture carrying properties.	In depth PHPP modelling and use of THERM for cold bridges
action 02	Fabric: Holistic package, negligible impact on frontage	Front walls lined with two layers of sheeps wool within timber frame lining, plus wood fibre board and lime plaster to 0.20 W/m^2K. Rear walls externally insulated with thick layer of EPS and render to 0.15W/ W/m^2K. Replacement triple glazed windows to 0.8W/ W/m^2K Achieved airtightness after works of $2.4m^3/m^2h$ @ 50Pa (original airtightness of $17m^3/m^2h$).	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and CO2 calculated.
action 03	Services: MVHR	MVHR supplies fresh air to living room and bedrooms, and draws moist stale air from kitchen and bathroom. Replacement gas/solar combi boiler provides top up heat via a small wet central heating system (radiators).	Monitoring strategy established by Dr Ben Croxford of UCL Bartlett
action 04	renewables Solar thermal	Roof mounted solar thermal panels top up the condensing gas combi boiler.	
action 05	people	Simple controls on the Rotex 'GasSolarUnit' minimise training and user errors.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Financial	Cost of energy saving measures £90k – included extensive costs due to fire damage and conversion from flats.	all
challenge 02	strategic	L-shaped plan and complex construction limited airtightness and potential to reduce CO2, as well as benefit drawn from MVHR.	02

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 22

Project title:	Residential Retro Fit: TSB #51: Shaftesbury Park Terrace
Location:	Wandsworth, London
Project size:	1 dwelling, 61sqm
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	1870
Construction type:	masonry - solid wall
End user:	Social housing via Peabody Trust
Funding source:	Technology Strategy Board
Contact:	Peabody Trust
Project team:	Feilden Clegg Bradley studios, Wates (contractor), Max Fordham

Key words: **People | heating storage | cost**

Summary: Edwardian mid-terrace two-storey two bedroom dwelling, with solid brick walls, pitched roof and stereotypical L-shaped footprint. Located in a conservation area. Used as test-bed by Peabody for retrofit of their pre-existing housing stock. (Residents to be kept in situ.)

Headlines:
Primary energy requirement reduced by 76% (measured)
Annual CO_2 emissions reduced by 70% (measured)
Cost £1295/sqm

Related literature: LR02 pp.36-39
Related case studies: CS15 – CS22

reference	action theme*	details	evidence
action 01	People: remain in situ	Exploration of an approach that allowed residents to remain in occupation – in particular a novel strategy for dealing with ground floor (timber suspended floor) by relocating services + backfilling with EPS beads.	As built
action 02	Strategic: Fabric first to minimise primary heating	Building fabric to be improved to a level where heat demand is largely satisfied by solar and by internal heat gains.	
action 03	Fabric: Holistic package, negligible impact on frontage	Front and rear walls of main house volume lined internally with aerogel within plasterboard sandwich to minimise space loss, to 0.14W/sqmdegC. Outrigger externally insulated with PUR insulation and timber rainscreen to 0.14W/sqmdegC. 400mm mineral wool to loft space. Ground floor void fully filled with platinum polystyrene cavity wall insulation beads. Replacement double glazed windows to front (1.4W/sqmdegC), triple glazed tilt and turn to rear. Airtightness after works of $5.9m^3/m^2h$ @ 50Pa.	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and CO2 calculated.
action 04	Services: MVHR	MVHR discounted due to pressure on space. Fan assisted passive stack draws stale moist air from kitchen and bathroom. Existing condensing gas boiler incorporated into a heat store, and tops up the heat store only when required. Heat is delivered via existing radiators.	
action 05	renewables	Heat store heated by solar thermal (roof mounted, primary), air source heat pump (secondary, incorporated into prototype fan-assisted passive stack ventilation system drawing warm air from kitchen and bathroom) and boiler (tertiary).	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Financial	Cost of energy-saving measures £78,876. High cost of bespoke services work (solar and boiler) at £50k. Cost of expensive aerogel insulation were justified by high cost/value of floor space	02, 03, 04
challenge 02	strategic	Minimal changes to street frontage necessitated double glazed sash windows. Triple glazed rear windows were negotiated with planners on the basis of a ‘balanced’ aesthetic / pragmatic solution.	03

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 23

Project title:	Residential Retro Fit: TSB #98: Easton Road
Location:	Laurence Hill, Bristol
Project size:	1 dwelling, 78sqm
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	Pre-1919
Construction type:	masonry - solid wall
End user:	Social housing via Self Help Housing Association (SHHA)
Funding source:	Technology Strategy Board
Contact:	SHAA
Project team:	White Design, Mears Group (contractor), Arup

Key words: **Passivhaus | insulation | cost**

Summary: A compact, Victorian mid-terrace two-storey two bedroom dwelling, with solid brick walls, pitched roof – typical of approximately 50% of Bristol's housing stock of 162,000 dwellings. Located in the most deprived area in Bristol.

Headlines:

Primary energy requirement kWh/sqm.year (savings 56%, measured)
Annual CO2 emissions kg CO2/sqm.year (savings 61%, measured)
Electricity generation (PV) Wh/year (measured)
Cost £641/sqm

Related literature: LR02 pp.60-63
Related case studies: CS15 – CS22

reference	action theme*	details	evidence
action 01	Strategic: Passivhaus	Designed to Passivhaus principles, but not commissioned	
action 02	Fabric: Holistic package, negligible impact on frontage to avoid planning permission	Front elevation lined internally with 260mm mineral wool wall insulation between timber stud, and protective services void, to 0.15W/m^{2}K. New lime render added to protect frontage from rainwater ingress. Rear elevation externally insulated with lime-rendered wood fibre insulation to 0.15W/ m^{2}K. 260mm mineral wool to loft space (0.15W/ m^{2}K) Ground floor untreated apart from DPM to protect wall insulation. Replacement double glazed sash windows combined with secondary double glazed units to front (0.8W/ m^{2}K), mainstream triple glazing to rear. Airtightness after works of 4m^3/m^{2}h @ 50Pa (previously 8m^3/m^{2}h @ 50Pa).	Monitoring of the occupants and the building have been undertaken, actual energy use monitored and CO2 calculated.
action 03	Services:	MVHR system (MVHR also controls moisture / RH levels in winter months)	Post occupancy monitoring
action 04	renewables	Solar thermal panels (roof mounted) to partially satisfy hot water demand.	
action 05	people	Primary aim: to identify technologies and processes that facilitate a lower carbon lifestyle. Building User Guide produced to promote this, along with ‘Hab shimmy portal’ – a simple flat screen that provides real time information around energy use to encourage responsible behaviour. Other measures include clothes dryer over bath, covered bike stand, recycling area and food growing planters.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	financial	Cost of energy-saving measures was £50,050, including £13.5k to windows and doors. Minimal changes to street frontage necessitated internal insulation of street frontage and double glazed sash windows combined with double glazed secondary casements internally, along with other measures that made the work more expensive.	02

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 24

Project title: Carbon Light Homes
Location: Kettering (Northhamptonshire)
Project size: 2 dwellings, 125 sqm each
Project type: newbuild
Dwelling type: semi-detached
Dwelling age: 2011
Construction type: Choose an item.
Date of works: 2009-2011
End user: private households
Funding source: private
Contact: Paul Hicks (Velux) paul.hicks@velux.co.uk
Project team: VELUX Group, HTA Design, the Kettering Borough Council, Willmott Dixon, and the North Northants Development Company

Key words: **daylight | ventilation | heat recovery | heat pump**

Summary:

(sources: http://www.activehouse.info/cases/carbonlight-homes/; https://www.velux.com/innovation/demo-buildings/carbonlight-homes-uk)

"The primary objective was to achieve a high level in the Code for Sustainable Homes (level achieved: 4) without the use of photovoltaics or continuous mechanical ventilation with heat recovery. It was decided to use low temperature radiators fed from a 'buffer' tank which is heated using a combination of solar thermal collectors and an air source heat pump.
The sun provides nearly all of the energy for the CarbonLight Homes' hot water and heating, and the houses are designed to reduce fossil fuel energy (such as electricity) to a minimum. With their solar collectors and air-to-water heat pumps, the CarbonLight Homes achieve a 70% reduction in CO2 emissions. The remaining 30% of emissions are offset through agreements with the local government to improve the energy efficiency of other homes in the area. The added challenge was to build to an East/West orientation to prove that you do not need a south facing plot to achieve an optimum solution.
CarbonLight Homes emerged as the winner of the Innovation Award for Building Technology at the prestigious British Homes Awards (BHA) held in Central London in 2013."

Headlines:

Primary energy requirement 85.5kWh/sqm.year (calculated)
Annual CO_2 emissions 8kg CO_2/sqm.year (calculated; offset by renewables)

Related literature:

Web articles: http://www.activehouse.info/cases/carbonlight-homes/
https://www.velux.com/innovation/demo-buildings/carbonlight-homes-uk
http://www.hta.co.uk/projects/velux-carbonlight-houses
http://www.worldarchitecturenews.com/project/2013/23111/hta-architects/carbonlight-homes.html
Paul Hicks, 2012. Model Home 2020 project Carbon Light Homes "Improving building performance without limiting the occupants"
http://cic.org.uk/admin/resources/velux.pdf
Velux 2011. CarbonLight Homes.
https://velcdn.azureedge.net/~/media/com/case%20studdy/carbonlight%20homes_uk/124255-01_model_home_2020_carbonlight_homes.pdf

Related case studies:

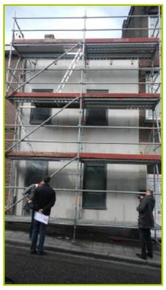
reference	action theme*	details	evidence
action 01	Strategic	The project team set out to design a CSH building with : • high levels of daylight and solar gains (achieved average 7.5% daylight factor) • renewable generation not relying on PVs • flexibility of ventilation (natural + MVHR)	
action 02	Strategic	Project initiated by manufacturer (Velux)	
action 05	Fabric	'U-value of 0.11 W/m²K for all walls, floor and roof. Air permeability through the structure of less than 3m³/h.m² at an air pressure of 50 Pascals (50N/m²). Triple glazed windows to the colder side (East elevation) to provide improved thermal protection and double-glazed windows to the warmer side (West elevation) to take advantage of solar gain.	
action 06	Services	Low temperature radiators are fed from a buffer tank which is heated using a combination of solar thermal collectors and an air source heat pump. How water is also serviced by solar thermal collectors. Natural ventilation strategy all year round with MVHR support during the heating period. Low energy light fittings throughout. Automated window operation and blind control to reduce solar gain, prevent glare and reduce internal CO2 levels.	
action 07	Renewables	Solar thermal collectors, air-source heat pump, MVHR	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
Challenge 01	Strategic	Floor area is about 30% larger than conventional UK 3-4 bedrooms houses	
Challenge 02	Strategic	East-West orientation	

**challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 25



Project title:	Reno2020 – “Rue Molinay 34”
Location:	Liege, Belgium
Project size:	1 dwelling, 108 sqm
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	before 1945
Construction type:	masonry - solid wall
Date of works:	2009-2012
End user:	private household
Funding source:	Public-private
Contact:	Jean-Marie Hauglustaine, jmhauglustaine@ulg.ac.be
Project team:	Belgian Building Research Istitute, Arcelor Mittal, Knauf, AGC Glass Europe, Aldes, University of Liege, CSTC, SECO, Eriges

Key words: **insulation | windows | facade**

Summary: (source: http://smart-er.eu/sites/default/files/attachments/Smart%20Energy%20Regions%20-%20Skills%20knowledge%20training%20and%20supply%20chains.pdf)

“The Reno2020 project engaged all construction actors, from stock owners to local material producers, to imagine efficient refurbishment solutions of dwellings in the suburbs of Liege, according to their typology. An innovative solution has been developed to replace the street façades of old, often insalubrious urban modest “blue-collar” houses. Among its strengths: set-up rapidity, high energy performance without loss of private or public space, locally-sourced materials and urban-scale retrofit potential.”

Headlines:

Primary energy requirement 151 kWh/sqm.year (savings 62%, calculated)
Project cost £890/sqm (2012 exchange rate)

Related literature:

Main report (in French) https://orbi.uliege.be/handle/2268/184931
COST Smarter WG2 case study (p.142) http://smart-er.eu/content/smart-energy-regions-skills-knowledge-training-and-supply-chains

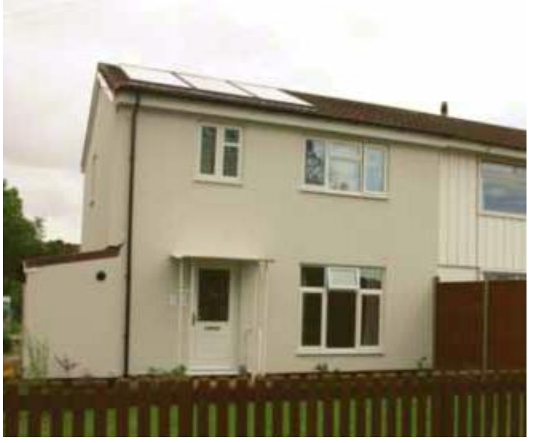
reference	action theme*	details	evidence
action 01	Strategic	The project engaged several partners: manufactures, researchers and a public housing association (the main funding source). The aim was to explore test the potential and cost of innovative fabric technologies applied to typical Belgian housing test pilots. The choice to focus on fabric renovation (and to exclude renewables) was affected by project partners (manufacturers) and by a limited budget. In comparison to a conventional brick façade reconstruction, the steel frame solution tested in this case study is faster and cheaper to build. However, payback cost is quite high (over 20 years)	Comparison of building costs was part of the project. Detailed cost breakdown is available (in French)
action 02	Fabric	Roof - Insulation of main roof (6 cm glass wool, total U = 0.24 W/m^{2}K) and replacement of roof of secondary volume (22 cm glass wool). Walls - Complete deconstruction of the street-facing brick façade and reconstruction with steel frame system “Styltech” by Arcelor Mittal (with 15 cm glass wool). Total U-value of the new façade is 0.3 W/m^{2}K. The system allows minimal thermal bridging, it is composed by a primary load-bearing steel frame, one secondary steel frame supporting the interior finishing and one secondary timber frame supporting the exterior finishing (plastered fiber-cement panels). Floor - The ground floor is insulated with 4 cm of polyurethane (total U-values: 0.43 W/m^{2}K over soil, 0.51 W/m^{2}K over void). Windows – Double glazed windows installed on roof (U_W = 1.4 W/m^{2}K) and façade (U_W = 1.89 W/m^{2}K).	
action 03	Services	The existing boiler replaced with condensing gas boiler. The ventilation system was installed to extract air from kitchen and bathrooms.	

*action themes: strategic / fabric / renewables / services / people

reference	Challenge theme**	details	relating to:
challenge 01	Financial	The budget limitation posed constraints on the technology chosen for façade renovation, and excluded the possibility to install PV and a heat pump.	Action 01

**barrier themes: strategic / existing building / financial / supply chain / people

Case study: CS 26



Project title:	Retrofit for the Future house
Location:	Cambridge
Project size:	1 dwelling, 86 sqm
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1947
Construction type:	steel frame
Date of works:	2010 (9 weeks)
End user:	private household
Funding source:	Technology Strategy Board
Contact:	Dr Minna Sunikka-Blank mms45@cam.ac.uk
Project team:	PRP Architects, Hill Partnerships, Cambridge City Council, Cambridge University

Key words: **insulation | occupant behaviour | in situ**

Summary:

(source: Minna Sunikka-Blank et al., 2012)

"The case study is located in a social housing area at the southwest side of Cambridge city, in Trumpington. The social housing scheme, which today is partly owned by the Cambridge City Council, was built in the 1950s by the British Steel Homes company as part of the large housing development. The case study and most houses in the area are all identical three-bed semi-detached properties, constructed using a steel frame (BISF) structure. Most of the households receive housing benefits, are considered as "fuel-poor" (paying more than 10% of their household income for energy) and, due to their economic situation, are pre-pay metre (PPM) clients, with high energy tariffs than in a traditional contract. As a part of the TSB "Retrofit for the Future" competition, the case study was retrofitted and monitored as a prototype for other social housing in the area. The retrofit strategy had to be feasible and replicable on a mass scale to any house of this type in any location in the UK. In total, 36,000 BISF houses and 1500 steel-framed Howard Houses were built after the war in the UK."

Related literature:

Minna Sunikka-Blank, Jun Chen, Judith Britnell & Dimitra Dantsiou (2012): Improving Energy Efficiency of Social Housing Areas: A Case Study of a Retrofit Achieving an "A" Energy Performance Rating in the UK. European Planning Studies, 20:1, 131-145

reference	action theme*	details	evidence
action 01	Strategic	The project team set out to design a retrofit on a typical steel frame house to improve the energy performance to EPC "A" level. The research team of the project (Cambridge University) was particularly interested in evaluating the impact of the occupants' behaviour on the performance of the house after the retrofit.	
action 02	Fabric	The external walls were insulated with 20 cm of phenolic foam, improving U-value from 2.1 to 0.12 m^2K/W. The roof was insulated with 35 cm of mineral wool. Parts of the ground floor was insulated with 2.5 cm of aerogel. The existing double-glaze windows were replaced with triple-glazed with PVC frame (U = 1.1 m^2K/W). External doors were replaced with triple-glazed doors (U = 1.5 1.1 m^2K/W). Target level of air permeability was 5 $m^3/m^2.hr$ @ 50 Pa. Pre-retrofit test on the dwelling showed air permeability level at 13.58 $m^3/m^2.hr$ @	
action 03	Services	New boiler with gas flue heat recovery. Waste water heat recovery unit for bath and shower. Continuously-running air extractors installed in kitchen and bathroom, air inlets provided by trickle vents in the new windows. LED lightings and energy efficient appliances for the kitchen.	
action 04	Renewables	Solar thermal collectors on the roof (3 sqm). PV panels on the roof (22.5 sqm) estimated achieve an annual yield of 1876 kWh.	
Action 05	People	Touch-screen panel monitoring house consumption to educate and raise awareness in the tenants. The house is occupied by an unemployed couple with 3 children.	

*action themes: strategic / fabric / renewables / services / people

reference	barrier theme**	details	relating to:
barrier 01	Financial	Further reductions of energy consumption (up to passivhaus standard) were considered not replicable on a large scale due to lower cost-effectiveness. The capital investment on PV panels installed in the project (about 6,000 £/kWp) was considered unaffordable in social housing retrofits.	action 01
barrier 02	Supply chain	Both architect and project officer were not based locally, this created some drawbacks and delays.	
barrier 03	People	The works caused a significant disruption to the occupants, who spend most of their time in the house. The ideal solutions would be temporary moving away from the property or using a campervan next to it. This would also facilitate the	

		construction works and reduce the overall time required.	
barrier 04	People	Despite fuel poverty and low-income conditions, the occupants showed unawareness of energy consumption (e.g. keeping relatively high indoor temperature, around 25 degrees) and no interest in the energy display provided with the retrofit. More interest was how towards the new kitchen appliances. This was related to the fact that the occupants preferred "familiar" appliances and had not personally invested in the energy display equipment. This highlights the need for coupling the roll-out of smart meters and feed-in-tariffs with education and awareness campaigns, especially for social housing.	action 05

**barrier themes: strategic / existing building / financial / supply chain / people

Case study: CS 27

Project title:	Retrofit and Replicate
Location:	South London
Project size:	1 dwelling
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1930
Construction type:	masonry - cavity
Date of works:	2008-2009
End user:	private household
Funding source:	Private (social landlord)
Contact:	ECD Architects, ecda@ecda.co.uk
Project team:	ECD Architects, Hyde Housing Association

Key words: **insulation | ventilation | renewables**

Summary: (source: http://www.greenspec.co.uk/building-design/retrofit-1930s-terrace-house/)

"ECD Architects approached Hyde Housing Association in 2007 with a proposal to undertake an exemplar retrofit project. Retrofit initiatives to date have focussed primarily on installing individual renewables or other low-carbon technologies. Hyde and ECD therefore agreed that the aim of this project would be to establish the most effective overall package of retrofit measures necessary to achieve 80% reductions in CO2 emissions, recommended by the Existing Homes Alliance, at a typical 3-bedroom mid-terrace house.
The project would include a post-construction 2-year monitoring period which would develop a full cost/benefit analysis, with a view to ascertaining the optimum expenditure. This would enable Hyde and others to make the more efficient and effective choices about how best to apply energy saving as part of large scale retrofit programmes."

Headlines:

Primary energy requirement 67 kWh/sqm.year (savings 84%, calculated)
Annual CO_2 emissions 17 kg CO_2/sqm.year (savings 83%, calculated)
Cost £ 50,000 (about £625/sqm)

Related literature:

Web article http://www.greenspec.co.uk/building-design/retrofit-1930s-terrace-house/
Web article https://ecda.co.uk/portfolio/court-farm-road/

reference	action theme*	details	evidence
action 01	Strategic	The purpose of this project was to establish the most effective package of retrofit measures necessary to achieve a 80% reduction in CO_2 emissions for a typical 3-bedroom mid-terrace house, adopting the following priorities: • minimising heat losses from the building fabric; • installing easily replicable, efficient form of space and water heating; • reduce energy requirements for lighting; • installing the most appropriate renewable forms of micro-generation. Over 80% reductions in CO_2 emissions (calculated) were achieved. The most effective measures towards this reduction ware fabric insulation (-27%), boiler replacement (-21%) and airtightness (-15%). Renewables (PV and solar thermal) accounted for -15%. It should be noted that the initial SAP rating of the property was 60, which is well above the national average.	Energy performance calculations
action 02	Fabric	External walls - Composite dry-lining panels (7 cm, phenolic foam and plasterboard) were used as internal insulation in combination with blown glass wool (4 cm) in the cavity of the external walls of the house main body (U = 0.15 W/m^{2}K). The walls of the rear extension were insulated with insulated panels (10 cm, phenolic foam) with silicone finish. Roofs – the pitched roof was insulated (below the rafters) with breathable multi-foil insulation. The loft floor was insulated with PIR panels (17cm, over the joists) covered by a floating floorboard (total U = 0.1 W/m^{2}K). The roof of the rear extension of the house was insulated PIR panels and glass wool in the eaves. Floor – phenolic foam panels installed in the suspended floors (U = 0.2 W/m^{2}K) Windows and doors - The existing double-glazed windows replaced with aluminium-clad triple-glazed windows with warm edge spacers and composite insulated timber frames (U_w = 0.7 W/m^{2}K). External doors were replaced (U_w = 1 W/m^{2}K	
action 03	Services	The existing gas boiler was upgraded with a more efficient condensing boiler. MVHR was installed, with 90% heat recovery. The heat recovery unit is bypassed in summer. The necessary for the DHW is supplied by the gas boiler and supplemented by solar thermal collectors located on both sides of the pitched roof (facing east and west). An automated system controls the water flow from the panels to favour the panel with the warmer supply. LED lightings were installed.	
action 04	Renewables	Eight 170W polycrystalline panels were installed on the rflat roof of the house extension at a pitch of only 5° to limit any impact on the neighbouring property. A wall-mounted display was installed to display information on the energy generated.	

*action themes: strategic / fabric / renewables / services / people

reference	challenges theme**	details	relating to:
challenge 01	Strategic	The use of heat pumps was not considered effective, since the carbon intensity of electric energy in the UK is more than twice than mains gas, a COP greater than 2.5 would have been required to make a heat pump advantageous in comparison to an efficient condensing boiler.	action 03
challenge 02	strategic	A biomass boiler would have required additional plant space and was also ruled out by the social landlord (to avoid tenants having to source and store a supply of wood pellets). The use of ground-source heat pumps in combination with underfloor heating was ruled out due to the costs and the difficulties of installation in existing floors.	action 03

**challenges themes: strategic / existing building / financial / supply chain / people

Case study: CS 28

Project title:	Low Carbon Adaptable Home
Location:	Dublin
Project size:	1 dwelling, 152 sqm
Project type:	newbuild
Dwelling type:	detached
Dwelling age:	2013
Construction type:	steel frame
Date of works:	2013
End user:	private tenant
Funding source:	Public
Contact:	Oliver Kinnane, oliver.kinnane@ucd.ie
Project team:	Enterprise Ireland, TrinityHaus Research Centre, Trinity College Dublin, Glenbeigh Off-site Construction
Key words:	**low carbon | off-site | modular**
Summary: (source: http://smart-er.eu/content/smart-energy-regions-skills-knowledge-training-and-supply-chains)	"The Low Carbon Adaptable Home is a full building prototype incorporating a prefabricated modular wall system. The house constitutes a new adaptable housing prototype that enables low energy operation and adaptation through its life cycle so that it can meet the changing needs of the occupants and be flexible to projected changes in climate. The core house is designed so that it can be stacked for use as multiple unit housing or enlarged with added pods for e□ample in the case of a growing family unit. The house was then rented on the open market and the occupant's usage and response to the house are monitored."
Headlines:	**Primary energy requirement 69 kWh/sqm.year (measured)** **Annual CO_2 emissions ? kg CO_2/sqm.year** **Cost ?**
Related literature:	COST Action Smarter case study http://smart-er.eu/content/smart-energy-regions-skills-knowledge-training-and-supply-chains Web summary http://www.trinityhaus.tcd.ie/projects-space.php
Related case studies:	

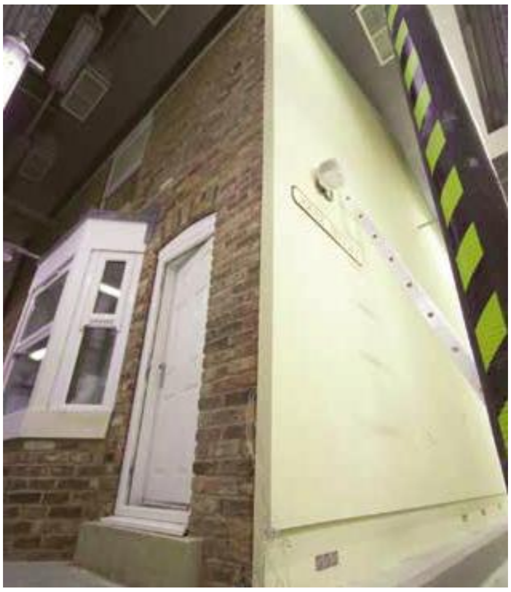
reference	action theme*	details	evidence
action 01	Strategic	The purpose of this project was to develop a working prototype of low carbon dwelling suitable for the Irish context designed to allow additional modules to accommodate changes in the household composition. The project involved Glenbeigh Off-site Construction to take advantage of off-site construction methods and support this Irish firm in showcasing the application of its product in the domestic sector.	The house has 33% higher energy consumption than forecasted by SAP and 15% higher than modelling results. Large difference between summer (1,658 kWh) and winter (4,692 kWh)
action 02	Fabric	External walls - Off-site light gauge steel frame externally insulated with 14 cm of PIR panels. Roof – - Off-site light gauge steel frame externally insulated with 15 cm of PIR panels Floor – Concrete slab insulated with 30 cm of EPS. Windows - Triple glazed low emissivity glass with argon-filled layers (U = 0.76 W/m2K).	
action 03	Services	An air-source heat pump with MVHR supplies ventilation and space heating. The system can be bypassed to allow for natural ventilation. The MVHR can supply cooling through forced ventilation. This is used at night when air temperatures are lower.	Monitored heating and ventilation load is 36 kWh/m^{2}yr. Background ventilation is 6.5 % of MVHR load. Winter heating load is higher than expected due to high temperature settings.
action 04	Renewables	Solar thermal panels on the roof for DHW assisted by back-up. Wiring is in place to allow for future installation of PV and wind turbine.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	The project brief required the challenging combination of flexibility and low carbon performance into a replicable prototype. The team developed an appropriate solution thanks to by adopting modular design and off-site construction.	action 01

**challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 29



Project title:	Salford Energy House - Saint-Gobain whole house retrofit
Location:	Salford
Project size:	1 dwelling
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1919 (replica)
Construction type:	masonry - solid wall
Date of works:	2015
End user:	researchers
Funding source:	Public/private
Contact:	Salford University, Applied Buildings and Energy Research Group, Prof William Swan, w.c.swan@salford.ac.uk
Project team:	Isover Saint-Gobain, University of Salford, Leeds Metropolitan University

Key words: **fabric | insulation | airtightness**

Summary: (source: https://www.salford.ac.uk/__data/assets/pdf_file/0003/562134/pdf1-Energy-House-brochure.pdf)

"The Energy House is the only full-scale building in an environmental chamber in Europe and the only full-scale, brick-built test facility in a controlled environment in the world. The house is a traditionally constructed, terraced building (with a neighbouring property). In its current state it is uninsulated. The heating is provided by a wet central heating system, fired by a gas condensing combination boiler. All of this can be changed to suit the testing requirements required by clients."

In 2015 Isover Saint-Gobain carried out a 3 months project to test a whole house approach carrying out a full retrofit of the building in a way that allowed stage by stage savings to be visible, in terms of performance changes in whole house heat loss and air permeability.

Headlines: **Heating demand reduced by 63% (monitored)**
Cost savings £350 per year (estimated)

Related literature: Energy House Brochure https://www.salford.ac.uk/__data/assets/pdf_file/0003/562134/pdf1-Energy-House-brochure.pdf
Web article https://www.isover.co.uk/references/case-study-salford-house

Related case studies: CS30

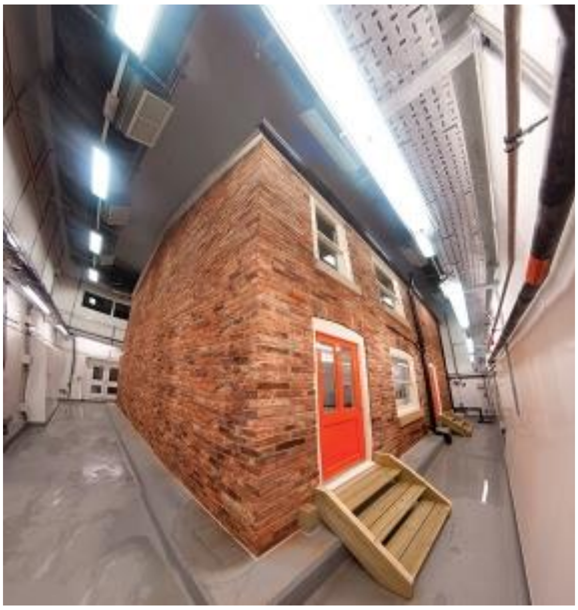
reference	action theme*	details	evidence
action 01	Strategic	The project adopted a fabric-first approach and aimed to simulate real-life conditions. The Energy House facility was prepared to replicate the typical current conditions of Victorian houses in the UK as a baseline (e.g. double glazing, some loft insulation). The selection of measures was restricted to commercially available technologies.	Heating demand reduced by 63% (monitored), cost savings £350 per year (estimated)
action 02	Fabric	External walls, loft and floor insulated with glass wool (17 – 20 cm). The floor was also covered with an airtightness membrane.	Total 63% reduction in heat losses. Air leakage through the building fabric reduced from 12.5m3/(h.m2) at 50 Pascals (Pa) to just 6m3/(h.m2). The installation of the airtightness membrane in the floor accounted for 42% of air leakage reduction.

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	Quantifying the specific impact of interventions on the building fabric is often difficult in real-life conditions due to several other factors in play.	action 01

**challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 30



Project title:	Salford Energy House - BEAMA Heating Controls Group
Location:	Salford
Project size:	1 dwelling
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	1919 (replica)
Construction type:	masonry - solid wall
Date of works:	2015
End user:	researchers
Funding source:	Public/private
Contact:	Salford University, Applied Buildings and Energy Research Group, Prof William Swan, w.c.swan@salford.ac.uk
Project team:	BEAMA, University of Salford

Key words: **simple controls**

Summary:
(source: https://www.salford.ac.uk/__data/assets/pdf_file/0003/562134/pdf1-Energy-House-brochure.pdf

"The Energy House is the only full-scale building in an environmental chamber in Europe and the only full-scale, brick-built test facility in a controlled environment in the world. The house is a traditionally constructed, terraced building (with a neighbouring property). In its current state it is uninsulated. The heating is provided by a wet central heating system, fired by a gas condensing combination boiler. All of this can be changed to suit the testing requirements required by clients."
In 2015 "the BEAMA (British Electrotechnical and Allied Manufacturers' Association) Heating Controls Study project is designed to assess the impact of different heating control sets on the consumption of energy in heating a home. The study aimed to bridge the gap between laboratory-based work and fieldwork, neither of which fully recreate a real-life, yet controlled, environment."

Headlines:

Cost reduction 40.7% (with thermostat and TRVs, monitored)
Cost savings £410 per year (with thermostat and TRVs, estimated)
Cost £340 (cost of thermostat and TRVs)

Related literature:
Energy House Brochure:https://www.salford.ac.uk/__data/assets/pdf_file/0003/562134/pdf1-Energy-House-brochure.pdf
BEAMA white paper:
https://www.salford.ac.uk/__data/assets/pdf_file/0012/562989/pdf2-BEAMA-Heating-control-White-paper.pdf

Related case studies: CS29

reference	action theme*	details	evidence
action 01	Strategic	The study looked to assess the impact of three different types of heating control arrangements and how they affected energy consumption, internal room temperatures and system performance. The project team recreated average winter temperatures by holding the environmental chamber at 50C. The heating system of the house was designed and installed to CIBSE Domestic Heating Design Guide standard.	
action 02	Services	Three options were tested: 1) boiler thermostat only (i.e. no local controls, used as baseline); 2) boiler thermostat and living room thermostat; 3) boiler thermostat, living room thermostat and thermostatic radiator valves (TRVs).	Results show that adding a thermostat (option 2) reduced energy cost by 12%, while adding both a thermostat and TRVs (option 3) reduced energy cost by 40.7%.

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Strategic	Quantifying the specific impact of heating controls is often difficult in real-life conditions due to several other factors in play.	action 01

**challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 31

Project title:	Heathcott road passive houses
Location:	Leicester
Project size:	68 homes
Project type:	newbuild
Dwelling type:	semi-detached
Dwelling age:	2017
Construction type:	timber frame
Date of works:	2017
End user:	researchers
Funding source:	Public
Contact:	Neil Hodgkin, head of Development at Saffron Lane Neighbourhood Council
Project team:	Saffron Lane Neighbourhood Council, rg+p architects, and Westleigh Partnerships

Key words: **passivhaus**

Summary: (source:

This project was initiated by Saffron Lane Neighbourhood Council as part of their effort to renovate one the most deprived areas of Leicester. The development was preceded by consultation with the local residents to identify the local housing needs. The area is adjacent to a community farm which provides food education, allotments for residents and opportunities for skills training of people with learning disabilities. The land is leased to a charity, which manages the estate. Income from the development enables to pay a full-time Debt and Welfare Support officer located on site. It is believed to be the largest passive house development in the UK.

Headlines:

Primary energy requirement <15 kWh/sqm.year (estimated)
Cost £9 million

Related literature:

CEERA response 04 by David Thorpe
Webpage http://www.buildingconstructiondesign.co.uk/news/airflow-helps-heathcott-road-development-achieve-passive-house-certification/

Related case studies:

reference	action theme*	details	evidence
action 01	Strategic	The aim of the project was to provide affordable low-carbon housing to a deprived area. This was achieved by designing the houses for a Passivhaus standard.	The houses are rented at about 80% of the local market levels, and can be heated for as little as £13 per year.
	Services	All houses are equipped with MVHR units.	

*action themes: strategic / fabric / renewables / services / people

Case study: CS 32

Project title:	Graylingwell district heating and CHP
Location:	Chichester
Project size:	750 homes
Project type:	retrofit and newbuild
Dwelling type:	various
Dwelling age:	2007 and later
Construction type:	Choose an item.
Date of works:	2007 - ongoing
End user:	Private housing
Funding source:	Private
Contact:	Eneteq (enquiries@eneteq.co.uk)
Project team:	Lynden Homes (Galliford Try), Eneteq

Key words: **Services | CHP**

Summary:

This development takes place on the site of a former Victorian hospital stretching over 34 hectares. The masterplan was designed through a collaborative placemaking process with local citizen and stakeholders. The development includes 750 new and retrofitted dwellings, 2,200 sqm of community space and 5,900 sqm of commercial space. It has received several awards between 2010 and 2014.

Headlines: **Cost of the heating network £7.2 million**

Related literature:

ADE / Eneteq case study https://www.theade.co.uk/assets/docs/case-studies/Eneteq_-_Graylingwell_Park_District_Heating_Scheme_Case_Study.pdf
Architect webpage https://www.jtp.co.uk/projects/graylingwell-park

reference	action theme*	details	evidence
action 01	Strategic	The project was developed from the inception stage to achieve Net Zero Carbon and CSH level 6.	
action 01	Renewables	The development includes a 2MW wind turbine and solar panels over building roofs.	
action 01	services	Heat is delivered by a district heating network powered by a CHP plant, located in the existing water tower.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	strategic	The designer of the district heating network (Eneteq) played a significant role in the development by devising a bankable financial model to fund the CHP powered district heating network and coordinating with the legal team to cover related legal aspects such as: Energy Service Company agreement, customer supply agreements, operations and maintenance contracts, gas supply agreement, metering and billing contracts, plant warranties, and equipment guarantees.	

**challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 33

Project title:	West Bridge Mill CHP
Location:	Kirkcaldy, Scotland
Project size:	16 flats
Project type:	retrofit
Dwelling type:	various
Dwelling age:	1855
Construction type:	masonry - solid wall
Date of works:	2016
End user:	Social housing
Funding source:	Private
Contact:	SAV Systems (info@sav-systems.com)
Project team:	LinkLiving, SAV Systems

Key words: **Services | CHP**

Summary: A 'B' listed former mill was renovated into 16 flats for vulnerable young people and a support centre. The building was serviced with CHP for heating and DHW to enable low operational costs.

Headlines:

Primary energy requirement ? kWh/sqm.year
Annual electricity demand 172,000 kWh
Annual heating and DHW demand 320,000 kWh
Annual CO_2 emissions 136,674 kg CO_2/year (21% savings on conventional mains and gas supply)

Related literature:

ADE / SAV Systems case study https://www.theade.co.uk/assets/docs/case-studies/CaseStudyWestBridgeMill.pdf
LinkLiving webpage https://linkhousing.org.uk/news-resources/latest-news/west-bridge-mill-relaunch/

Related case studies:

reference	action theme*	details	evidence
action 01	Services	SAV Systems installed a 15kWe/ 30kWth LoadTracker CHP unit able, which is able to supply 69% of site heating and DHW, and 66% of electrical demand.	

*action themes: strategic / fabric / renewables / services / people

Case study: CS 33

Project title:	Westfields social housing CHP
Location:	Edinburgh
Project size:	192 flats
Project type:	newbuild
Dwelling type:	various
Dwelling age:	2009-2015
Construction type:	Choose an item.
Date of works:	2009-2015
End user:	Social housing
Funding source:	Private
Contact:	SAV Systems (info@sav-systems.com)
Project team:	Dunedin Canmore Housing Association, SAV Systems

Key words: **Services | CHP**

Summary: A new development containing 192 affordable housing units and 8 business units in a deprived area of Edinburgh

Headlines:

Annual electricity demand 860,000 kWh
Annual gas demand 1,545,000 kWh
Annual CO_2 emissions 631,182 kg CO_2/year (20% savings on conventional mains and gas supply)

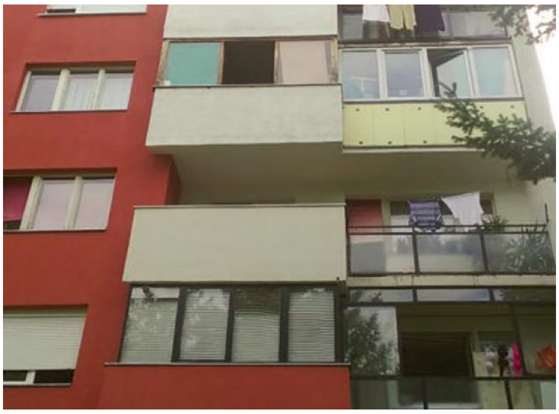
Related literature: ADE / /SAV Systems case study https://www.theade.co.uk/assets/docs/case-studies/LoadTrackerCHPCaseStudy-Westfields.pdf

Related case studies: CS33

reference	action theme*	details	evidence
action 01	Services	SAV Systems installed four 15kWe/ 30kWth LoadTracker CHP units, which are able to supply 74% of site heating and DHW, and 54% of electrical demand.	

*action themes: strategic / fabric / renewables / services / people

Case study: CS 35



Project title:	Flat retrofit in Serbia
Location:	Belgrade, Serbia
Project size:	1 dwelling, 64 sqm
Project type:	retrofit
Dwelling type:	apartment
Dwelling age:	1960
Construction type:	other
Date of works:	2011
End user:	Private
Funding source:	
Contact:	Aleksandra Krstic-Furundzic akrstic@arh.bg.ac.rs

Key words: **Insulation | fabric first**

Summary:

(source:

Between 2009 and 2011 several housing blocks in the Karaburma district of Belgrade were retrofitted to reduce their energy consumption. The retrofit focused on adding thermal insulation to external walls and replacing windows.

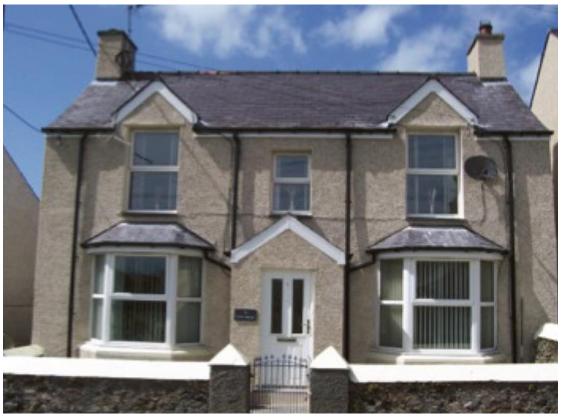
Headlines: **Primary energy requirement reduced by 28% (estimated)**
Cost £22/sqm (2011)

Related literature: Smarter COST Action WG3 case study http://www.smart-er.eu/sites/default/files/attachments/Smart%20Energy%20Regions%20-%20Cost%20and%20value.pdf

reference	**action theme***	**details**	**evidence**
action 01	Strategic	LCC was performed for a 30 years life cycle of the retrofit, the payback period was calculated to be just over 5 years. The retrofit increased property value between 20% and 25% (in comparison to nearby low performance apartments)	Savings in energy consumption were estimated at 28% (based on 2 months energy bills after retrofit)
action 02	Fabric	The external façade of the flat is about 40 sqm. External walls – existing walls of bricks and concrete were covered with 5 cm of EPS (total U = 0.45 W/m^2K) Windows – existing timber frame windows were replaced with double-glazed windows with PVC frame (U = 2.3 W/m^2K)	

*action themes: strategic / fabric / renewables / services / people

Case study: CS 36



Project title:	Cymdeithas Tai Eryri's ARBED 1 scheme
Location:	North Wales
Project size:	410 dwellings
Project type:	retrofit
Dwelling type:	various
Dwelling age:	various
Construction type:	Choose an item.
Date of works:	2009-2011
End user:	Social housing tenants
Funding source:	Arbed phase 1 and Cymdeithas Tai Eryri (RSL) match-funding
Contact:	Susan Walton (assessor)
Project team:	Cymdeithas Tai Eryri (RSL)

Key words: **Heat pumps**

Summary:
(source: Walton, S. 2013. A report on Cymdeithas Tai Eryri's ARBED 1 scheme and its effectiveness.)

"Cymdeithas Tai Eryri (CTE) has undertaken a very successful retro-fitting scheme to reduce fuel poverty among its tenants, and to reduce CO2 emissions. The work was carried out under the Welsh Government's ARBED programme and delivered within the Môn a Menai Strategic Regeneration Area in North Wales. It included houses belonging to the Isle of Anglesey County Council as well as CTE's own. The main focus was hard to heat homes. The measures installed were solar photovoltaic panels, air source heat pumps, external wall insulation (and solar hot water panels on some of the Anglesey Council houses)."

Headlines: **Annual CO2 emissions reduced by 49% (calculated)**

Related literature: Walton, S. 2013. A report on Cymdeithas Tai Eryri's ARBED 1 scheme and its effectiveness.

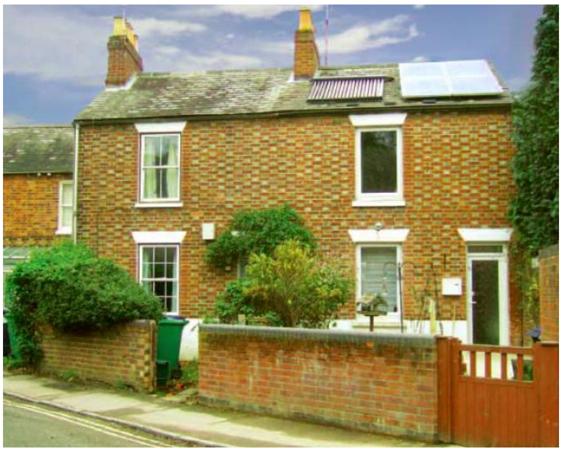
reference	action theme*	details	evidence
action 01	Strategic	The 410 dwellings involved by the schemes received different combinations of measures depending on their conditions and access to gas mains. The average RdSAP rating of properties was increased from 52 to 70. Estimated financial savings of £125 per year (18%) and carbon savings of 49% per year.	
action 03	Fabric	74 houses received sold wall insulation (external), average cost per house £13,000	
action 04	Services	34 off-grid houses received heat pumps as replacement for the main heating system (solid fuel), average cost per house £7,520	
action 05	Renewables	PV panels on south-facing roofs were installed in 258 of the houses, average cost per house £6,370. 83 houses received solar thermal panels for DHW, average cost per house £2,975.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	people	Tenants were generally positive about the work and the increased levels of comfort within their homes. Some tenants reported problems with the heat pumps and concerns with the costs of running them. The RSL realised that tenants need to be better informed on the operation of the new systems in order to get the best outcome.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 37



Project title:	Retrofit for the Future house (Oxford)
Location:	Nelson Street, Oxford
Project size:	1 dwelling, 80 sqm
Project type:	retrofit
Dwelling type:	semi-detached
Dwelling age:	
Construction type:	masonry - solid wall
Date of works:	2010
End user:	Private
Funding source:	Public/private
Contact:	Dr Rajat Gupta (Oxford Brookes University) rgupta@brookes.ac.uk
Project team:	Oxford City Council, Oxford Brookes University, Leadbitter Group, Ridge

Key words: **Insulation | MVHR | supply chain**

Summary: “This Oxford City Council Victorian semi-detached house in Nelson Street with two rear extensions added in 1972 and 2003, was described as a very cold house by the residents, especially the first floor bathroom that had three exposed external walls and a roof. Project Core Objectives:

- Reduce the carbon emissions from the energy consumption of the
- property by 80%.
- Reduce fuel bills from £600 per year to £150 per year.
- Use practical tried and tested technologies.
- Improve health, comfort and quality of life for tenants.
- Identify lessons learnt and apply to wider social housing stock.

Headlines: **Annual CO_2 emissions reduced by 85% (measured)**

Related literature: Web article https://www.sustainablehomes.co.uk/oxford-whole-house-retrofit-reduces-co2-by-over-80/
Case study (link)

reference	action theme*	details	evidence
action 01	Strategic	The monitored energy consumption of the house before retrofit was about 155 kWh/sqm per year. Energy and GHG savings were achieved in three stages: • reducing losses from fabric and infiltration, which cut GHH emissions by 66%; • installing efficient DHW and lighting equipment, bringing GHG savings to 75%; • adding solar thermal and PV panels to offset emissions, bringing GHG savings to 85%.	
action 02	Fabric	External walls – the existing brick facade of the front wall was maintained and insulated internally with 8 cm of insulated plasterboard (total U = 0.24 W/m^2K). The rear wall received the same internal insulation and an additional 20 cm of rendered insulation on the outside (total U = 0.1 W/m^2K). The gable wall was insulated externally with 20 cm of EPS (total u= 0.1 W/m^2K). Roof – the loft was insulated with 42 cm of insulation at ceiling line with airtight vapour barrier (total u= 0.1 W/m^2K). Ground floor – a new floating chipboard floor with 1 cm insulation was installed on the existing screed and concrete floor. Windows – the existing double-glazed windows were replaced with new triple-glazed (U = 0.8 W/m^2K)	
action 03	Services	MVHR was installed in the loft. A 'sunpipe' was been installed in the roof over the stairs, with a controllable vent to improve natural light and natural ventilation in the central part of the house.	
action 04	renewables	Solar thermal and PV panels (8 sqm) were installed on the south-east roof.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	Supply chain	The delivery of the project within 16 weeks required tight coordination of suppliers and contractors and training workers to ensure high quality of works necessary to for adequate installation.	

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 38

Project title: Cymdeithas Tai Eryri improvement of 'hard to heat' homes in Gwynedd
Location: South Gwynedd, Wales
Project size: 24 dwellings
Project type: retrofit
Dwelling type: various
Dwelling age: various
Construction type: Choose an item.
Date of works: 2011-2012
End user: Social housing tenants
Funding source: Renewable Heat Premium Payment for Social Landlords Phase 1
Contact: Susan Walton (assessor)
Project team: Cymdeithas Tai Eryri (RSL)

Key words: **Heat pumps | hard to treat | off-grid**

Summary:
(source: Walton, S. 2013. Outcomes from improvements to 'hard to heat' homes in South Gwynedd.)

"Cymdeithas Tai Eryri (CTE) set out, with a grant from the Renewable Heat Premium Payment for Social Landlords, on a project to improve the energy efficiency of 24 of its 'hard to heat' houses in South Gwynedd. These properties are all off the mains gas grid, and most had coal as the primary fuel for providing domestic heating and hot water (a few had oil or LPG instead). CTE retro-fitted air-to-water source heat pumps systems and insulated each property, with the intention of reducing tenants' fuel costs.
The project has caused a significant shift to electricity as the primary domestic heating fuel. Following the retro-fit the majority of the houses in the project now have electricity as their primary fuel, and electricity is also the most consumed fuel."

Headlines: **Annual CO2 emissions reduced by 51% (calculated)**

Related literature: Walton, S. 2013. Outcomes from improvements to 'hard to heat' homes in South Gwynedd
Related case studies: CS39

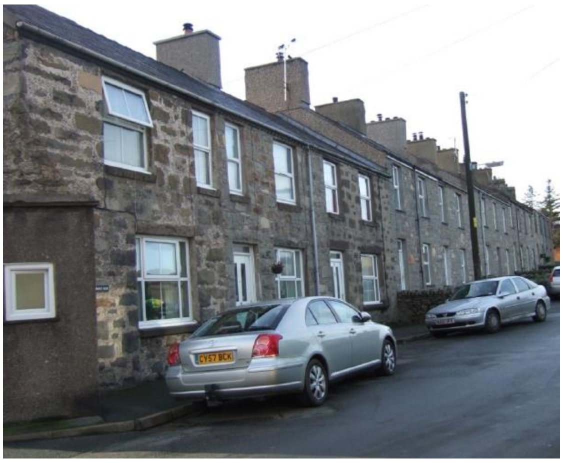
reference	action theme*	details	evidence
action 01	Strategic	The project improved the fabric of the dwellings and introduced air source heat pumps in alternative to the heating sources used by the tenants (coal, oil, wood) with the aim to improve comfort and reduce carbon emissions. All tenants reported an increase in the perceived level of comfort after the retrofit, which can be linked dot the improvement of the building fabric RdSAP rating of house before retrofit were ranging from 9 to 61, with average of 38. After retrofit rating range was 62 to 72, with average of 65. Switching to electricity as main source caused a 15% increase in electricity use, with some tenants still using coal on the side.Bills and estimates from tenants before and after the retrofit indicate an average 13% increase in heating spending. This was due in part to rising cost of electricity and solid fuels. It should also be considered that heating costs would have been much higher without the retrofit.	RdSAP calculations; electricity bills a and estimates by tenants
action 02	Fabric	External insulation with render	
action 03	Services	Air-to-water heat pumps (6.9 kW) installed with accompanying radiators, setting up a central heating system based on electricity. 16 houses retained an additional solid fuel source by receiving a new multi-fuel stove.	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	people	After the retrofit, some of the tenants have not used the new system or have felt the need to top up with solid fuel heating. The main reason appears to be worry about the cost of running the heat pump continuously, which is actually required for the system to work more optimally.	Action 01 and 03

** challenge themes: strategic / existing building / financial / supply chain / people

Case study: CS 39



Project title:	Trem y Môr Terrace renovation pilot scheme
Location:	Trefor, Wales
Project size:	5 houses
Project type:	retrofit
Dwelling type:	mid terrace
Dwelling age:	Pre-1930
Construction type:	masonry - solid wall
Date of works:	2010
End user:	Social housing tenants
Funding source:	Cymdeithas Tai Eryri (RSL)
Contact:	Dafydd Wyn Horan
Project team:	Cymdeithas Tai Eryri (RSL), Hillserve Insulation Specialists, Rothwell Plumbing, Wigan (solar thermal) British Gas

Key words: **Heat pumps | hard to treat | off-grid**

Summary: Cymdeithas Tai Eryri retrofitted 5 adjacent terraced units in Trefor as a pilot scheme to test a combination of measures for hard-to-treat homes. The houses received wall and loft insulation and were equipped with air-to-water heat pumps (and accompanying radiators) as alternative to solid fuel stoves.

Headlines: **Annual CO2 emissions reduced by 56% (calculated)**
Cost £20,000 per house

Related literature: Dafydd Wyn Horan, 2011. Report on the Trem y Môr Terrace, Trefor renovation pilot scheme.

Related case studies: CS38

reference	action theme*	details	evidence
action 01	Strategic	Estimated savings of 1,400 per house per year. Tenants reported financial savings after the works, possibly up to 50%. Large differences between the savings of different houses. Larger savings were achieved by tenants who understood the new systems and sought to reduce energy demand.	RdSAP rating increased by 30 on average
action 03	Fabric	External walls – insulated internally on the front wall and externally at the rear. Cost per house £5,368, expected to reduce 20% of carbon emissions. Roof – loft insulation, cost per house £3,200 Windows and doors – new double-glazed windows and insulated doors	
action 04	Services	Air-source heat pumps, cost per house £7,200, expected savings of £500 per year	
action 05	Renewables	Solar thermal panels for DHW installed on roof, cost per house £4,650, expected to meet 50% of DHW load demand save £50 per year	

*action themes: strategic / fabric / renewables / services / people

reference	challenge theme**	details	relating to:
challenge 01	people	Tenants were generally satisfied with the outcome of the retrofit but would have liked the RSL to coordinate works and support residents in understanding new systems. Some tenants complained about the poor conditions of the properties after the works.	All actions

** challenge themes: strategic / existing building / financial / supply chain / people