CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

Low Carbon Built Environment
Amgylchedd Adeiledig Carbon Isel

Patterson@cardiff.ac.uk

LCBE@cardiff.ac.uk

Photo: After retrofit

Six 1990s Domestic Low Carbon Retrofits

Joanne Patterson PhD[a], Emmanouil Perisoglou PhD CEng MIET[a], Esther Tallent[a], Miltiadis Ionas[a], Xiaojun Li PhD[b],

[a]Welsh School of Architecture, Cardiff University, [b]School of Architecture and Planning, Hunan University

Case study

Six 1990s semi-detached homes in Ceredigion were retrofitted with a whole house energy system, combining appropriate energy demand reduction, renewable energy supply and energy storage technologies [1]. With different patterns of use and different heating systems, including air source heat pumps (ASHP) already installed in 4 of the homes, oil boilers and solid fuel in the other 2, each home had specific energy requirements, despite being extremely similar in external appearance and relatively new.

Our goals were to:

- design and implement affordable and replicable whole house energy systems.
- reduce energy use, energy bills and carbon emissions.
- improve thermal comfort for residents.
- evidence outcomes through a comprehensive programme of computer modelling and monitoring.

Photo: before retrofit

Photo: during retrofit

Low carbon solutions

Following the planning, design and procurement process, where appropriate stakeholders were fully engaged, the following low carbon solutions were installed:

- Reduce energy demand: fabric improvements including external wall insulation with plinth extension below ground, window and door replacement and top-up loft insulation. Positive input ventilation (PIV) systems. Prior to LCBE involvement, four homes had air source heat pumps and a new hot water cylinder installed. Two retained fossil fuel heating systems. The heating systems were not changed as part of the project.
- Renewable energy supply: bolt-on solar photovoltaic (PV) panels, either 3.5 kW_p or 4.2 kW_p.
- Energy storage: a Tesla Powerwall 2 battery (13.5 kWh) with appropriate electrical works.

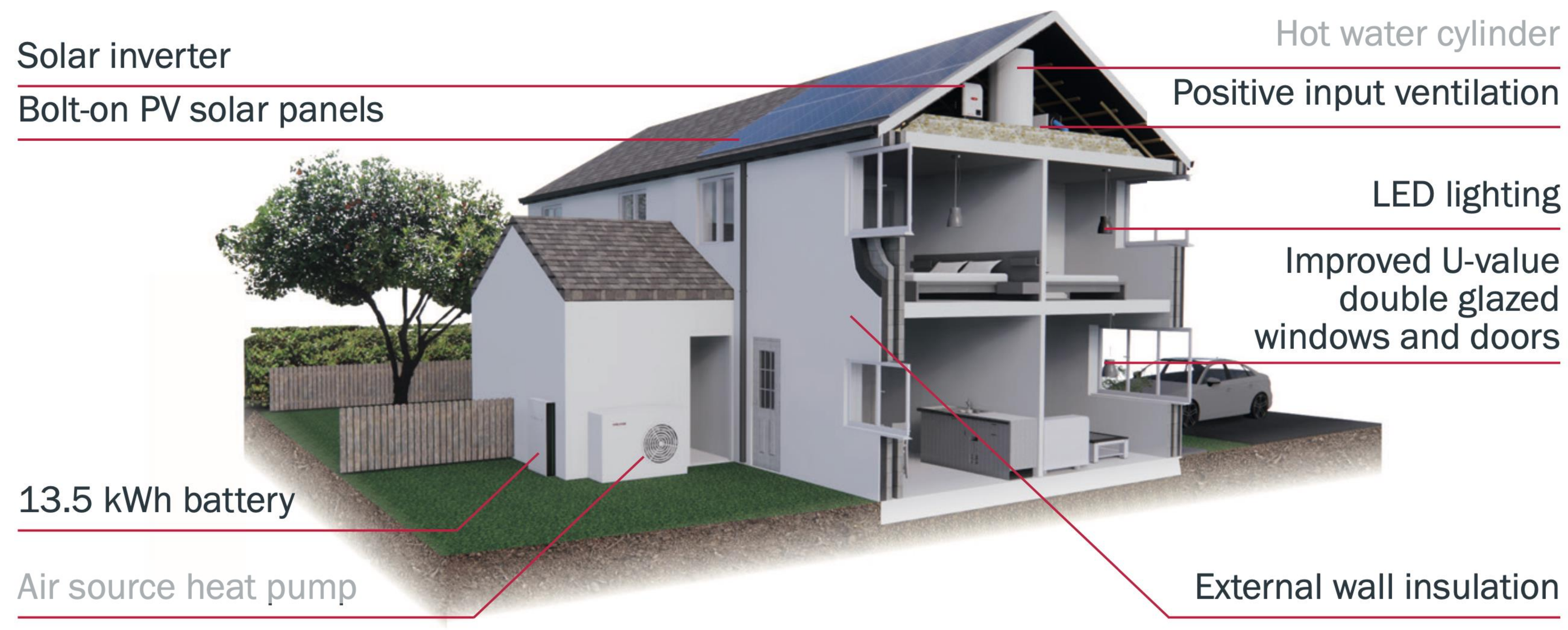

Figure: Low carbon solutions

Research methods and project workflow

- Pre-retrofit monitoring data and detailed surveys were undertaken in the planning phase to understand the homes and identify potential strategies, these were then optimised using computer models such as DesignBuilder, HTB2 and VirVil SketchUp [2].
- A package of solutions tailored to the homes were selected in collaboration with relevant stakeholders, taking into account location, orientation, shape and likely occupancy patterns. The team supported the design of the tailored solutions and created a specification package for the suppliers and installers.
- Following procurement and implementation, a comprehensive monitoring programme took place [3,4]. This involved the performance evaluation of the installed systems and its benefits in energy and comfort.
- Pre- and post-retrofit monitoring allowed for the quantification of the benefits and for comparisons against predictions and benchmarks. Monitoring also assisted in building diagnostics indicating errors in installation and commissioning such as faults in PV generation and battery storage.

Results

- All homes saw reductions in electricity imported from the grid; those with ASHPs saw a 45% reduction in electricity bills and 50% in carbon emissions, while self consumption was 85%.
- There were significant differences in energy use between the homes, despite the homes being so similar in external appearance.
- Consumption increased slightly in the homes that did not want to move away from fossil-fuel heating systems, although energy import was reduced by 22% overall. This is explained by different occupancy patterns, behaviour and general level of maintenance of the homes.
- Reduced heat loss through the building fabric helped overcome thermal comfort issues and ensured a consistent temperature was achieved throughout the day in the living spaces.

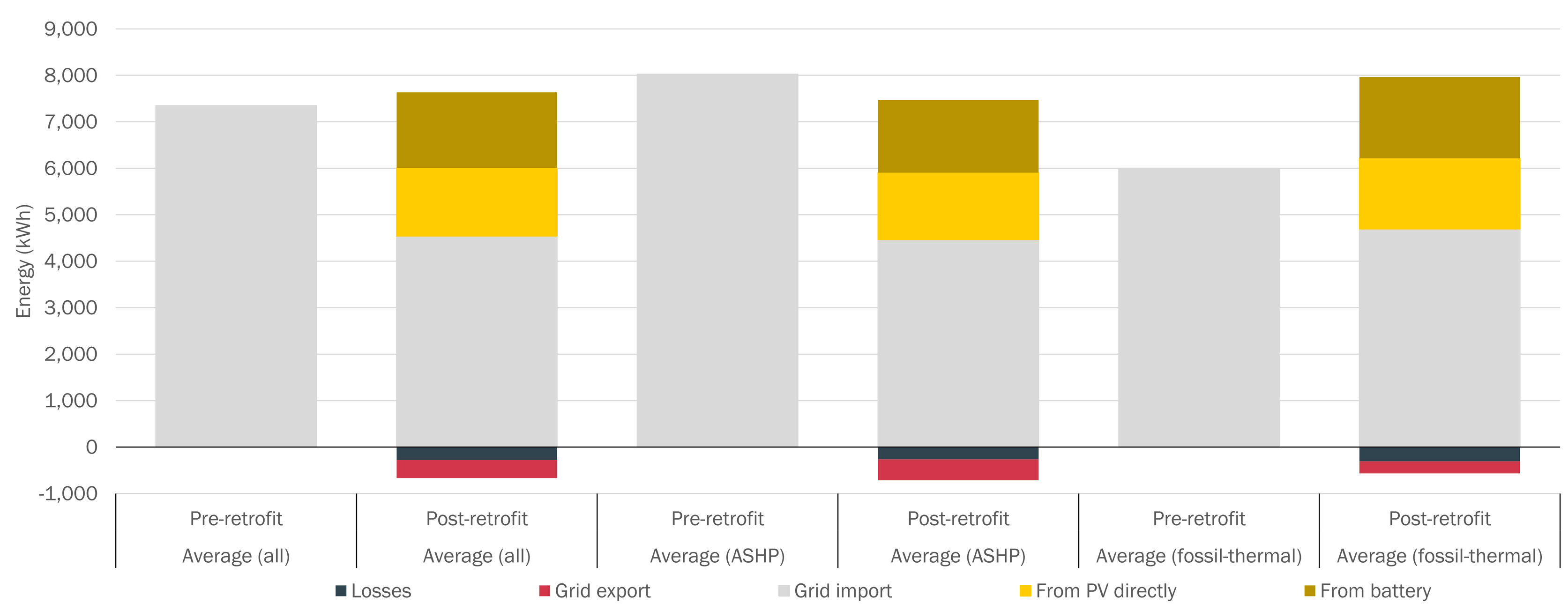

Figure: Pre- and post-retrofit energy import and export

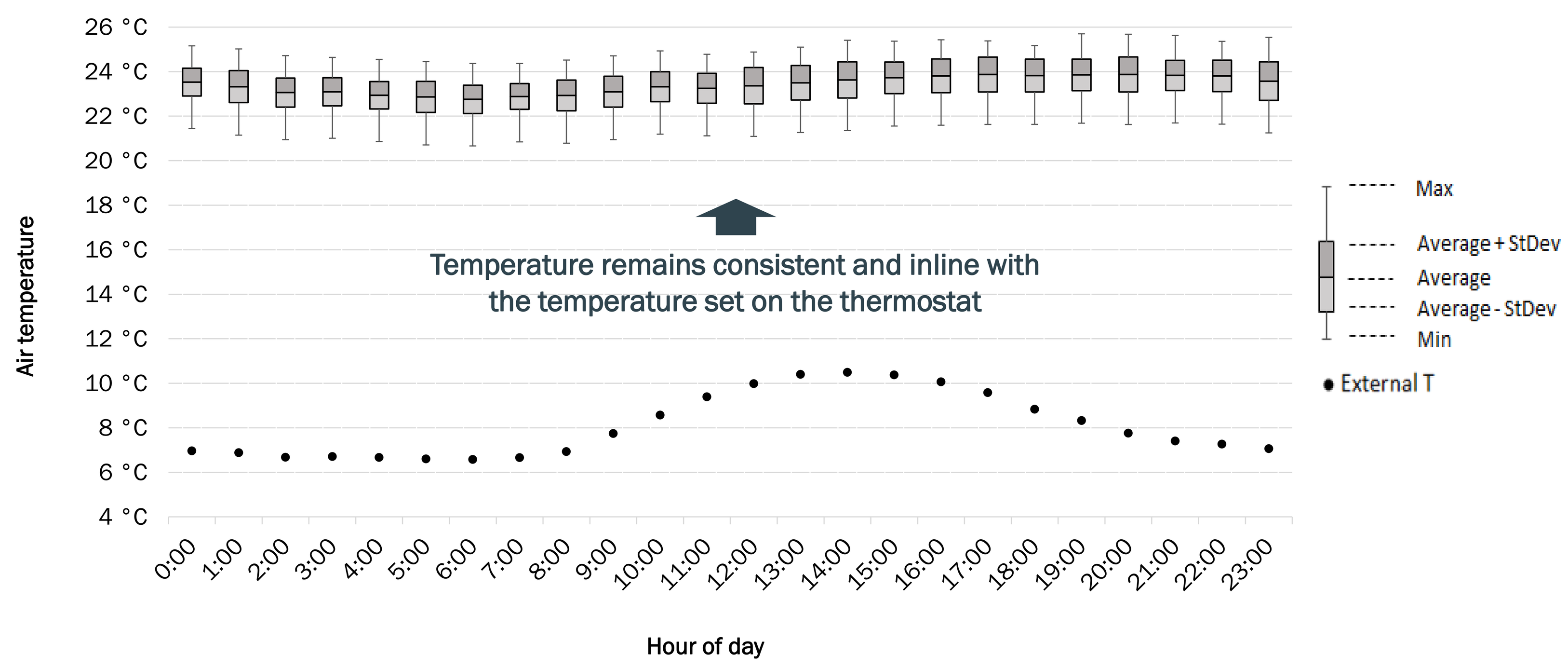

Figure: Daily temperature profile of a lounge during the 2021-22 heating season

Lessons learnt

- Providing relevant, frequent information to residents from the outset can support decision making and engagement including visits for monitoring before and after works.
- Two homes retained fossil-fuelled heating as residents were concerned their heating costs would increase. This made taking a consistent approach across all six homes not possible and creates long term maintenance complexities for the social housing company.
- Homes with pre-installed heat pumps had immediate energy import benefits from the installation of photovoltaic panels.
- Positive Input Ventilation was installed in favour of a MVHR system which would have involved more disruption and complex ducting.
- Electrical works, including the solar PV panel, battery and distribution board replacement were carried out by different contractors. This made the installation challenging, less efficient and more costly, with one contractor site works are smoother.
- The rural, remote location meant that deliveries were difficult and installations more costly.

References

1. Patterson, J. L., Coma Bassas, E. and Varriale, F., Systems based approach to replicable low cost housing: renewable energy supply, storage and demand reduction, Smart Energy Regions - Skills, knowledge, training and supply chains, Welsh School of Architecture, 2016, pp. 239-245.
2Jones, P., Lannon, S., Li, X., Bassett, T. and Waldron, D., Intensive building energy simulation at early design stage. Presented at: Building Simulation 2013: 13th International Conference of the International Building Performance Simulation Association, Chambéry, France, 25-28 August 2013..
3. Perisoglou, E., Ionas, M., Patterson, J. and Jones, P., Building monitoring protocol development for deep energy retrofit. IOP Conference Series: Earth and Environmental Science 329, 2019.
4. Perisoglou, E., Li, X., Ionas, M., Patterson, J., Bassas, E.C. and Jones, P., Evaluation of building and systems performance for a deep domestic retrofit. In Journal of Physics: Conference Series (Vol. 1343, No. 1, p. 012176). IOP Publishing, 2019.

Acknowledgements

We would like to acknowledge the support and dedication of staff at Wales and West Housing, particularly Kate Solomon. We would also like to acknowledge the support of Jack Morewood, who assisted with the production of this poster.

Led by

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

In partnership with

Tai Wales & West Housing

UNDEB EWROPEAIDD EUROPEAN UNION
Llywodraeth Cymru Welsh Government
Cronfa Datblygu Rhanbarthol Ewrop
European Regional Development Fund

Presented at the

CIBSE Technical Symposium Cardiff, UK, 11 - 12 April 2024