Low Carbon Built Environment
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Photo: 1960s semi-detached home post-retrofit


Photo: pre-1919 solid wall mid-terrace home post-retrofit

Five domestic retrofits in South Wales

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Case study

Five homes across South Wales underwent a 'deep retrofit' between 2013-15. The homes varied in age and condition, from pre-1919 solid wall to cavity wall construction built in the 2000s, with either two or three bedrooms. The low carbon solutions were tailored to address the needs of each housing type, combining appropriate energy demand reduction, renewable energy supply and energy storage technologies [1]. The battery of two of the homes was replaced in 2018 with a more efficient one.

Our goals were to:

- Design and implement affordable and replicable whole house energy systems.
- Reduce energy use, energy bills and carbon emissions.
- Improve conditions for residents.
- Evidence this through a comprehensive programme of modelling and monitoring.


Photo: post-2000 detached home post-retrofit


Photo: pre-1919 end-terrace home post-retrofit


Photo: 1950s semi-detached home post-retrofit

Low carbon solutions

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

- Energy demand reduction: passive measures including external and internal wall insulation, loft insulation, cavity wall insulation and window and door replacement. Active measures included LED lighting, appliances, mechanical ventilation with heat recovery (MVHR) or Positive Input Ventilation (PIV) and heating system replacement with more efficient alternatives.
- Renewable energy supply: solar photovoltaic (PV) panels in all homes, ranging from 2.5 to 4.5 kW_p.
- Energy storage: lead acid batteries ranging from 2 to 18 kWh.

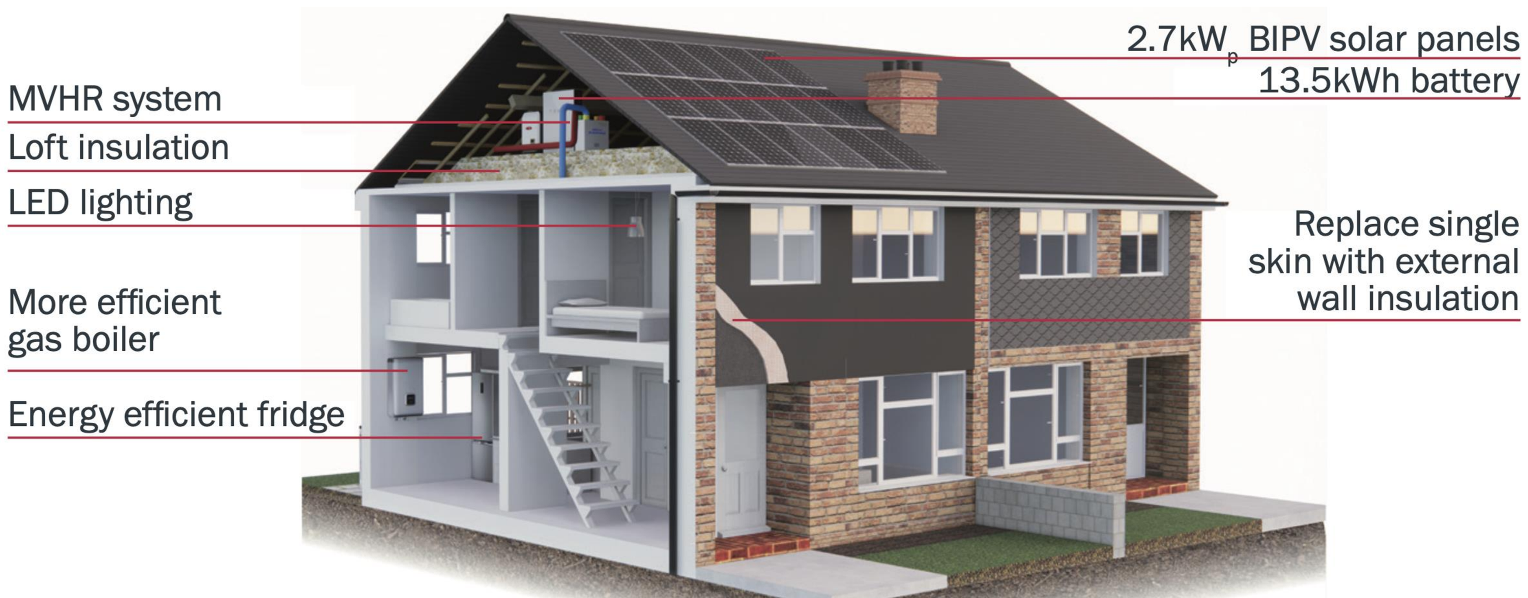

Figure: Example of one of the homes with low carbon solutions installed

Research methods

- Pre-retrofit monitoring and detailed surveys were undertaken to understand the homes and identify potential strategies. These were then optimised using computer modelling.
- A package of technologies were selected that were tailored to the homes, taking into account location, orientation, shape and likely occupancy patterns. HTB2 and VirVil SketchUp tools were used to size the solar panels for the roof area available [2].
- Modelling results were shared with the homeowners and decisions were made based on cost, energy and CO_2 reduction evidence.
- A comprehensive monitoring programme took place before and after the work [3] involving evaluating individual systems with energy and environmental sensors to demonstrate the benefits of solutions. Pre-retrofit monitoring focused on existing systems and the fabric, helping the project team make decisions about additional insulation for the walls and window replacement. Post-retrofit monitoring allowed for actual performance to be compared against pre-retrofit monitored data, modelling predictions and relevant benchmarks [4]. Monitoring also enabled diagnostics indicating underperformance of lead-acid batteries that were later replaced by lithium-ion batteries as the technology developed.

Results

- Using the whole house energy system retrofit approach, energy savings of up to 56% for space heating and 78% reductions of import from the electricity grid were achieved compared to a typical Welsh home.
- At one home electricity consumption increased by 18% due to occupancy changes (2 to 7 residents) and the impact of COVID and working from home arrangements. 2020 electricity generation was 16% lower compared to 2016 due to solar availability.
- Despite an increase in demand and decrease in generation in the one home, the new battery helped to reduce electricity import by 25% and export reduced 75% resulting in a rise from 33% to 58% in self-sufficiency.

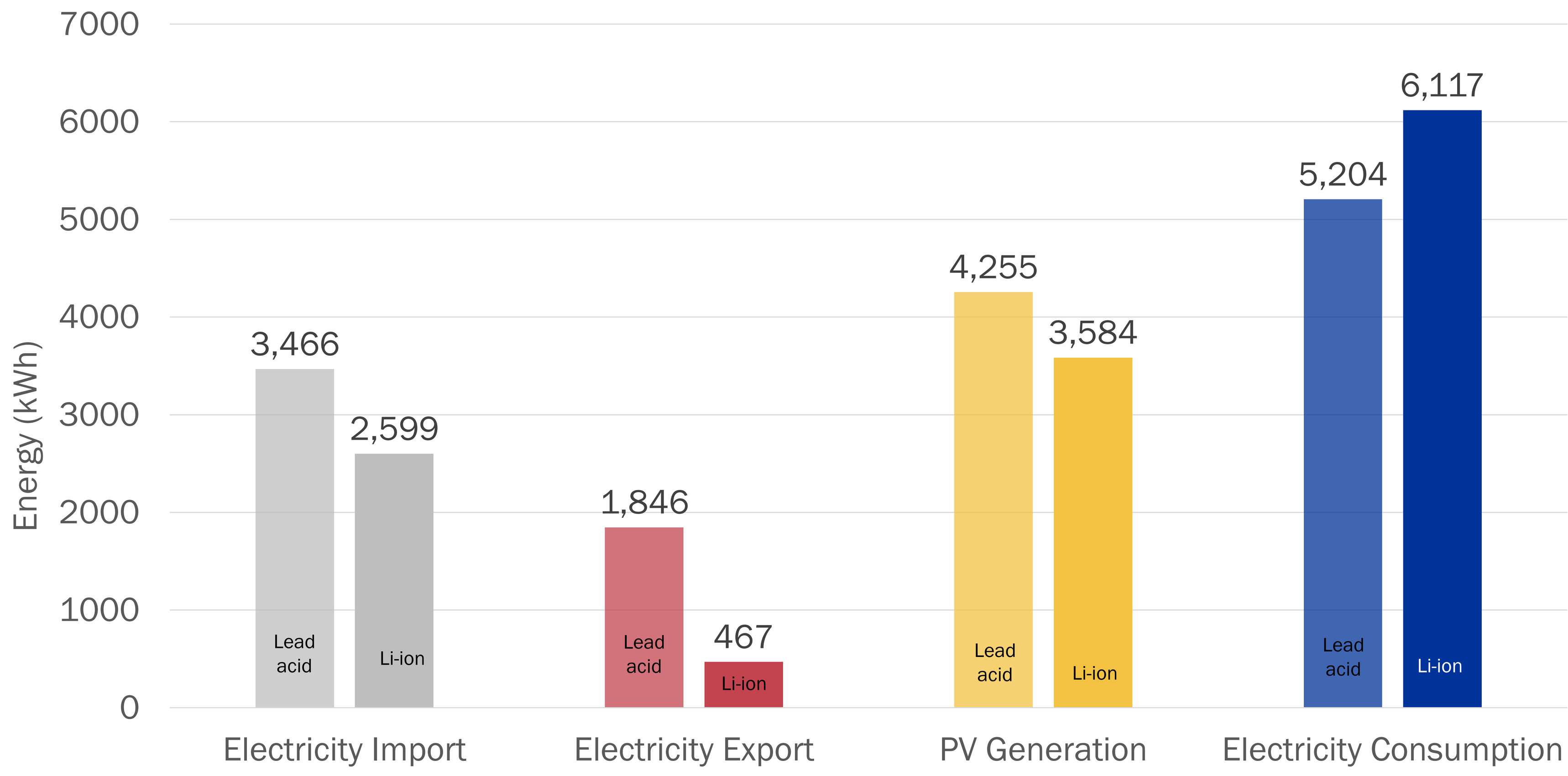

Figure: A comparison between a year with a lead acid battery (2016) and the lithium-based battery (2020) using monitored data at one of the homes

Lessons learnt

- The whole house energy system was designed for each home rather than the occupants. This proved particularly important for homes where occupancy changed. For example, one household was initially occupied by a two-person family who moved out due to personal reasons. A much larger family with very different energy needs moved in. Energy consumption increased. The larger family benefitted more from having the energy measures installed.
- Monitoring has shown that carbon emissions have reduced along with lower energy bills, while also improving comfort for residents.
- Building fabric improvements should be carried out at the same time as the replacement of building systems to reduce incidental costs.
- The design and installation of MVHR systems is challenging in existing homes due to the layout of joists. Careful planning and design is needed to minimise disruption on site. Where little work took place to improve the fabric resulting in minimal improvement in airtightness, a PIV system was preferred for ease of installation.
- At the time of the retrofit in 2013-15 the domestic battery market was in its infancy. Lead acid batteries initially installed were used to 'test' storage as part of the whole house approach. When the market developed these batteries were replaced with more efficient lithium-ion batteries which enabled import to be reduced and export to be increased.
- Monitoring helped with the decision-making process as data indicated discharging issues with the original lead acid batteries.

References

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Acknowledgements

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

Led by

In partnership with

Presented at the

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