

<b>Institution:</b> Cardiff University		
<b>Unit of Assessment:</b> Architecture, Built Environment and Planning (13)		
<b>Title of case study:</b> Driving investment into affordable, low-carbon housing across Wales		
<b>Period when the underpinning research was undertaken:</b> 2012 – 2020		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Phillip Jones	Chair of Architectural Science	01/09/1984 - 31/03/2020
Joanne Patterson	Senior Research Fellow	06/01/1997 - present
Ester Coma-Bassas	Research Associate	14/10/2013 - present
Simon Lannon	Senior Research Fellow	22/08/1988 - present
Elena Perisoglou	Research Associate	01/09/2012 - present
Xiaojun Li	Research Associate	01/05/2013 - present
Ed Green	Senior Lecturer	02/11/2015 - present
Wayne Forster	Professor	01/01/1992 - present
<b>Period when the claimed impact occurred:</b> 2015 – 2020		
<b>Is this case study continued from a case study submitted in 2014?</b> No		
<b>1. Summary of the impact</b> (indicative maximum 100 words) <p>Homes in the UK generate 20% of national CO<sub>2</sub> emissions. Affordable, low-carbon housing is critical to reducing emissions at scale. Cardiff research realised the first affordable low carbon house using available technologies, verifying a 'whole house' approach to retrofitting, including heating, lighting and ventilation for application across existing national housing stock. This research led Welsh Government to invest £91M in grants to private and local authority developers (who built over 1,400 affordable and low-carbon homes) and launch a £19.5M retrofit investment to decarbonise existing housing stock, targeting 1,700 homes for retrofits.</p>		
<b>2. Underpinning research</b> (indicative maximum 500 words) <p>The Welsh Government target of a 95% reduction in overall carbon emissions will not be reached without significant reduction in the carbon released from residential properties. The Welsh School of Architecture (WSA) at Cardiff University addressed this issue by developing a 'whole house' methodology for combining energy demand, storage, and supply technologies that can be replicated at an affordable cost for both retrofits and new build homes.</p> <p><b>2.1 Developing a 'whole house' retrofit methodology</b></p> <p>In 2009-2010 the Cardiff team investigated potential deep carbon reductions in the housing stock by combining renewable energy supply and energy demand reduction via fabric improvements and energy efficient technologies. Through the Technology Strategy Board 'Retrofit for the Future' programme [G3.1], the Cardiff WSA team applied a 'whole house' retrofit to a 1980s urban semi-detached house. This retrofit work highlighted the benefits of a 'whole house', systems-based approach rather than relying on a single technological solution. By integrating low-energy technologies into the building structure, cumulative cost efficiencies were realised [3.1]. The retrofit combined technological and architectural solutions such as mechanical ventilation heat recovery (MVHR), ground-source heat pumps, and photovoltaic (PV) panels. WSA analysis of the household energy use between October 2011 and May 2012 demonstrated a 74% reduction in CO<sub>2</sub> emissions after the retrofit [3.2].</p> <p>WSA research expanded to evaluate practical retrofits of typical Welsh homes using the 'whole house' systems-based approach. Funded by the Low Carbon Research Institute (LCRI), supported by an EU Convergence Programme [G3.2] and £15.1 million from industry partners (e.g., Tata Steel), the WSA led the planning, design, implementation, and evaluation of an affordable and replicable approach to retrofit five houses representative of house types</p>		

across Wales. Depending on the needs of each building, the five houses were retrofitted with wall and loft insulation, double-glazing, MVHRs, PVs and energy storage technologies, and were monitored for actual energy use before and after retrofit. Across the five retrofitted houses, CO<sub>2</sub> emissions were reduced by 50–75%, with annual cost savings of between £402 to £621 for each household [3.3]. In September 2015, the retrofits were Highly Commended in the Innovation Award category at the 2020 Construction Excellence Wales awards.

## 2.2 The SOLCER House

Alongside the retrofits, WSA researchers applied a low-carbon and affordable ‘whole house’ systems-based approach to new builds. This resulted in the planning, design, and construction of the SOLCER House. Completed in 2015, it was the first affordable energy-positive house built in the UK. The original 100m<sup>2</sup> SOLCER House cost £1,200 per m<sup>2</sup> to build, within the range of costs normally incurred by social landlords for new build houses. Extensive monitoring and computer simulation over a 4-year period showed that the SOLCER House generates more energy per year than it requires for heating and electrical power under normal occupancy conditions. This led to energy cost savings of around £1,000 per year, particularly important for social housing occupants [3.4].

The SOLCER House won the Breakthrough Project Award at the UK Buildings and Energy Efficiency Awards 2015 and Sustainable Project of the Year at the Cynnal Cymru Awards 2015, which are run by Wales’ sustainable development and renewable energy not-for-profit sector. The architect of SOLCER House, Ester Coma, won the Construction Excellence Wales Young Achiever of the Year Award in 2015.

## 2.3 Informing Welsh Government on decarbonising housing

Building on its research in low-carbon and affordable new-build housing, WSA undertook commissioned research for Welsh Government, which resulted in the 2017 ‘More | better’ report [3.5]. The research evaluated efficiency and ease of replication of low-carbon housing case studies that could be built for less than £1,500/m<sup>2</sup>, drawing upon findings from the SOLCER House. The report highlighted a number of delivery pathways and construction techniques which could be combined to increase the stock of affordable low-energy housing. It recommended that Welsh Government fund exemplar housing projects to support these delivery pathways and construction techniques, encouraging widespread adoption of the construction of affordable low-energy housing [3.5].

In 2018, the WSA was commissioned by Welsh Government to review solutions for decarbonising existing housing stock through case studies of low-carbon retrofit and new-build projects. A multi-stage process, WSA’s Stage 2 project report combined multiple national-level datasets to develop a taxonomy of fourteen housing types prevalent in Wales. The efficacy of potential retrofit schemes was modelled for each housing type [3.6]. Using this modelling, the report recommended retrofit pathways to decarbonise Welsh housing stock.

## 3. References to the research (indicative maximum of six references)

[3.1] Forster, W., Heal, A (2009) Low Carbon Retrofit: Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s Urban Semi-detached House  
<https://orca.cf.ac.uk/52413/1/Forster%20Retrofit.pdf>

[3.2] Jones, P. J., Lannon, S. C. and Patterson, J. L (2013) Retrofitting existing housing: how far, how much? Build. Res. Infor., 41 (5) pp. 532-550  
<https://doi.org/10.1080/09613218.2013.807064>

[3.3] Jones, P.J., Perisoglou, E and Patterson, J.L (2017) Five-energy retrofit houses in South Wales. Energy and Building 154, pp. 335-342  
<https://doi.org/10.1016/j.enbuild.2017.08.032>

[3.4] Jones P.J., Xiaojun, Coma Bassas, E, Perisoglou, E and Patterson J.L (2020) Energy-positive house: performance assessment through simulation and measurement. Energies 13 (18), 4705 <https://dx.doi.org/10.3390/en13184705>

**[3.5] Green, E. and Forster, F (2017)** More | better: an evaluation of the potential of alternative approaches to inform housing delivery in Wales. Cardiff: Cardiff University. Report for Welsh Government, <http://orca.cf.ac.uk/98055/>

**[3.6] Green, E. Lannon, S. Patterson, J.L and Iorwerth, H. (2019).** Homes of Today for Tomorrow STAGE 2: Exploring the potential of the Welsh housing stock to meet 2050 decarbonisation targets. Cardiff: Cardiff University. Available from HEI on request.

#### Relevant grants

**[G3.1]** “Solutions for a holistic optimal retrofit”, Charter Housing Association Ltd. March 2010 to June 2012, PI: Joanne Patterson, total value £25,631.

**[G3.2]** “Low Carbon Research Institute,” West Wales and the Valleys Convergence Operational Programme ERDF 2007-2013. Total value £18,232,250.

#### 4. Details of the impact (indicative maximum 750 words)

Cardiff’s development of the SOLCER House prototype for affordable low-carbon new build housing, and its analyses demonstrating the viability of decarbonisation retrofits, led Welsh Government to initiate two low-carbon housing programmes: **1)** the 2017 Innovative Housing Programme which provided £91million to incorporate sustainable housing designs in over 1,400 new homes, and **2)** the 2020 Optimised Retrofit Programme securing £19.5million to decarbonise existing housing stock and provide new training and employment opportunities.

##### 4.1 The Innovative Housing Programme

On 10 July 2015, the UK Government withdrew its funding for the Zero Carbon Homes policy, effectively cancelling the previous Government’s plans for adopting zero-carbon housing by 2016. On 16 July 2015, the Cardiff-developed SOLCER house was opened, designed to demonstrate an affordable, zero-carbon, energy efficient home. The opening of the house attracted visits from Welsh Government ministers including Edwina Hart AM (Minister for Economy, Science and Transport), with further visits including Carl Sargeant AM (Secretary for Communities and Children) and Claire Perry MP (UK Energy Minister). The research received national media coverage including *BBC*, *The Guardian*, and *Daily Mail* **[5.1]**.

Lisa Dobbins, Head of Housing Decarbonisation for Welsh Government, wrote that “*Prior to the construction of the SOLCER House, we were not aware of any nearly-zero-carbon ‘typical’ housing that could be constructed for an affordable budget*” **[5.2]**. Dobbins noted that SOLCER’s ‘whole house’ systems-based approach gave Welsh Government the evidence that widespread low-carbon housing was “*an achievable and reasonable goal for Wales*” that could support the development of an economically viable supply chain **[5.2]**. Dobbins wrote that “*significant changes in thinking were adopted by Ministers based on this research, and our strategy has evolved as a result*” **[5.2]**.

The influence on strategy is evident in comments by the Secretary for Communities and Children, Carl Sargeant AM, who, after visiting SOLCER House, stated on 4th November 2015: “*I think that we can move forward with that proposition the Member refers to — integrating [SOLCER] into our house building programme*” **[5.3a]**. Sargeant later commissioned the ‘more | better’ report from WSA **[3.5]**, and responding to its conclusions in November 2016, wrote: “*Recent research commissioned from the Welsh School of Architecture has highlighted a range of innovative practice in this area on which I want us to build*” **[5.3b]**.

In October 2017, Sargeant announced in the Senedd that: “*It was clear to me that traditional approaches to house building would be very unlikely to deliver the changes needed. A new, innovative approach was needed and the report I commissioned from the Welsh School of Architecture demonstrated that, although there is no silver bullet, there are many potential models and methods available. That’s why, in February of this year, I launched the innovative housing fund*” **[5.3c]**.

The Innovative Housing Programme (IHP) launched by Sargeant was initially a £10million government grant scheme to build new affordable housing across Wales focused on

promoting low-carbon and energy-positive housing designs. Now in its fourth year, the IHP provided £91 million in funding across 50 housing projects and built approximately 1,400 homes across Wales. Lisa Dobbins, Head of Housing Decarbonisation for Welsh Government noted that the IHP “*continues to drive the embedding of new energy and design solutions into the housing sector in Wales,*” with many IHP-funded projects drawing directly on the innovations and principles developed through the SOLCER House, leading to lower energy costs and reduced year-on-year carbon emissions [5.2]. Examples of homes built through the IHP that incorporated SOLCER-demonstrated principles include:

- Forty-six homes constructed by Carmarthen County Council and six retrofits. The homes, which include photovoltaic, battery storage, and heat recovery elements (demonstrated in the original SOLCER House), were made available to social housing tenants in December 2020. Jonathan Morgan, Head of Homes & Safer Communities at the Authority confirmed the impact of the Cardiff research: “*By visiting the SOLCER House and your direct involvement we have been able to go beyond the general Building Regulation standards and use technologies and achieve thermal levels that have not previously been seen in our homes*” [5.4].
- Eighteen homes built by Swansea Council, who commissioned the WSA to model the impact of a new low carbon standard for its newly built homes. The modelling illustrated that it was possible to enhance the existing Passivhaus approach by bringing in elements of the SOLCER methodology, introducing a new ‘Standard’ of home to be built by the Council. Swansea Council wrote: “*The SOLCER house concepts were incorporated to further maximise the efficiency, while bringing down the unit costs in order to maximise the Housing Revenue Account resources*” and “*without the reduction in unit cost, it is not clear that the council would have had the resource to meet its energy efficiency ambitions at scale*” [5.5]. The enhancements, validated through the WSA’s modelling of the proposed design, led to a further thirty-four low-energy social houses built to this standard and 25 under construction. The new homes include multiple SOLCER-demonstrated elements, including Ground Source Heat Pumps, photovoltaic solar roofs, battery storage and a Mechanical Ventilation Heat Recovery (MVHR) system.
- Sixteen homes were constructed by Pobl Social Housing in Neath to reduce fuel poverty for housing association tenants through net-positive housing schemes. Pobl noted its “*original concept was inspired by the prototype SOLCER House*” and the housing includes cladding technology first demonstrated at SOLCER [5.6].
- Fourteen homes in Bridgend, commissioned by Wales and West Housing. The houses were designed by private company Zenenergy Ltd, and Wales and West Housing confirmed that these homes “*follow the design of the innovative SOLCER House*” [5.7].

The launch of the IHP, and the success of the SOLCER approach, have further influenced the housing landscape, as attested by Andy Sutton, Co-Founder of Sero Homes, a private low-carbon housing developer. Sutton wrote that SOLCER “*has driven awareness of this approach as part of a low/zero carbon home solution and has helped increase confidence and recognition of these in the marketplace and in government*” [5.8].

Wider international influence and impact are demonstrated by the 2015 visit to SOLCER House by the Vice-Premier of China, Liu Yangdong, and the two houses built by a developer in Xi’an in the Shaanxi Province, China. The houses “*adopted the SOLCER house’s whole-house demand, storage and generation integration approach*” [5.9]. They were completed in 2019 and achieved China’s nearly-zero-energy building standard, and “*some of the performances even went beyond*” the standard requirements [5.9].

#### 4.2 The Optimised Retrofit Programme

In 2019, Welsh Government’s Decarbonisation of Existing Homes Advisory Group produced the ‘Better Homes, Better Wales, Better World’ report that set ambitious targets for retrofits to achieve net zero carbon by 2050. Proposed actions within *Better Homes* include multiple references to WSA research, restating the specific target in [3.6] that housing stock must be



retrofitted to beyond the Government's Standard Assessment Procedure (SAP) rating of 90 to achieve an EPC Band A rating. The report also cites Cardiff's **[3.6]** research when recommending Welsh Government urgently commence a 10-year programme to prioritise the retrofit of certain homes. On 24 September 2019, the Welsh Minister for Housing and Local Government acknowledged *Better Homes* as a "hard-hitting but potentially transformational report" and "based on the evidence behind the report, I suspect we will need to pursue optimised retrofit solutions" **[5.3d]**.

In August 2020 Welsh Government announced a £9.5million Optimised Retrofit Programme (ORP) to install energy efficiency measures in up to 1,000 homes owned by registered social landlords and councils **[5.10a]**. The ORP includes funding for SOLCER-demonstrated principles, including heat-pumps, intelligent energy systems and solar panels, and named five recommended schemes that would supply retrofits to over 1,700 homes across Wales **[5.10b]**. Then in November 2020, Welsh Government announced they would increase ORP funding by an additional £10million, for a combined total of £19.5 million **[5.10b]**. Announcing the additional finances, the Welsh Minister for Housing and Local Government said "ORP is based on research with the Welsh School of Architecture and the recommendations in 'Better Homes, Better Wales, Better World' published in 2019" **[5.10b]**.

The ORP is now part of Welsh Government's "green recovery" to mitigate the economic effects of the COVID-19 pandemic. The ORP has wider scope to enhance the local economy by creating local jobs, training and apprenticeship opportunities and supply chains as part of a new Welsh retrofit industry **[5.10b]**. In preparation, Welsh Government announced that colleges have begun developing retrofit academies and "The Construction Industry Training Board (CITB) has begun developing accredited standards for the training, making Wales a first mover region for decarbonisation of homes and creating the benefits that come with it" **[5.10c]**.

#### **5. Sources to corroborate the impact** (indicative maximum of 10 references)

**[5.1]** Collated Media coverage of SOLCER house launch in July 2015.

**[5.2]** Testimony from Lisa Dobbins, Head of Housing Decarbonisation, Welsh Government.

**[5.3]** Collated Senedd Cymru transcripts and letters: **a)** 4<sup>th</sup> November 2015 Record of Proceedings 17:52 to 17:56; **b)** 30<sup>th</sup> November 2016 Letter to John Griffiths AM; **c)** 24<sup>th</sup> October 2017 Plenary Para 275-276, **d)** 24<sup>th</sup> September 2029 Plenary Para 420.

**[5.4]** Testimony from Jonathan Morgan, Head of Homes & Safer Communities, Carmarthenshire County Council.

**[5.5]** Testimony from Mark Wade, Head of Housing and Public Health, Swansea Council

**[5.6]** "Homes as power stations", Welsh Housing Quarterly Magazine

**[5.7]** Welsh Government news article, "Welsh Government support for our innovative Bridgend housing development"

**[5.8]** Testimony from Andy Sutton, Co-Founder of Sero Homes.

**[5.9]** Testimony from Xi'an Xiaoyuan Technologies Co., Ltd.

**[5.10]** Welsh Government Press Releases on Optimised Retrofit Programme: **a)** "£9.5 million programme to reduce housing's carbon footprint" Welsh Government, 9 August 2020 **b)** "Social housing sector to set Wales on the path to decarbonise thousands of homes and boost green economic recovery" 6 November 2020 **c)** "Written Statement: The Optimised Retrofit Programme 2020-21" Cabinet Statement, Welsh Government, 6th November 2020