

Energy efficiency and microgeneration in historic buildings in Edinburgh's UNESCO World Heritage Site



The solar systems installed under Changeworks' Renewable Heritage project (© Changeworks)

Older, traditionally built properties are notoriously hard to treat in terms of improving energy efficiency, and this can be greatly exacerbated where their historic status places planning restrictions on improvement measures. Many of the most popular and cost-effective measures are not viable for use in these buildings.

Edinburgh-based sustainable development organisation Changeworks (www.changeworks.org.uk) has been at the forefront of pioneering research and practical demonstration projects in this area. Their recent award-winning projects, **Energy Heritage** and **Renewable Heritage**, provide best-practice examples of what can be done to reduce the energy demand in such properties and allow them to generate their own renewable energy, all without compromising their historic appearance and cultural integrity. Subsequent projects, such as **Double Glazing In Listed Buildings** and a number of technical report for Historic Scotland, have also contributed to policy changes and best practice.

Links to detailed project reports and guidance published by Changeworks are included at the end of this article.

The challenge

Take as an example a traditional Scottish tenement flat, built from stone in the 1800s and grade 'B' listed due to its quality and its location in central Edinburgh. It is inherently sustainable in some respects, by virtue of its embodied energy, use of local materials, thermal mass and longevity.

However, it has solid walls, no loft, an expensive electric heating system, single glazing and its large rooms and high ceilings mean there is a lot of space to heat. Its location in the Old Town puts the householder at high risk of fuel poverty¹, one of the primary causes of which is poor energy efficiency. Around a third of householders in pre-1919 properties are in fuel poverty².

Consider some of the most commonly recommended measures to improve energy efficiency in a home: cavity wall insulation cannot be applied to solid stone walls; loft insulation is not an option unless the flat is on the top floor; double glazing is not permitted as it is a listed building; a gas boiler may not be permitted if the flue would go through the front wall, and the configuration of tenements can mean that some flats have no other external walls.



The tenement block: a predominant house type across Scotland
(© Changeworks)

Now consider some of the more high-tech options to enable this flat to generate its own energy: solar panels and air source heat pumps may well not be permitted if they would be visible in this historic setting; wind turbines would not perform well in this built-up area; there is no water source for a hydro turbine; biomass systems are fraught with complications in urban settings due to concerns over particulate emissions; and a ground source heat pump would be hard to install due to limited ground space and legal complications due to the multi-ownership of the block.

Such limitations can make these buildings extremely hard and expensive to heat adequately, leading either to high fuel bills and emissions, or – for those unable to afford such bills – to cold, uncomfortable homes. In some cases the poor energy efficiency of these buildings can lead to damage of the fabric and health problems for the occupants, as cold buildings often attract damp, condensation and mould.

¹ *Fuel poverty map of Edinburgh* (Changeworks & The City Of Edinburgh Council, 2005)

² *Scottish House Condition Survey: Key findings 2008* (Scottish Government, 2009)

The solutions

Changeworks has delivered a number of award-winning research and demonstration projects, working in partnership with a number of key organisations to demonstrate how traditional and historic properties can be made more efficient and generate their own energy. The success of their projects has largely been due to the close working relationships with **Lister Housing Co-operative**, **Edinburgh World Heritage**, **Historic Scotland** and **The City Of Edinburgh Council** (among others).

As a charity, Changeworks received funding to develop and manage these projects from a number of sources, including charitable trusts and local authorities. The capital works were also funded from a number of sources, which are noted below.

1 Renewable Heritage



Solar systems installed in the hidden roof valleys of listed Georgian buildings (© Changeworks)

As part of Changeworks' **Renewable Heritage** project, solar water heating systems were installed in 49 grade 'B' listed Georgian tenement flats in Edinburgh's Old Town, a conservation area and part of the UNESCO World Heritage Site. Solar systems were provided to householders on all floors of the tenement buildings (even those at basement level), with the panels being hidden in roof valleys to satisfy conservation requirements. This has delivered an innovative microgeneration solution for both historic housing and tenements, and is now upheld as an example of best practice that can be replicated across Scotland. This was recognised by Energy Action Scotland when they awarded the Renewable Heritage project top prize in the national *EnergySavers 2009 Award*.

In the first phase of the project, panels were installed in hidden roof valleys formed by the 'M'-shaped roofs of the Georgian tenements, making them invisible to all intents and purposes; pipework was then run down through the buildings to serve all flats in the stairs. In the next phase, panels will be installed on angled frames on the flat (mansard) roofs of Victorian and 1980s tenements (these installations are forthcoming, although permissions have already been granted).

Project planning

The project required considerable planning, and extensive negotiations with planning and building conservation bodies to ensure they were satisfied with the proposed installations. As a result of this close working partnership, Changeworks receive full support for the project.

All microgeneration systems were assessed, however it quickly became apparent that solar water heating systems would be the most viable option for these buildings. A feasibility study was necessary to scope the solar installations and ensure the project was technically sound; this study was funded by the Scottish Government's *Scottish Community and Householder Renewable Initiative*³ fund, and included structural surveys of the roofs to ensure they would bear the load of the panels. These surveys found that additional strengthening was needed for the Victorian flat roof timbers, to cope with the added weight and wind loading of panels on angled frames.

Consents

The Georgian tenements are listed and so Listed Building Consent was needed; however Planning Permission was not necessary due to the proposed panel location in hidden roof valleys. The reverse was the case for the Victorian and 1980s tenements: they are not listed so no Listed Building Consent was necessary, but Planning Permission was needed as the panels would be visible on the flat roofs. Building Warrants were needed in all cases.

Technical details

Lister Housing Co-operative was keen to install a system that was simple, efficient, durable and easily maintained. As such, 49 individual systems rather than one large communal system were installed. Flat-plate panels were selected rather than evacuated tube systems, on the basis that they are both simple and robust. The panels were made by AES Solar Systems, Scotland's only solar panel manufacturer, and installed by local organisation Glendevon Energy: this local team will make future maintenance simpler, as well as helping sustain the local economy.



Scottish-made AES solar panel
(© Changeworks)

Rather than assuming the often-quoted 4m² of panels per household, the systems were specifically sized for the individual households, and AES was able to make one bespoke panel of 3.3m² for each property⁴. This smaller size not only maximised the systems' efficiency but also allowed as many households as possible to receive solar systems, as this was ultimately dictated by the roof space available.

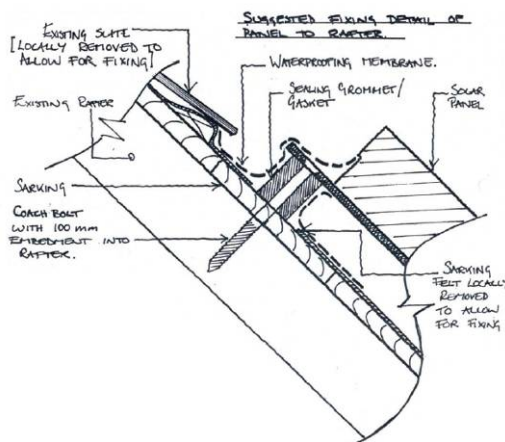
³ Now called *Community And Renewable Energy Scotland (CARES)*, and managed by Community Energy Scotland.

⁴ In most cases. Some smaller or larger flats were fitted with correspondingly-sized systems.



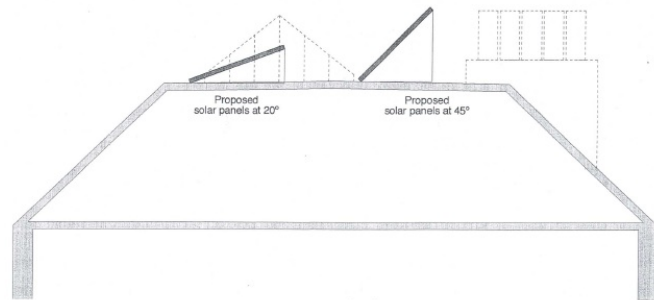
The solar panels being delivered onto the tenement roofs (© Lister Housing Co-operative)

Due to the weight of the panels and the small size of the loft hatches in older tenement buildings, the panels had to be lifted onto the roofs with a crane (left). This was done on a Sunday to minimise traffic disruption, and a partial road closure permit was secured. No scaffolding was needed for the installations to the Georgian tenements as all works could be done in the safety of the roof valleys: scaffolding will however be needed for the flat-roof installations.



Roof fixing detail (© Robertson Eadie)

On the pitched-roof installations, the panels are fixed through the roof covering onto the rafters. On the flat roofs the panels will be set at an angle on metal frames. In both cases the installations are easily reversible, an important consideration for building conservation bodies. To maximise the number of flat-roofed properties benefiting, two rows of panels will be installed, and the front row will be set at a shallower angle so they do not overshadow the rear row. This will affect the performance of the front panels, but this will be carefully monitored and reported.

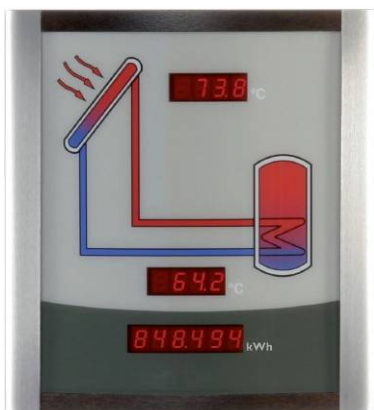


The proposed flat roof installations (© Lorn Macneal Architects)

A single length of pipework connects each panel to its hot water cylinder. The pipework passes from the panel through the roof and the attic space (where the pump stations are located), and then through any intervening flats, before connecting up with the cylinder. The pipework has no joints, so no leakage can occur in other properties. The old hot water cylinders were replaced with new twin-coil cylinders (one coil for the solar system and another for the boiler): these are slightly larger (taller) than the old cylinders but the space in the airing cupboards proved more than adequate.

Each flat has a display monitor so the householders can see how much energy their system is generating. A more detailed data logger is fitted onto the pump station of each system, which it was decided to site in the roof space. These are secured to

wooden back-boards, and flooring and lighting have also been fitted to satisfy health and safety requirements.



Display monitor (© Changeworks)



The pump stations (© Lister Housing Co-operative)

The systems should generate at least half of the hot water needs of each property. The capital costs were around £4,000 per system, which is slightly higher than average due to the complexity of the installations. The works were funded by the UK Government's Low Carbon Building Programme Phase II, the ScottishPower Energy People Trust, Lister Housing Co-operative and Edinburgh World Heritage.

Lister Housing Co-operative has secured further funding to install additional solar water heating systems, on more of their Georgian tenement stock with hidden roof valleys. The flat roof installations will follow on from these works. (Lister Housing Co-operative is also investigating the potential for installing photovoltaic panels on their tenement roofs to benefit from clean electricity and income through the UK Government's recently-launched Feed-In Tariff finance scheme.)

As part of the Renewable Heritage project, Changeworks published comprehensive best-practice guidance and a case study of the project. *Renewable Heritage – A guide to microgeneration in traditional and historic homes* is available online (see end for link), and hard copies are available from Changeworks.

2 Energy Heritage – energy efficiency first!

Before looking to renewable forms of energy, it is critical first to reduce the energy used by the building. As part of Changeworks' **Energy Heritage** project – carried out before their Renewable Heritage project – a wide range of sensitive energy efficiency improvements were installed in historic homes in central Edinburgh.

Once again working with Lister Housing Co-operative, Changeworks developed a pilot project improving a stair of 9 occupied flats in a Georgian, grade 'B' listed tenement block in Edinburgh's World Heritage Site. The improvements focused on windows, basement floors, roofs, heating and lighting systems, and behavioural education. While some measures are relatively commonplace, others involved using innovative systems to avoid compromising the appearance of these historic buildings.

Technical details

Windows are a notoriously contentious issue in Edinburgh, as they are integral to the appearance of the building. However, many of the old buildings in Edinburgh have extremely large single-glazed windows through which a significant amount of heat is lost, and double glazing was not permitted in listed buildings in Edinburgh when the project was developed. The Energy Heritage project therefore installed a combination of the following:

- High-quality draughtproofing⁵ – effective in cutting out draughts and heat loss from gaps around the window
- Internal timber shutters – an original feature in many older properties, but often painted or nailed closed over the years, these were re-instated and proved very effective for night-time insulation
- Bespoke secondary glazing systems⁶ – designed for historic properties, this system avoids the intrusiveness of conventional secondary glazing and achieved an excellent thermal performance.



Storm Windows secondary glazing
(© Changeworks)

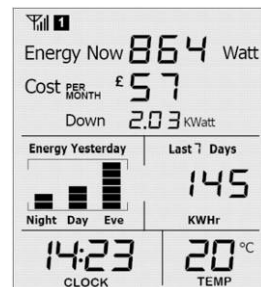
In the two basement flats, concrete floors had been installed in the 1970s. A slim-profile, high-performance floor insulation⁷ was installed on top of these floors, improving the thermal insulation by a factor of six without requiring any of the major remedial works necessary with conventional solid floor insulation (removing and re-siting electrical sockets, skirting boards, bathroom and kitchen units, and trimming or replacing doors, for example). This floor insulation was of an extremely high specification, and was the first such installation in Scotland. The insulating material has since been tested and approved by the BRE for use as internal wall insulation.



Spacetherm floor insulation being laid
(© Changeworks)

Low-energy lighting was installed throughout the flats, and old, inefficient boilers were replaced with modern, 'A' rated condensing boilers. The only aesthetic consideration for these installations was the boiler flues, which were sited to the rear of the flats to satisfy planning requirements.

Smart monitors and energy advice visits provided an educational element, to complement the physical improvement measures: involving the householders and raising their awareness of energy efficiency was felt to be vital to the project. The smart monitors in particular proved popular with the householders, allowing them to see the cost of their electricity use. These monitors display the cost, carbon emissions and energy consumption of a home, and update in real time, allowing the user to see the effect of turning appliances on and off.



Smart monitor display
(© Changeworks)

⁵ Ventrolla (www.ventrolla.co.uk)

⁶ Storm Windows (www.stormwindows.co.uk)

⁷ Spacetherm (www.spacetherm.com)

These improvement measures were all installed without the need for any permissions, although the planning department was consulted at an early stage to confirm their support. All these measures were designed to be widely replicable, and as such the project did not investigate major disruptive works such as solid wall insulation.

Impact

The impact of these improvement measures was modelled using national energy modelling software⁸. These models predicted annual savings of around £175 per household, and a 35% reduction in CO₂ emissions.

In-situ U-values were also measured, in collaboration with Historic Scotland and Glasgow Caledonian University. The following U-values were identified:

Building element	U-value
600mm sandstone wall	1.4
Single-glazed timber-framed sash window	5.5
As above + secondary glazing	2.3
As above + internal timber shutters	2.2
Concrete floor	3.6
As above + floor insulation	0.6

Full cost details are available in the *Energy Heritage* guide. The capital works were funded by Edinburgh World Heritage, Lister Housing Co-operative, the Scottish Government's *Wider Role* fund, and ScottishPower through their *Energy Efficiency Commitment*⁹.

As with Renewable Heritage, Changeworks published an award-winning best-practice guide as part of the project, which includes a detailed case study. *Energy Heritage – A guide to improving energy efficiency in traditional and historic homes* is available online (see end for link), and hard copies are also available from Changeworks.

3 Double Glazing In Listed Buildings

In 2010 Changeworks led another high-profile demonstration project, trialling bespoke double-glazing systems in listed buildings in Edinburgh's UNESCO World Heritage Site. This is yet another contentious issue, however by using slim-profile, high-performance technologies and carefully monitoring their efficiency and aesthetics, Changeworks demonstrated that double glazing can be successfully installed in historic buildings. This project was also conducted in partnership with Lister Housing Co-operative, Edinburgh World Heritage, Historic Scotland and The City Of Edinburgh Council.

As well as installing slim-profile double glazing into all windows in a Georgian, listed, stone-built tenement in the UNESCO World Heritage Site, Changeworks also tested the thermal performance (U-values) and embodied energy of all the different glazing units installed. This provided a holistic approach, enabling appearance to be balanced with other significant factors such as performance, embodied energy, cost, longevity, installation and maintenance.

⁸ National Home Energy Rating (NHER) and Standard Assessment Procedure (SAP).

⁹ Now called *Carbon Emissions Reduction Target (CERT)*.

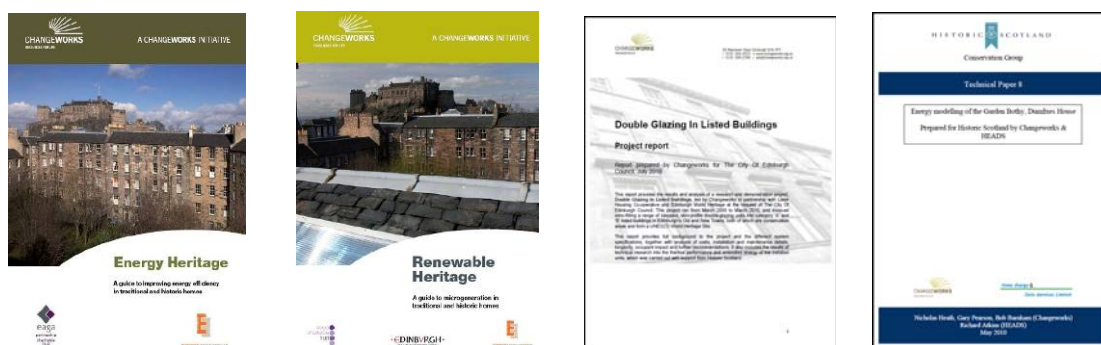
One of the most significant outcomes of the project was the subsequent decision by the local authority to change their policy for listed buildings in Edinburgh, meaning that this type of double glazing is now permitted across the city's listed buildings. Changeworks published a comprehensive report on this project in spring 2010, which is available on their website (see below for link).



The top-left window of this grade 'A' listed building has slim-profile double-glazing (© Changeworks)

Through these projects, Changeworks has shown that sensitive improvements can be made to such buildings, actively enhancing their cultural, social and environmental value and making them among the most sustainable existing housing in Scotland.

Publications and reports



The *Energy Heritage* and *Renewable Heritage* guides, running to around 100 pages each, are available in hard copy from Changeworks. They can also be downloaded online, together with the full *Double Glazing In Listed Buildings* project report and a number of technical research papers written for Historic Scotland.

- ***Energy Heritage – A guide to improving energy efficiency in traditional and historic homes*** (Changeworks, 2008):
www.changeworks.org.uk/uploads/83096-EnergyHeritage_online1.pdf
- ***Renewable Heritage – A guide to microgeneration in traditional and historic homes*** (Changeworks, 2009):
www.changeworks.org.uk/uploads/Renewable_Heritage_Online.pdf
- ***Double glazing in listed buildings – Project report*** (Changeworks, 2010):
www.changeworks.org.uk/uploads/Double-Glazing-In-Listed-Buildings-Project-Report.pdf
- ***Technical Paper 3: Energy modelling analysis of a traditionally built Scottish tenement flat*** (Changeworks, 2008 on behalf of Historic Scotland):
www.historic-scotland.gov.uk/energy_modelling_analysis_tenements.pdf
- ***Technical Paper 8: Energy modelling of the Garden Bothy, Dumfries House*** (Changeworks & HEADS, 2010 on behalf of Historic Scotland):
www.historic-scotland.gov.uk/technicalpaper8.pdf
- ***Technical Paper 9: Slim-profile double glazing*** (Changeworks, 2010 on behalf of Historic Scotland): www.historic-scotland.gov.uk/slim-profile_double_glazing_2010.pdf

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