Building and Community Energy Retrofit Housing in Wales

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Background

The necessity to retrofit existing housing in the UK,

- The target of an 80% reduction in the UK's carbon emissions by 2050;
- The domestic sector accounts for some 29% of the UK's total energy;
- The housing stock in the UK is replaced with a proportion of only around 1% a year, it is estimated that most of the UK's housing stock that will exist in 2050 has already been built.

This paper presents an energy modelling-led approach to investigate energy retrofit housing in Wales, UK, for individual buildings, and community scale with the integration of a micro-grid connection and battery storage. The investigation considers combinations of existing and emerging low carbon technologies through a systems based approach, combining reduced energy demand, renewable-energy supply and energy storage. Energy positive performance could be achieved when more energy is exported compared with that imported over a whole year.

Methodology

The simulation tools employed in the research include HTB2 and VirVil SketchUp. Both HTB2 and VirVil SketchUp were developed at the Welsh School of Architecture, Cardiff University.

HTB2 is typical of the more advanced numerical models, using as input data, hourly climate for the location, building materials and construction, spatial attributes, system and occupancy profiles, to calculate the energy required to maintain specified internal thermal conditions. The software has been developed over thirty years, and has undergone a series of extensive testing and validation, including the IEA Annex 1, IEA task 12 and the IEA BESTEST.

VirVil SketchUp is an extension development of HTB2 for urban scale modelling. By linking SketchUp with HTB2, it can carry out dynamic thermal simulation for multiple buildings in a community or urban scale, with consideration to overshadowing impacts from the neighbourhood.

Based on the output from thermal simulation, hourly energy models were developed to integrate energy demand, supply and storage at both building and community scales.

Retrofit case studies in South Wales, U.K.

2000s built, 3-bed semi-detached

Pre-1919, 2-bed mid-terrace

1950s built, 3-bed semi-detached

- Fabric insulation
- LED lighting
- Energy-efficient boiler

- PV roof
- Batteries storage

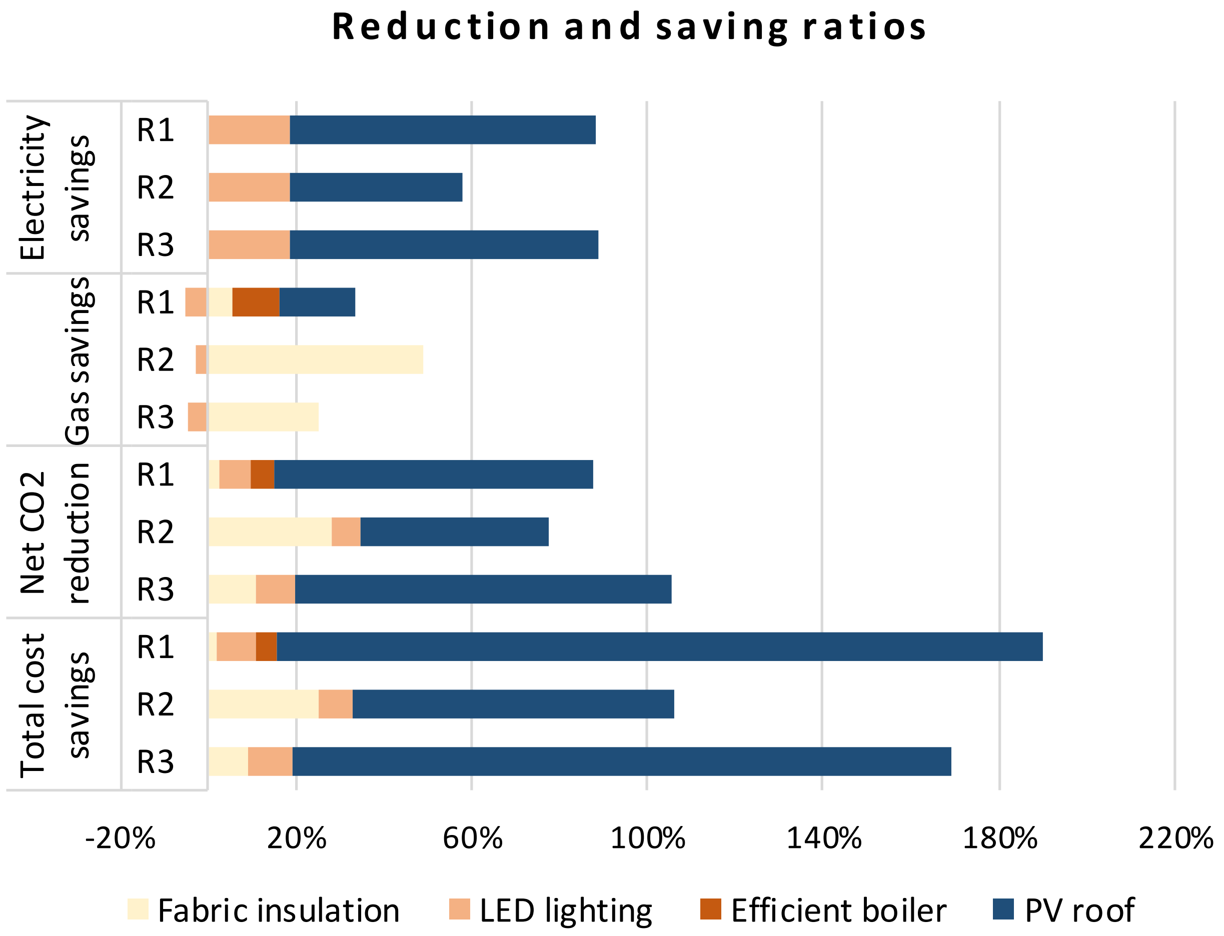
A integrated system based approach

Electricity energy positive buildings
Low carbon/near-zero carbon buildings

Information summary of the retrofits

	Retrofit 1	Retrofit 2	Retrofit 3
Basic information	2000's, 3-bed filled cavity wall 86m^2 semi-detached , southeast facing, with gas heating.	Pre-1919, 2-bed 74m^2 solid wall, mid-terrace south facing, with gas heating.	1950's, 3-bed 80m^2 cavity wall semi-detached southeast facing, with gas heating.
Energy-efficient strategies	a. loft insulation; b. LED lighting; c. new gas boiler and hot water tank.	a. rear external wall insulation, front internal wall insulation; b. loft insulation; c. LED lighting.	a. external wall insulation; b. loft insulation; c. LED lighting.
PV	4.5 kW$_p$ PV roof.	2.6 kW$_p$ PV roof.	3.97 kW$_p$ PV roof.
Energy storage	Lead acid battery with 18kWh storage.	Lithium battery with 2.0 kWh storage.	Lithium battery with 10kWh storage.

Performance prediction for the retrofit housing case studies, by HTB2 and the energy demand, supply and storage model.



Proposal for a community scale replication

	Community 1 (retrofit 1)	Community 2 (retrofit 2)	Community 3 (retrofit 3)
Total floor area	4969 m^2	9200 m^2	10064 m^2
The energy efficient components	The performance of all properties upgraded to that of retrofit 1: Wall U-value (0.26 $W/m^2.K$), Window U-value (2.0 $W/m^2.K$), 300mm loft insulation, LED lighting, Efficient system boiler.	The performance of all properties upgraded to that of retrofit 2: Wall U-value (0.38 $W/m^2.K$), Window U-value (2.0 $W/m^2.K$), 300mm loft insulation, LED lighting, Efficient combi-boiler.	The performance of all properties upgraded to that of retrofit 3: Wall U-value (0.20 $W/m^2.K$), Window U-value (2.0 $W/m^2.K$), 300mm loft insulation, LED lighting, Efficient combi-boiler.
PV	312 kW_p PV roof.	389 kW_p PV roof.	452 kW_p PV roof.
Battery (Community scale)	Lithium battery: 290 kWh	Lithium battery: 220 kWh	Lithium battery: 360 kWh
Further optimisation strategies	PV applied on both roofs for east-west oriented houses.	PV area tailored according to roof size, to reduce roof losses due to standardised module sizes.	PV applied on both roofs for east-west oriented houses.

Performance prediction for a community scale replication, by VirVil Sketchup and the energy demand, supply and storage model.

	Community 1	Community 2	Community 3
Total electricity generation by PV	5319 kWh/household/yr	3103 kWh/household/yr	3377 kWh/household/yr
Electricity from grid	315 kWh/household/yr	1021 kWh/household/yr	790 kWh/household/yr
Electricity to grid	2444 kWh/household/yr	2055 kWh/household/yr	2059 kWh/household/yr
Electricity export to import ratio	7.76	2.01	2.61
Electricity self-sufficient ratio	90%	49%	60%
Gas supply	2394 kWh/household/yr (28 kWh/m²/yr)	5203 kWh/household/yr (70 kWh/m²/yr)	4625 kWh/household/yr (58 kWh/m²/yr)
Net operating carbon emission	-588 kg/household/yr	587 kg/household/yr	340 kg/household/yr

Discussion and conclusion

The results indicate that, the combination of reduced energy demand, renewable energy supply and battery storage could reduce net carbon emission by 88%, 78% and 110% for the three retrofits, demonstrating that a near-zero energy and for one case energy positive performance, can be achieved.

There can be added benefits from a community performance compared to an individual house performance due to,

- the increased area of PV applied to different orientations and building type variations (detached, semi-detached, terrace);
- for some east-west oriented houses, PV applied to the whole roof rather than the south facing side can significantly increase the total electricity generation;
- it is possible for some but not for all communities to achieve an energy positive performance with the current energy retrofit strategies, such as Community 1.

Thank you