

REFURBISHMENT CASE STUDY 37

HOLYROOD PARK LODGE EDINBURGH

THERMAL UPGRADE WORKS TO A 19TH CENTURY
LODGE HOUSE



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Holyrood Park Lodge, Edinburgh:

Thermal upgrade works to a 19th century lodge house

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HISTORIC ENVIRONMENT SCOTLAND REFURBISHMENT CASE STUDY 37

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THERMAL UPGRADE WORKS TO A 19TH CENTURY LODGE HOUSE

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1. INTRODUCTION

This Refurbishment Case Study describes the repair and upgrade works carried out at Holyrood Park Lodge in Edinburgh, currently a visitor centre for Holyrood Park. The works focussed on improving the thermal performance of the building with appropriate materials that preserved the character and appearance of the listed building and minimised disruption to the remaining original fabric. The lodge was built as a picturesque dwelling, one of six around the park boundary for gatekeepers to the Royal Park, and later for the use of the Royal Park Constabulary. The domestic scale made it well suited for showcasing a range of thermal upgrade measures that have been tested on previous domestic projects delivered by HES, which strike a balance between building conservation and energy efficiency. Consideration was given to wider issues of sustainability, such as the durability of the measures and their embodied carbon. The visitor centre exhibition was redesigned, featuring interpretative and artefact displays with inbuilt capacity for interchangeable video and graphic features, and the second ground floor room was reconfigured as a retail unit. Integrating these works within the project required additional planning and design input for the fabric interventions to ensure a 'whole building approach' that accommodated the end use.

Holyrood Park Lodge has been in the care of Scottish Ministers since 1994 and, before the refurbishment works started, it was accommodating a small display area providing information about Holyrood Park on the ground floor, whilst the remainder of the building used for informal meeting space, storage and welfare for staff. Previous refurbishment and decoration were functional in style and had detracted from the character of the building. An important part of the project, in addition to the thermal improvements, was to retain or reinstate some of the traditional finishes and details that had been lost and are often overlooked in conventional refurbishments. It was felt that this would improve the amenity of the spaces in the lodge and show that thermal upgrade work does not have to be visually intrusive or damaging. As the building is a Property in Care and part of the HES Estate, long-term monitoring and regular inspections prior to and after the works has been achievable. Such continued access is rarely possible when work is being done in private homes. The ease of access also allowed HES to design and deliver a standard set of upgrade measures in a location that can readily be shown to interested parties, including homeowners, building professionals and others involved in the refurbishment sector.

2. BACKGROUND AND CONTEXT

2.1 The site

Holyrood Park Lodge is a Category B listed Victorian lodge building, located in a prominent position at the entrance to Holyrood Park in Edinburgh (Figure 1). The house and grounds sit within the Holyrood Park scheduled monument area, bounded by the Palace of Holyroodhouse on one side and the Scottish Parliament building on the other. It was built in 1857 in a neo-gothic style to the designs of Robert Matheson, Clerk of Works for Scotland, who carried out a programme of gradual improvements to the Palace, the Park and the Abbey Precincts at the request of Queen Victoria and Prince Albert. Holyrood Park Lodge position marks a gateway, one of four road entrances to the park. All the lodges share a distinctive gabled, picturesque style, however, Holyrood Park Lodge with its distinctive diamond flues and decorative curvilinear bargeboarding is the earliest of the purpose-built lodges and contributes significantly to the character of Holyrood Park. The construction of the Scottish Parliament in the late 1990s and the integral landscaped connections out from the building to the open vista of Holyrood Park, changed the parkland setting of the lodge, which now sits at the east end of the parliament precinct.



Figure 1. Holyrood Park Lodge viewed from the north west.

2.2 Building structure and previous works

The construction of the lodge is traditional, with external masonry of coursed snecked ashlar, internal linings mainly of lath and plaster upstairs, and a mixture of lath and plaster and modern plasterboard downstairs.

The building's footprint began as an L plan with two roof pitches intersecting at the chimney stack; later works added a new porch to the north, and a narrow kitchen on the south wall. For clarity in this report, the floor plan (Figure 2) is marked up with the names of the rooms as they would be used post-refurbishment.

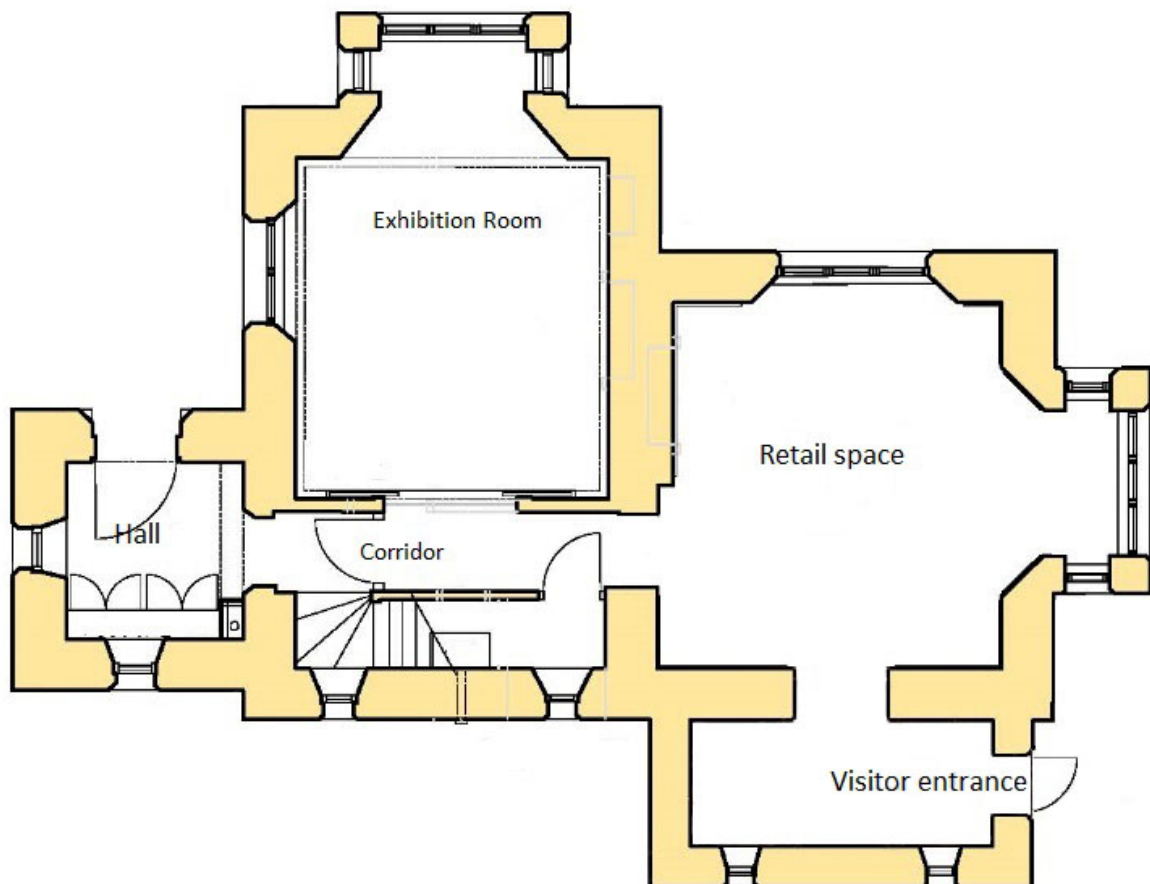


Figure 2. Ground floor plan of the Lodge.

By 1994, when the Lodge came into the care of Historic Scotland (now Historic Environment Scotland), the building's appearance had been altered with modern windows and some inappropriate stonework repairs, following the removal of an addition in the north west corner. A degree of settlement to the south east corner of the building was also evident. To improve the condition and appearance of the building, a programme of repair works was carried out by HES. Most of the external alterations were reworked to a more traditional style and more appropriate timber windows

(single-glazed casements) were installed (Figure 3). However, the internal work was more conventional, with modern decorative finishes and details. The floors were covered in a hardwearing commercial carpet; the original timber floorboards remained underneath and in reasonably good condition, although the ground floor room to the east had dropped by several inches in one corner (Figure 4).



Figure 3. Single-glazed windows from the 1990s works.



Figure 4. The downstairs meeting room showing the modern finishes and the settlement of the timber floor.

2.3 Refurbishment considerations

Holyrood Park Lodge is a typical Victorian lodge building, representative of many similar traditionally-built properties in Scotland, which require improvements to their thermal performance in line with government policy and targets for carbon reduction. As a listed building and a Property in Care of Scottish Ministers, located within the Holyrood Park scheduled area and the Palace of Holyroodhouse Inventory Garden and Designed Landscape (GDL), Holyrood Park Lodge merits the highest degree of care and attention, as part of this wider setting and surroundings. The project approach was to allow for a range of energy efficiency upgrade measures to be showcased using sympathetic materials and methods.

3. RECORDS AND DRAWINGS

3.1 Existing drawings

Largely due to the institutional ownership, there was a good record of drawings describing various programmes of work to the lodge from the 1940s (Figure 5). Later interventions were also recorded, including stabilisation works on the south east corner, which were required due to subsidence. Drawings from the 1993 works were very useful in establishing services routes and changes in room layouts. The paper drawings had been scanned and were easily accessible. CAD drawings prepared by HES

Building Architectural Technicians provided basic floor plans and elevations to be developed for this project. Building checks and a new set of measured drawings were also required to plan the insulation and refurbishment work and for the shop fitters and exhibition contractors.

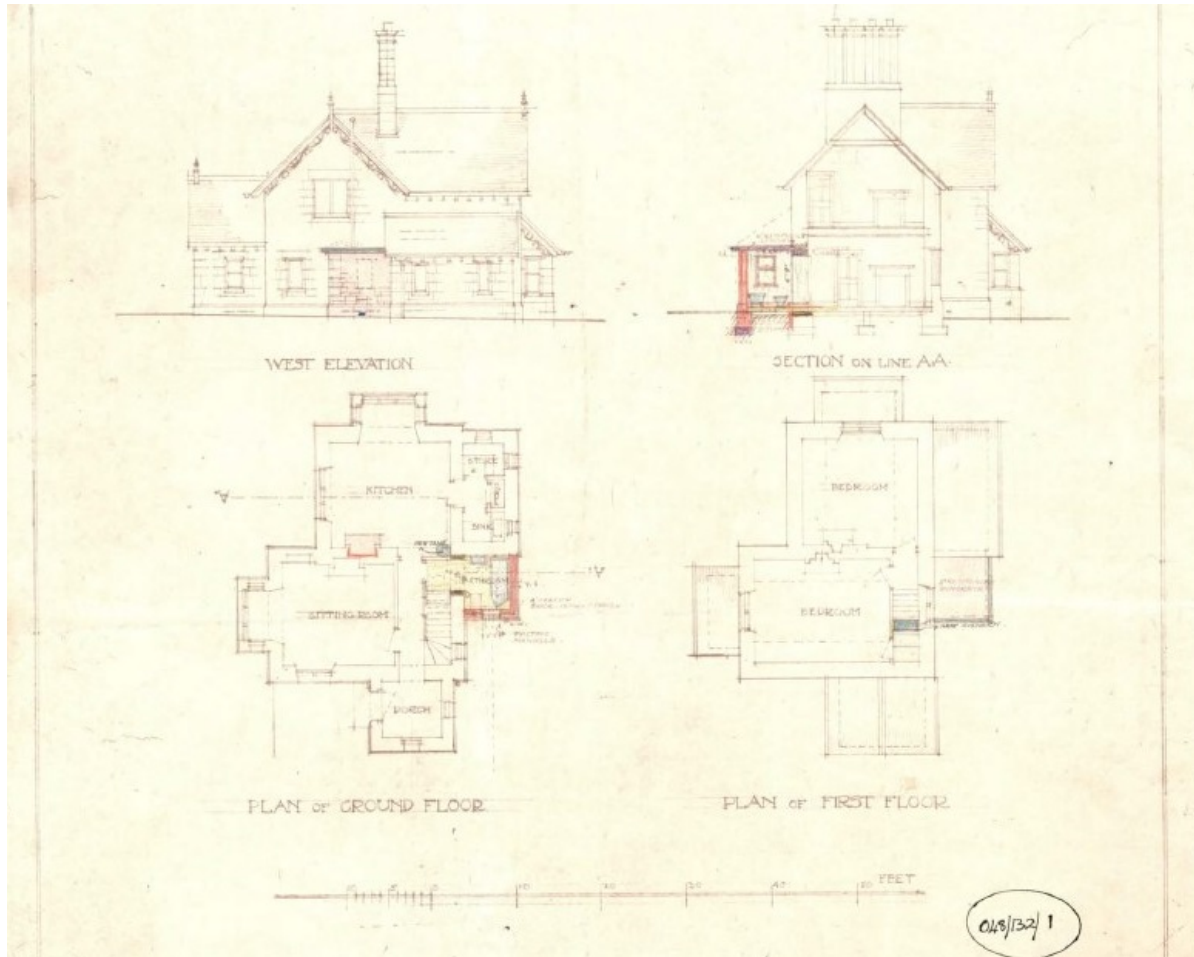


Figure 5. A Ministry of Public Buildings and Works drawing of the Lodge from 1942.

3.2 Laser scan

As part of an existing programme of laser scanning at HES sites, the lodge was scanned in 2015. A point cloud was created which held the raw data and was used for the creation of new drawings (Figure 6). While the scanning process is a well-established discipline, the lodge presented some specific issues, mainly due to the extensive tree cover that partially interrupted the scanning process. However, this was resolved and an accuracy of +/-10mm was agreed as being enough for the purposes of the working drawings.

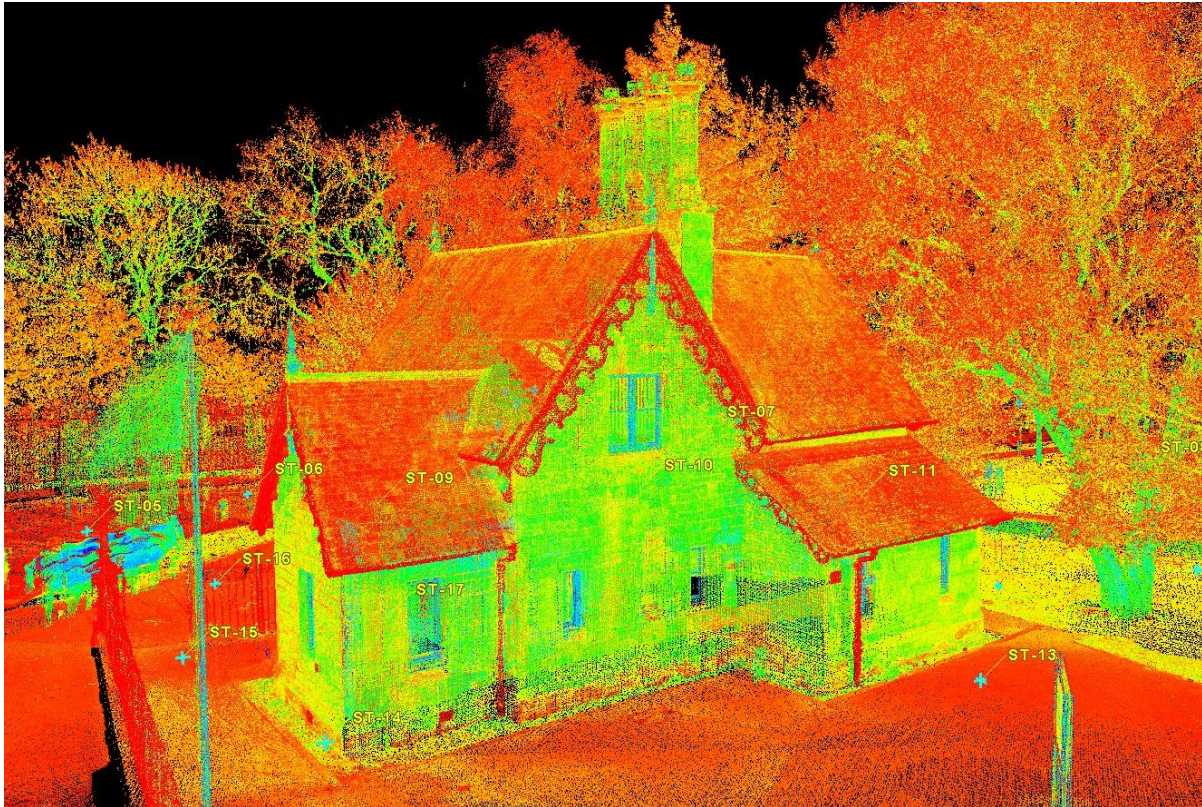


Figure 6. The point cloud of the Lodge from the laser scan in 2015.

3.3 Building Information Modelling (BIM)

BIM is becoming the standard requirement for design, procurement and construction teams, especially in larger projects, and there was a desire in HES to understand its application and assess the utility of the BIM software to work with existing traditional buildings. As part of the thermal upgrade project, the point cloud was converted to a 3D model using Revit software to create a reasonably accurate representation of the building (Figure 7). This was not a simple aspiration to achieve, however, as the Revit conventions and parameters do not lend themselves to the modelling of existing buildings, still less traditional properties, where there has been some structural movement and most building components are non-standard in size and design. It became obvious that there were differences between the existing CAD drawings and the new Revit model built from the scan data and on-site measurements. It is important to acknowledge that absolute accuracy is not always required; this will depend on the purpose of the model. In this case, the purpose was to provide a framework into which information about services and the interventions could be recorded. The 3D model proved to be a good way of capturing project information, such as electrical and other service routes. Scans of older drawings could be stored in the Revit file, as well as all the Operation and Maintenance Manuals. This made the production of information for the Health and Safety file at the end of the project much simpler,

demonstrating that BIM is useful for the holding and sharing of building and construction information for traditional buildings.

Restrictions for multiple access to some software meant that information could not really be shared within HES in the way that a full BIM adoption strategy requires. It became clear that there was a desire from the project team to progress with 2D information such as printed elevations and plans in the traditional way, and this was practical and realistic, as the contractor and subcontractors were working from paper drawings. The trial helped to highlight some of the issues of using BIM for existing buildings and fed into the wider strategy for the adoption of BIM across the HES estate.



Figure 7. An output of the BIM model made for the Lodge.

4. DESIGNING AND PLANNING THE WORKS

4.1 Project objectives

The work was funded with £80,000 from the HES Technical Research Team under the Energy Efficiency in Traditional Properties Research Strand. The aim of the project was to demonstrate best practice in energy-efficiency retrofit for traditional buildings and to provide an exemplar

property which could be used for demonstration and teaching purposes as part of the HES Engine Shed's training and development programme. It would also demonstrate the successful re-use and adaptation of a domestic building as a visitor centre with interpretative display and retail unit, without affecting the existing character of the building as an entrance lodge to Holyrood Park. The immediate area around the building was recognised to be in need of attention but, within this project, the internal works were the priority to allow the new retail unit to start operations and the new interpretative display room to open to visitors. The thermal upgrade works were designed to be visible to visitors, enabling them to see the traditional construction and new material interventions through new built-in inspection panels.

The project had six objectives:

1. Deliver a thermal upgrade to the building envelope.
2. Demonstrate best practice refurbishment and upgrade for a traditional property.
3. Enable works for the installation of the exhibition space and new shop space.
4. Provide a meeting room where the measures could be demonstrated and viewed.
5. Assess the improvements against the Energy Performance Certificate (EPC) methodology.
6. Undertake building fabric monitoring to assess the effects on the fabric.

4.2 The works

The works consisted of a whole house energy efficiency retrofit project and a fit-out as a shop and interpretation centre. The later 1980s alterations and decoration were removed, and the building envelope was internally insulated with vapour-permeable and naturally derived insulation materials. The latter involved laying wood-fibre insulation underneath the existing timber suspended floors, installing blown cellulose insulation behind the existing lath and plaster and plasterboard finishes, installing wood-fibre insulation within the roof space and attic floor (to form examples of both warm and cold roof structures), insulating the cooms (sloping ceilings) with wood-fibre board, reinstating lost fireplaces to the original designs, reinstating missing/damaged cornice and joinery details, and redecorating with traditional colours and a breathable clay-based paint on the ceilings.

The approach from the start of the project was to retain finishes and fittings from significant earlier phases of the building, remove unsympathetic modern materials (such as woodchip and flush fire doors) and re-introduce features that had been damaged or destroyed during past works, as part of a sensitive upgrade and restoration scheme.

The thermal upgrades were guided by the HES conservation principles, which follow the conservative repair approach of minimal intervention, minimal loss of fabric and technical compatibility. The approach centred on designing measures that delivered improvements to the building fabric ‘as far as reasonably possible’ and achieved an appropriate balance between thermal upgrade and the retention of historic material in the building. The improvements were not directed to achieve specific performance criteria of building elements, rather they were based on what had been done before on similar buildings and what had been found to have been successful in other projects. So, in this case, the improvements were based on what the building could reasonably take and not to achieve a specific U-value (the rate of heat loss through a building element). The selection of insulation materials was based on the principle of allowing the building to ‘breathe’, maintaining ventilation paths, and avoiding impermeable materials or finishes. There was a strong desire to ensure some of the interventions were visible and could be shown to stakeholders as good practice.

The thermal upgrade works were developed from interventions that had been carried out in previous energy upgrade pilots on a range of traditional buildings (described in Historic Environment Scotland Refurbishment Case Studies). These interventions had been inspected and reviewed by an independent external conservation accredited surveyor in 2017, to assess whether they were functioning as intended and not causing damage to the fabric or the occupants. The report of this project review is published as Technical Paper 24: Review of Energy Efficiency Projects.

4.3 Statutory consents

At an early stage in the development of proposals, the project team liaised with the City of Edinburgh Council Conservation Officer, demonstrating that the intention was to minimise alteration and disturbance of the fabric, and avoid alterations that would affect the character of the building. The local authority advised that due to the minimal impact of the works, Listed Building Consent would not be required, and they were supportive of the refurbishment proposals. Scheduled Monument Consent was not required either for the extent and scope of works proposed. Appointments were recorded in line with Construction Design Management legislation and guidance. The Health and Safety at Work requirement for an asbestos survey was arranged prior to start of any works; the report noted that no asbestos containing materials were found.

4.4 Procurement

The thermal improvement measures and associated work required were set out in the drawings and Description of Works with details of materials to be used, linked to building areas. This included the associated works for the shop and the interpretation space. The project was tendered through the Public Contracts Scotland portal, which is the required route for the

procurement of public sector projects. The contract used for the works was the GC Works Minor Works Contract. The successful contractor attended a pre-start meeting to discuss the construction phase of the project and ensure the requirements of the project were identified and communicated clearly. This was particularly important as many of the measures, were not common work practices for most building contractors. The procurement route was appropriate, in as much as the successful contractor proved to be skilled and experienced, and delivered the work to a high standard, however, the process did highlight some inherent issues with the public sector procurement system, as smaller companies were less familiar with the protocol, leading to delayed tenders and potentially some competent local companies failing to bid. This may mean that training and skills are not being disseminated to the wider domestic building sector, which is an issue that HES is keen to address.

5. PRE-INTERVENTION MONITORING

5.1 U-Value monitoring

In order to understand the degree of thermal improvement delivered by the package of thermal improvement measures, pre- and post-intervention monitoring was carried out by a specialist building monitoring company. This started with measuring the U-values of the walls and roof elements in three upstairs locations: the top of the stairwell, the staff room sloping ceiling (coom), and the ceiling, wall and coom of the meeting room. This measuring operation required a 10-degree C difference between the internal temperature and the external air temperature. To achieve this temperature difference, monitoring in the winter season was necessary. Additional heating was required to maintain this temperature difference, and this was run for the three weeks of monitoring in the winters of 2015 and 2017. Two years' worth of data was obtained. (Figure 8 shows the process of measuring the heat flow through the coom ceiling at the east elevation.) The pre-intervention results showed that the walls at the lodge performed thermally as anticipated for solid walls, with a measured U-value average for the west elevation of 1.07 w/m²K.

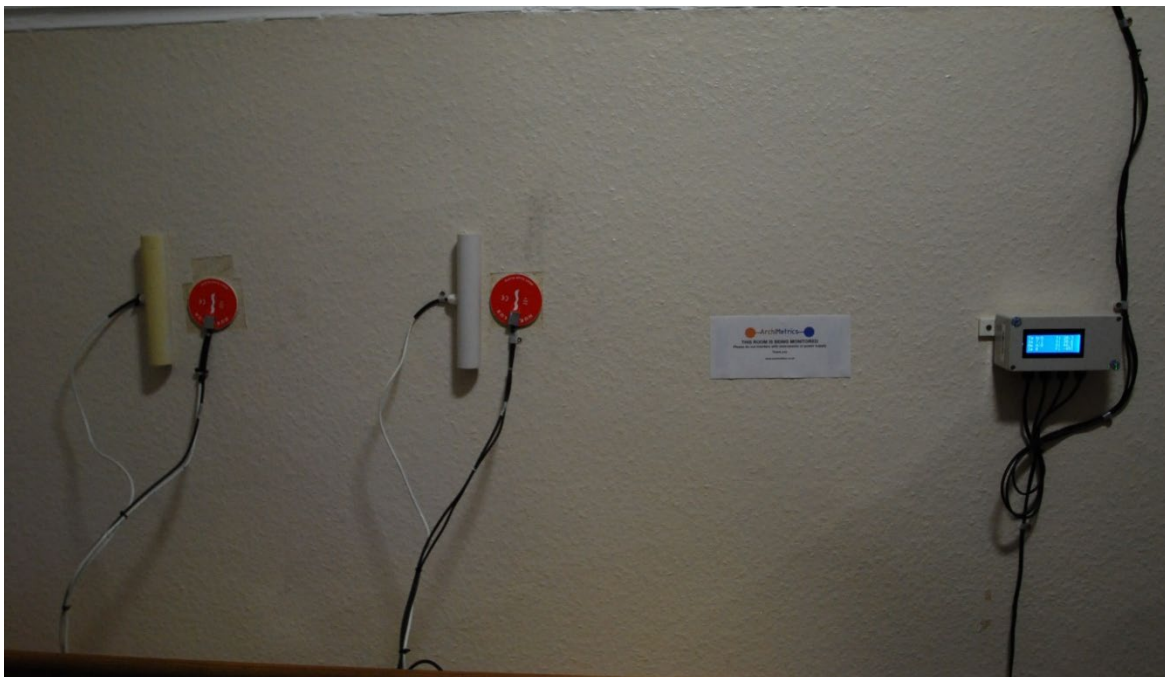


Figure 8. Equipment for the pre-intervention monitoring of U-value in the east coom ceiling.

As the results from the monitoring built up, the opportunity was taken to assess how the measured U-values compared with calculated values, using standard industry software. Most calculated values didn't align exactly with measured ones, however, there is good correlation with one of the east wall measurements (greyed out cells in Table 1), where a ratio of mortar and stone has been allowed for. This showed that where there is

confidence in the make-up of the wall, a calculated U-value measurement can align well with the measured value. Other areas of the east and west walls with measured and calculated values are also shown at Table 1.

Location/Element	Thickness	Calculated U-value (W/m ² K)	Measured U-value (W/m ² K)	Measurement error	U-value range (W/m ² K)
First floor meeting room, east wall	550mm	1.58	1.20	6.12%	1.13 – 1.27
First floor meeting room east wall (60/40 stone/mortar ratio)	550mm	1.23	1.20	6.12%	1.13-1.27
First floor meeting room, flat ceiling to roof	1150mm	0.47	0.24	5.94%	0.22-0.25
First floor meeting room, flat ceiling to attic	120mm	0.55	0.36	7.04%	0.33-0.39
First floor east coom ceiling (isolated)	210mm	1.94	1.22	5.57%	1.15-1.29
First floor east coom ceiling (un-isolated)	210mm	1.94	1.28	5.53%	1.21-1.35
First floor stair landing, west wall	560mm	1.56	1.07	6.59%	1.00-1.14

Table 1. Measured and calculated U-values of the east and west walls pre-refurbishment.

5.2 Wall humidity monitoring

In addition to the assessment of the U-values of the masonry walls, measurements were taken of the relative humidity and temperatures of the west elevation. This was done with a series of probes installed at four different depths at the top of the stairwell on the west wall (Figure 9), which would allow a humidity profile to be established in the solid wall. Understanding the humidity in solid walls is important, as consideration must be given to any effects of added insulation which might affect the dew point within the wall thickness. A condensation risk assessment is necessary to understand if there is a risk in the use of certain insulation techniques and the potential for condensation to cause dampness. This

process is extensively used in refurbishment, but work by HES has shown that, if vapour open materials are used, such moisture is able to wick away and disperse with no long-term effect on the fabric. This monitoring would establish a baseline humidity level in the wall and allow comparison with the results in the same place after the insulation work was completed. Figure 10 shows the fluctuations in the relative humidity within the wall core over a 12-month period. These pre-intervention data are compared to post-intervention humidity results in section 11.1.



Figure 9. The in-situ U-value and humidity measuring equipment in place at the top of the stairwell. Note the four probes measuring humidity within the wall.

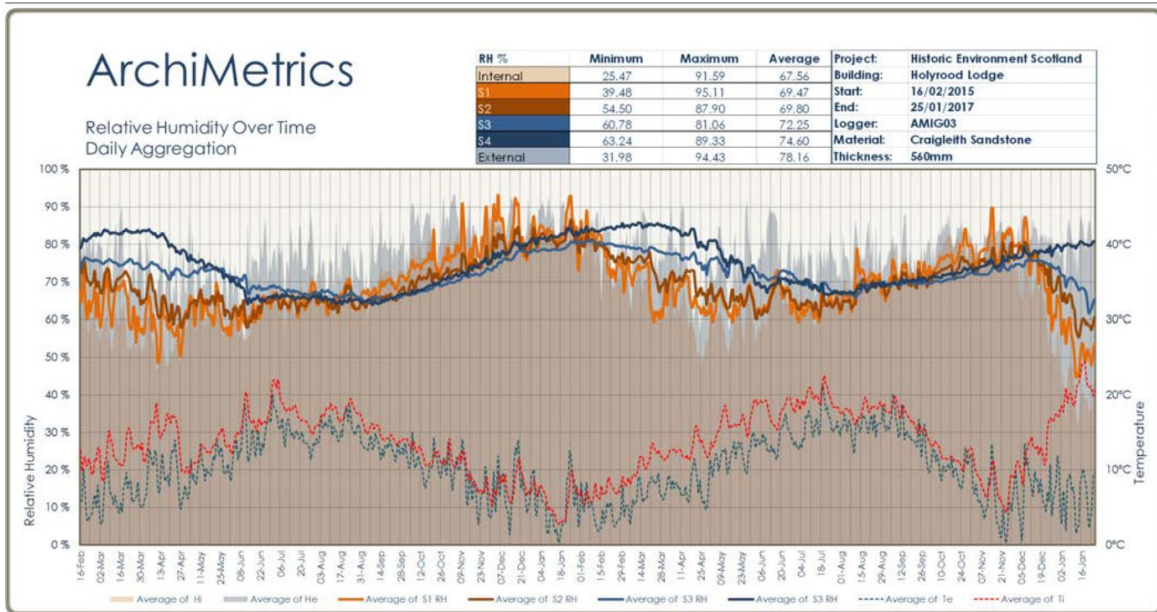


Figure 10. Graph of relative humidity over a 2-year period, February 2015 – January 2017.

5.3 Air leakage

In order to assess how the works improved the air tightness of the lodge, multiple pre-intervention air pressure tests were carried out in Winter 2017 (Figure 11). Not all of these tests conformed to the standard procedure, deliberately so, and were designed to establish how leaky the building was in different states. This included identifying how the building performed when it was ‘in service’, which is different from the condition a building is in when it is tested for compliance purposes. Three of our series of tests, however, equated to the standard compliance test, where only the windows were un-taped, flues and other openings in the fabric were closed off, and a de-pressurising fan was used in accordance with BS EN 13829:2001. The result achieved was an average of 15.29 m³/h/m². This is a typical figure for an unimproved building, and provides a useful benchmark to counter the quote that older buildings are exclusively draughty. The pre-intervention air leakage results are compared to post-intervention data in section 11.4.



Figure 11. The fan on the back door for the air pressure test in Winter 2017.

6. THE SITE WORKS

6.1 Repair of the ground floor timbers

The ground floor of the lodge has suspended timber floors throughout. In the south east room where there had been building settlement, the floor sloped and was uneven; repair and remedial work was required. The floor covering was removed, and floorboards carefully lifted and set aside for re-use. Some joists were off the level by some 40mm, apparently the result of a partial collapse of two dwarf walls that ran across the room. In addition, the joists ends were not well bedded or packed into the external walls. New supports were built up to carry the joists. A new level was established using the hearth stones in each room as a datum. Despite the building settlement, the existing floor joists were in good condition and only required minor repairs. The joists were levelled with timber packers and slate pieces. To give additional lateral stiffness, additional braces or 'dwangs' were fastened at right angles to the joists (Figure 12) at regular intervals. In the north east room, sections of the floorboards were also lifted to check the floor's condition and route new power and data conduit and cabling for the shop.



Figure 12. The additional stiffening put into the ground floor joists using 'dwangs'.

6.2 Approach to damp

While the location of the lodge is low-lying and the ground around is prone to water run-off from the modern hard landscaping to the south west, the underfloor void (solum) appeared dry. There were some small areas of wet rot on the underside of the joists, close to the wall junction, where at some point the floor void had been damp. The dry state of the floor void may be due to improvements in surface drainage in the garden area, as part of the 1990's works. It is common with some approaches to refurbishment to lay a concrete floor after removal of a suspended timber floor. This is not suitable for traditional buildings, as the moisture in the ground is prevented from evaporating; this means the solum becomes damper and water rises up the masonry of the walls and partitions, exacerbating the very dampness the intervention seeks to exclude. A considerable amount of loose masonry material and other debris was removed from the floor void on the ground floor (this amounted to about 40 rubble bags) reducing the solum level below the floorboards by about 40mm. This is expected to have improved the air flow in the floor void considerably (Figure 13). Externally, the iron grilles in the masonry walls that allow outside air into the solum were cleaned to ensure full air movement into the insulated space (Figure 14).



Figure 13. The cleaned-out floor void prior to the insulation being fitted.



Figure 14. The external ventilation grilles to the floor void. These were cleaned to ensure full air movement.

6.3 Insulation to the timber floor

Following the repair and upgrade of the timber joists on the ground floor, wood-fibre insulation was fitted between the joists. The wood-fibre insulation is a semi-rigid batt, 100mm thick, specified for use in the floors and the attic spaces, allowing a single product bulk buy (Figure 15). The wood-fibre board was cut into the required lengths with a wide toothed

hand saw, not seen very often today, this type of saw is able to effectively cut fibrous materials without the teeth clogging up (Figure 16).



Figure 15. The wood-fibre insulation batts for use in the floor and the roof spaces.



Figure 16. Cutting the wood-fibre board with a wide toothed hand saw.

The cut batts were mounted on timber runners fastened to the lower edge of the floor joists. The tolerance in cutting gave a snug fit between the joists; the runners giving some closure on any gaps. However, absolute air tightness was not desired either, as some air movement was considered desirable. Due to the thickness of the insulation at 100mm, the finished level of the insulation was approximately 10mm below the level of the top of the joist (Figure 17).



Figure 17. The floor insulation in place between the joists in the hall prior to the boards being laid.

6.4 Relaying the timber floorboards

Following the insulation work, as many as possible of the floorboards were re-laid. Due care was taken when lifting the floorboards, but about 50% of the floorboards from the ground floor were unsuitable for reuse, due to deterioration and damage from service installations. A decision was therefore taken to relay the floor in the exhibition room with the original floorboard timbers, making up the shortfall with salvaged boards from the other areas, and fit new timber tongue and groove floorboards in the shop and corridor areas. Care was taken to ensure that the floor was re-laid around the hearth stones in the traditional way (Figure 18). The original flooring was sanded in the workshop before laying and finished with two coats of water-based varnish. The quality of the original timber flooring became very obvious to see when compared to the new flooring in the

shop and corridor. While the new timber was of acceptable quality, it was much paler in colour due to less resin and faster growth, and was also slightly softer, making it susceptible to marks and dents from foot traffic and when moving materials and equipment. The floorboards on the first floor were not lifted as they were in good condition and the thermal upgrade did not require intermediate floors to be insulated.



Figure 18. The re-laid floor in the exhibition room, note the rich colour of the historic timber and the mitred edging around the hearthstone on the right of the image.

6.5 Wall insulation

Because of the expense and disruption, wall insulation in traditionally built properties should only be considered after all other energy efficiency measures have been adopted. Due to the visual characteristics of the exterior masonry, external wall insulation was not considered appropriate in this case. The preferred approach was to consider what was feasible at the interior wall face; cellulose fibre insulation blown into the air gap behind the existing lath and plaster wall linings was selected. This method has been trialled in several HES projects (for a summary see Technical Paper 24) and has been a simple way of improving thermal performance, while allowing the retention of original plaster linings. However, it is not yet seen as conventional builders work and it proved difficult to find a contractor who would install the measure. At the lodge the air gap behind the lath and plaster was quite narrow, approximately 38mm, and to achieve a reasonable fill in the void, many holes had to be made in the plaster. Extensive plaster patching was needed for this, as well as redecoration. This resulted in extended site time to ensure the work was thoroughly and carefully carried out.

Whilst blown wall insulation remains an effective option for upgrading lath and plaster walls, further evidence is needed to show that there are no damaging effects on the building fabric. To assist with this, the in-situ monitoring at the stairwell will allow for a continued assessment of the effects of these thermal upgrade measures to be made available. Visitors can also see what has been done with the blown insulation, through an inspection wall panel in the meeting room on the first floor (Figure 19).



Figure 19. Fitting the interpretation panel to show the blown cellulose fibre behind the lath and plaster.

6.6 Windows

The existing windows in the lodge were all single-glazed casement type windows of varying dates, with most having been fitted as part of the 1995 repair works. The casements in the shop corridor and main hall were fitted into original frames, with traces of the once common green paint in the lower layers. All frames and casements were in good condition, so the decision was taken to keep them and upgrade the glass with slim profile double glazed units from a Scottish supplier. For this work, the casements were removed to the contractor's workshop to fit new higher performance glass units, overhaul the hinges and stays, and check over that they are functional and operable before re-installing into the building frames (Figure 20).



Figure 20. The new double-glazed units set into the existing casements.

All the new insulated glass units (IGU's) units were bedded in traditional linseed oil putty; to separate the linseed oil from the window edge seals, silicone was used on the edges. Some industry guidance indicates that linseed oil may damage the edge seals of double-glazed units. To assess these possible effects, two fixed casements in the interpretation room were only bedded with linseed oil putty, with no barrier between the unit and the putty. The condition of this double-glazed unit will be monitored. (At the time of writing of this document there have been no visual changes to the window assembly.) In addition to the improved glass, draught strips were rebated into the casement edges to reduce air infiltration (Figure 21). This worked well on the smaller windows but, where there had been building settlement or a poorly fitting frame, the gap was too much for the cushion strip to make up and an air gap remained. This was especially noticeable in the first-floor meeting room where the window opening on the gable wall was distorted by the building settlement. Following the main project work, silicone beading was applied to cover the remaining air gap.



Figure 21. The cushion-type draught strip fitted to the casements.

6.7 External doors

Panelled and similar traditionally made door types often have slimmer components to create their distinctive appearance. Modern insulation materials such as aerogel-based products can offer a good solution for increasing the thermal performance of traditional door types where the panels are thin and for retaining the existing doors within the building door frames. At Holyrood Park Lodge, aerogel board was therefore added to improve the thermal performance of both external doors. It was decided to leave the timber beading and door mouldings in place around the inset panels and to directly apply the aerogel blanket (5mm thick) to the fielded panels on the inside of the door, then cover with a thin plywood panel (6mm thick), all cut to size for a good fit (Fig. 22). All existing hardware was retained.



Figure 22. One of the ledged and braced doors at the lodge before being redecorated, showing the plywood panel on top of the aerogel board.

6.8 Roof slope - Ceiling cooms

In traditional buildings, the upstairs rooms often sit under the roof pitch with sloped ceilings; in Scotland these are called cooms. These areas confer an additional level of complexity when carrying out energy assessments, and the Energy Performance Certificate (EPC) assessment has a simplified way of modelling performance. The practicalities on site of installing insulation into the cooms can be tricky with many standard insulation products. For Holyrood Park Lodge, wood-fibre board was selected and panels were cut to the right width to suit roof rafter spacing and to be able to slid down into the coom space from the roof attic above. The cut batts were slightly soft and just flexible enough to pass by variations in thickness of the rafters; if cut too wide, the batts could not be fed between the surface edges of the rafters, and if cut too narrow, the fit would have been

too loose to perform as well as intended. Old nails, wiring and stray cut of timber can all impede the moving of the insulation batts. It is possible to remove the lath and plaster from the cooms and insulate the ceiling faces from below. However, this is extremely disruptive, results in the loss of lime plaster and creates construction dust. It obliges the relining and re-plastering of the room, resulting in considerable extra cost. It is desirable, therefore, to develop methods of insulating without extensive downtakings.

6.9 Roof space - Warm roof

The roof to the upper floor of Holyrood Park Lodge has two attic spaces separated by the masonry of the chimney breast. To access each of the attics the ceiling hatches were enlarged to give more space and improve safe working access into these areas. Proprietary ceiling access panels with drop down ladder steps were fitted in the first-floor meeting room and the staff room. This allows easier access for inspections and for visitors to see the works undertaken. Wood-fibre was selected for insulation, since it absorbs and releases water vapour as internal conditions change with temperature. Any condensation from changes in dew point will be absorbed into the wood fibres and will not bead up and run down the insulation, which can happen with some materials. One roof space area, the south facing gable, was fitted with wood-fibre board fastened between the rafters, much as was done on the timber floor. This gave what is termed a 'warm roof' (Figure 23).



Figure 23. The wood-fibre insulation in the south gable space; a 'warm roof'. Note the insulation continuing down in the coom.

During the installation work, it was questioned if the wood-fibre batts should be tight up against the sarking, giving a single roof layer, or leave a 30mm gap. Conventional practice recommends a ventilation gap, and this was adhered to for most of the roof slope. To assess the effects of having no air gap, two insulation boards - covering the width between three rafters - were reset close against the sarking. In-situ humidity monitoring equipment was installed in both areas to allow assessment of any difference in the condition of the insulation and sarking timbers. The monitoring was set in place in the Autumn of 2017 and was conducted over the following two winters. Initial results suggest that there is only a minor difference in relative humidity between the ventilated space and the unventilated wood-fibre insulation. Monitoring is continuing in this area until winter 2020.

6.10 Roof space - Cold roof

The east facing gable roof was insulated at attic level, with the wood-fibre batts being laid between the ceiling joists, much as is done with mineral wool and other insulation products. This gave what is termed a 'cold roof' (Figure 24).

Having these two options in one building allowed easy demonstration of the two techniques, enabling an ongoing assessment about what type of intervention is best or most appropriate. There are benefits to both approaches. The warm roof provides a more complete thermal envelope to the structure and can accommodate water tanks and piping. It also means that stored items are kept at a higher and generally drier temperature. Organic materials such as leather and paper are less likely to attract mould or become foxed or discoloured. A cold roof however is quicker and simpler to deliver, it reduces the heated volume of the building, retains the heat in the habitable spaces and can be carried out with a greater range of insulation materials. As the work in this type of roof is simpler, it can be done by the homeowner or by semi-skilled operatives.



Figure 24. The wood-fibre insulation batts laid flat between the ceiling joists to give a 'cold roof'.

7. VENTILATION

7.1 Ventilation requirements of traditional buildings

In modern refurbishment, there is a high importance placed on airtightness. While this is desirable for reducing heat loss, in older buildings this should not be carried to excess. All buildings require adequate ventilation for the health of the fabric and, more importantly, for the health of the occupants. When refurbishment work is designed there must be conscious provision for ventilation. Traditionally, ventilation was provided by passive means and, unless the occupancy and use are very high in a building, this principle is still appropriate. Open flues generally provide a passive stack effect of moving air up through the flue and drawing it out of the building. Fresh air can come in through vents at ground level and move through the building, generally behind existing linings. Modest air infiltration through gaps in windows also contributes to ventilation.

In modern construction, the building regulations for ventilation focus mainly on extract fans in kitchens and bathrooms, and trickle vents in windows. However, this is not always sufficient to ensure enough fresh air comes in. Water vapour, carbon dioxide and other waste gasses need to escape. At the lodge, the ventilation plan was a simple adjustment of traditional ventilation routes and facilities. This consisted of re-opening all window casements that had been previously painted shut and fitting new window hardware to allow their controlled operation, a new opening in the

hall, the re-venting of two closed hearths and the full reinstatement of one fireplace.

7.2 High level ventilation

For security reasons, and due to the nature and pattern of use of the building, it was decided that most windows on the ground floor of the lodge would be kept closed. To ensure the proper flow of air through the ground floor areas however, a small quarter light at high level in the north hall was modified to be operable with a pulley (Figure 25). This simple device does not have any power or electrical requirements, making it simple to maintain. Its height and size made it a low security consideration (Figure 26).



Figure 25. Internal view of the opening light.



Figure 26. External view of the light, shown fully open.

Providing ventilation to roof spaces following insulation work is important to avoid condensation and, as the filling of the cavity behind the lath and plaster linings can cut off the air flow from the floor void up into the roof space, alternative arrangements will often have to be made. In this case, additional ventilation was not required as there was plenty of existing ventilation in the roof area, due to gaps at eaves level.

7.3 Hearths and flues

As part of the ventilation plan above, the hearths were modified. Chimneys and flues are a defining architectural feature of a historic building and

should generally be kept open to allow dispersal of water vapour from walls. At the lodge, all hearths had been closed off as part of the 1990s work. To progress thinking on the ventilation benefits of open flues and to improve the natural ventilation of the meeting room, where there might be up to ten people, it was decided to re-instate the hearth and mantelpiece in the meeting room to allow full air movement through the flue. In addition, a larger vent plate would be put into the former hearth opening in the interpretation room and shop (Figure 27). Both these interventions would allow the re-instatement of air movement in the flue and a degree of passive ventilation to both rooms.



Figure 27. The new ventilation grille in the former hearth in the interpretation room.

When the room is in use, in conjunction with a small opening of the window, this is considered an adequate means of air extraction. Dimensions and sizes of the masonry surround were taken from another lodge in the park, and a cast iron inset and grate supplied from an architectural salvage retailer. As the width of the room had been narrowed by the creation of a new door at some stage in the past, the opening was made slightly narrower to better match the proportion of available width. However, a reasonably sympathetic assembly was achieved (Figure 28). The hearthstone had become uneven and loose and required re-bedding. This was set to be nearly flush with the timber floor, allowing a 10mm up stand to account for the thickness of the carpet. Traditional hearth stones are always level with the floor; raised hearths are a modern adaptation.



Figure 28. The re-instated chimney piece and hearth in the meeting room.

7.4 Humidity buffering

The ceilings were painted with an off-white clay-based paint; the purpose of which was to provide a degree of humidity buffering. Clay paint can absorb and release water vapour and can assist in managing internal humidity levels. In addition to these benefits, such paint is low in volatile organic compounds (VOCs) which can build up in refurbishment and new build.

8. OTHER WORKS

8.1 Electrical and data cabling

As there was to be a new retail unit and exhibition space in the ground floor, and an office in the upstairs room, enhancements were made to the existing power and lighting circuits. This included new power sockets and lighting terminations for retail and exhibitions purposes. New data cabling was also required for the shop counter and upstairs office. To anticipate future demands Ethernet cabling was also provided to the meeting room.

These new cables were routed behind the lath and plaster before the insulation was blown in.

8.2 Electrical fittings

To improve the visual amenity of the lodge, the lighting for the stairwell and the upstairs rooms was re-modelled with new but traditional pattern fittings and pendants in brown Bakelite (Figure 29). These were more appropriate for a domestic scale building than the large luminaires that had been installed in earlier works. LED bulbs were used, but attention was paid to achieving the correct 'colour temperature' to give a soft warm light. The temperature selected was 7500 Degrees Kelvin. In many cases, a bulb temperature over 7500 can be too bright for traditional interiors, unless there is a specific need. Some LED bulbs can give rise to a cold blue light, caused by this higher frequency of emitted light. This can affect perception of colour and personal comfort.



Figure 29. New light fittings of traditional pattern contributed to the improvement in amenity at the Lodge.

8.3 Plaster repairs and finish of internal surfaces

Internal finishes in the lodge were generally simple and with plain-run cornices, but the lodge had been redecorated many times in the last 25 years, generally in an institutional way. Many of the walls were covered in a

'woodchip' type covering, with multiple layers of emulsion paints. This resulted in a largely impermeable surface, prone to condensation and resulting in mould spots behind cupboards. This woodchip wallpaper was steamed off and the surface taken back to smooth plaster. Only minor areas of repair were required.

On the corners or 'arrases' of plastered areas, the timber bead was returned to its original finish with the plaster edge strips uncovered; in Scotland this detail is called a 'quirk' (Figure 30) and softens the edges of corners and other terminations.



Figure 30. During the redecoration, the configuration of the timber corner detail, called a 'quirk', was re-instated.

Once the new electrical works and insulation were completed, repairs were carried out to the plaster surfaces, before being covered with a layer of lining paper and painted with a low VOC emulsion paint of traditional colour. Lime plaster was specified for repair to match existing but, in some places, modern gypsum plaster was used for small areas of repair. Modern, quicker-setting mixes are frequently used internally for small patch repairs, where the curing time of lime plaster affects the progress of works, and the tendency of lime plasters to shrink on drying can affect the integrity of the repair. This proved to give an unexpected issue when the works were

complete, and the exhibition room was about to be fitted out with the graphics and displays. As it was late summer, the heating in the building had been off for some time, and the downstairs rooms were cool. It was noticed what seemed to be damp patches around the edges of the door and by the new vent grille in the exhibition room. This caused concern to the shopfitters and the installation was suspended. Following investigation and assessment, it was apparent that condensation was forming on the areas of new plaster; an issue that was mistakenly thought to be rising damp coming through. A lime-based or gauged plaster would have been more suitable technically, having the same properties as the original and it would have also retained the authenticity of the plaster surfaces. (HES is currently undertaking research into historic plaster mixes, to better inform specifications for repair projects.)

8.4 Heating and thermal comfort

The lodge was heated by a conventional wet system, with a relatively modern condensing boiler. Due to this and for reasons of cost, it was decided to leave this in place. Some radiators were moved to allow for the reflooring and shopfitting works. New installations were made to give localised heating in two locations with a new form of electrical heating. An infrared heating panel was placed over the re-instated hearth in the upstairs meeting room (Figure 31) and another on the ground floor retail space by the shop counter area. Radiant heat is delivered by the panel through the infrared radiation heating the objects it falls on and not the air itself. While it cannot be called a low energy heat source, it delivers thermal comfort more directly and often allows comfort with lower air temperatures. These systems suit large spaces where only localised heat is needed, and airtightness is hard to achieve. The panels are controlled by a thermostat mounted on the wall close by.



Figure 31. The infrared heating panel over the chimneypiece in the meeting room.

8.5 Floor coverings

To minimise the use of synthetic materials in the refurbishment, a natural wool carpet was laid on the first-floor rooms and corridors. The underlay that was used was also a recycled natural fibre product.

9. INTERPRETATION AND ACCESS

An important part of the project was, and is, that the experience gained from the refurbishment project would become available and easily accessible to the public. As such, the works are being described in this report and the ground floor of the building is open to the public most days. In the exhibition room on the ground floor, there is a section devoted specifically to the building and the recent works. The first floor is also accessible for viewing and inspection of the measures. Interpretation panels have been placed on the walls to describe the works undertaken. In the meeting room and the staff room, hatches and doors were formed to view insulation materials that would otherwise not be visible (Figure 32).

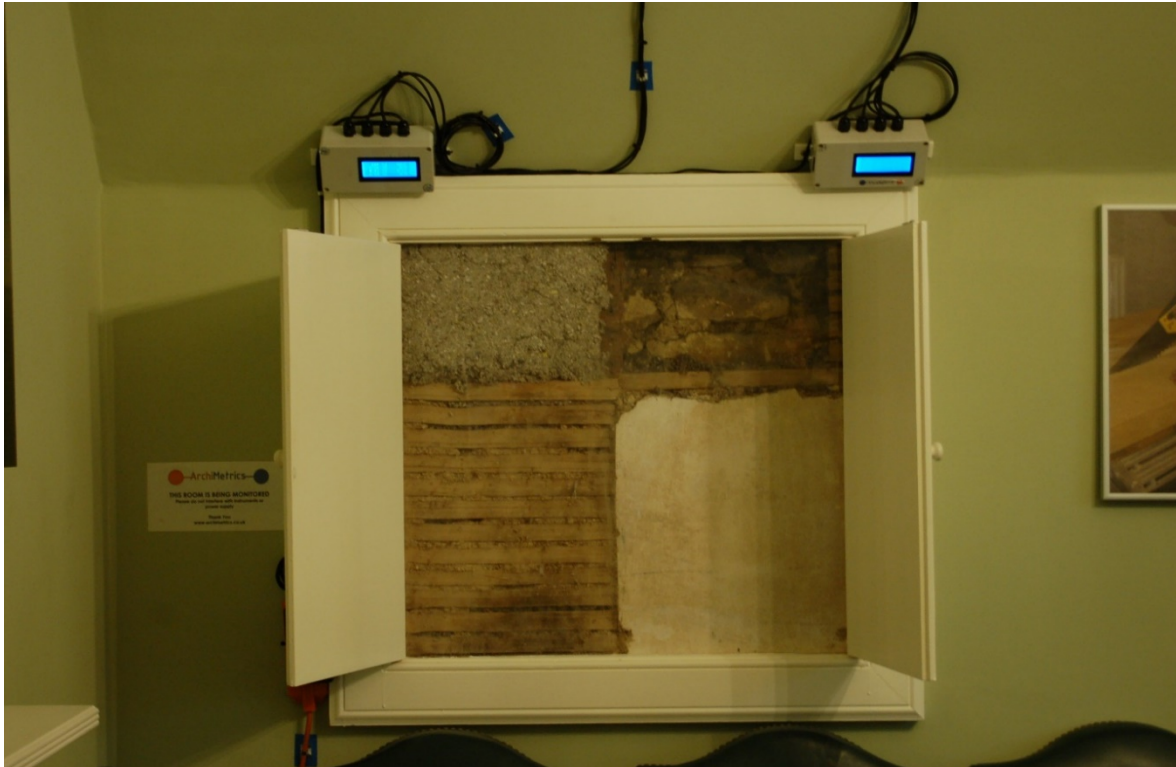


Figure 32. The opening hatch in the wall to allow view of the blown cellulose wall insulation in the meeting room. Note the display panels from the monitoring equipment.

10. COSTS FOR THE MEASURES

10.1 Refurbishment costs

In all refurbishment projects, cost is a significant factor. This project sought to establish baseline costs for simple refurbishment measures in traditional and historic buildings. While the work was carefully specified and instructed, none of it was complex, and was entirely within capability of a medium-sized joinery company. The list of costs below is not exhaustive for all the work but seeks to capture the key energy efficiency improvements that readers may wish to consider when planning such works. Although those costs are for the specific project, they can be indicative of the total cost for energy efficiency upgrades to a detached cottage of a total floor area of 98m². (There is broad similarity with rates established at Kirkton of Coull in Aberdeenshire and at 11 Annat Road in Perthshire, both described in Refurbishment Case Studies 16 and 20 respectively.)

Measure	Cost (2017)	Cost (2020)
Wood-fibre board insulation to timber floors	£6,677	£7,416
Insulation to two external doors	£800	£889

Double glazed units to casements	£6,690	£7,431
Blown cellulose behind plaster	£7,582	£8,422
Warm roof insulation (wood-fibre board)	£1,622	£3,070
Cold Roof insulation (wood-fibre board)	£482	
Porch roof (wood-fibre board)	£925	£1,027
Repair wall plasterwork and lining paper	£1,940	£2,155
Re painting with clay paint	£1,198	£1,331
New opening quarter light in hallway	£410	£455
New traditional pattern lighting, first floor	£400	£444
Re-instatement of first floor fireplace	£2,300	£2,555

Table 2. Costs for the refurbishment works as in the Tender pricing document in 2017 and updated to current pricing levels using the BCIS indices.

10.2 Costs for other works

Several elements of work were required in relation to the shop and exhibition spaces which were unrelated to the thermal and decorative upgrade. These included the track lighting, adaptations to create the shop space and exhibition room, data cabling provisions and other miscellaneous items. The total contract sum for the project was £80,000.00.

11. POST INTERVENTION MONITORING

11.1 Conditions in the wall

The works were completed in July 2017 and building monitoring was resumed in February 2018. The first year of post-intervention monitoring was limited in scope to two areas: wall insulation assessment and measuring of relative humidity on the west facing elevation. Before intervention, relative humidity values varied significantly, mainly due to the building being underheated, however, monitoring has shown that, post-refurbishment, the west wall behaves much as traditional walls behave in heated buildings, with a much lower relative humidity level. These relative humidity levels are an improvement to both the internal environment and the wall conditions, showing that the insulation had indeed a positive impact. A representative graph of humidity through the wall section,

including within the insulation, is shown in Figure 33.

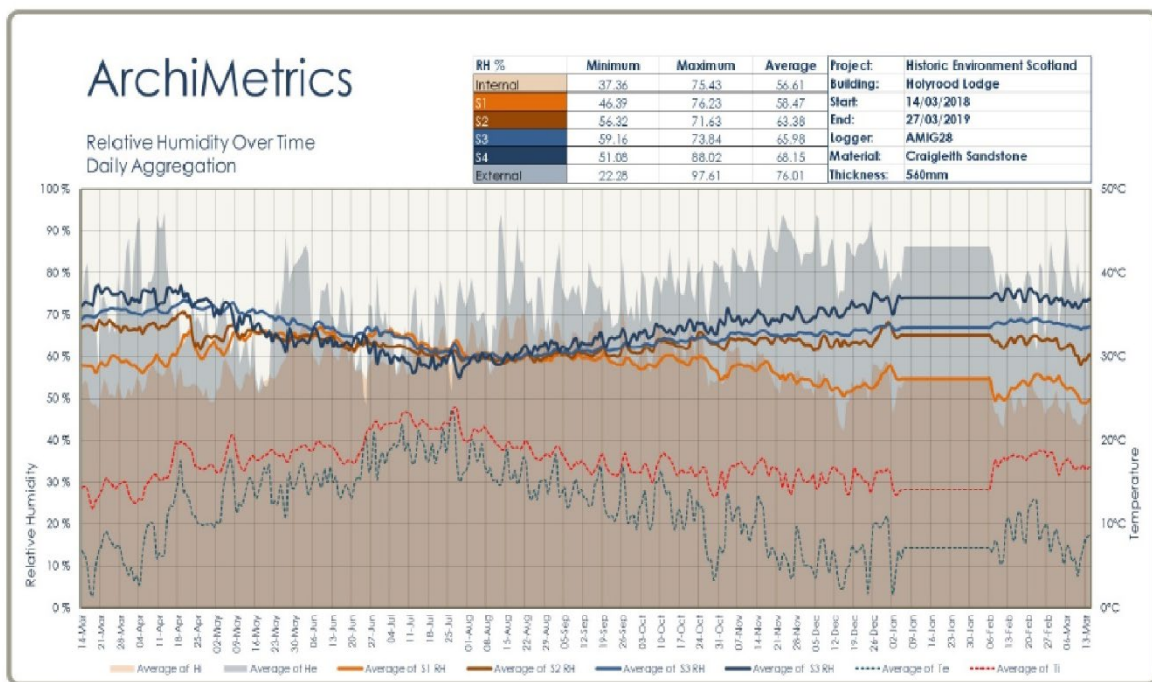


Figure 33. Post-refurbishment humidity levels over time through the section of the west wall.

11.2 Wall insulation assessment

Following the insulation works to the walls with blown cellulose fibre, U-value measurements were taken again to assess the efficiency of the insulation measure to the walls. These were taken from the west wall at the stair landing on the first floor. The post-improvement U-value was 0.65 W/m²K; This compares well to the calculated value for the insulated wall of 0.69 W/m²K and with a measurement error of 4.9%. Against the pre-intervention value in this location from Table 1 (1.07 W/m²K), the improvement in the thermal performance of the wall is about 36%. This improvement in wall performance at the Lodge is similar to where the same measure has been carried out elsewhere, which is giving some confidence in this measure delivering good results in traditional buildings with mass walls, and a lath and plaster lining.

11.3 Roof insulation

In the winter of 2018/2019, additional monitoring was carried out focussing on the conditions in the warm roof at the interface of the insulation and the sarking, as well as within the insulation material. During the monitoring period, a dashboard type display was developed to allow an at-a-glance assessment of the conditions in the roof insulation. A screen grab of this display is shown below (Figure 34). The results so far are indicating that the effectiveness of the improvements is generally as expected. The

specific area of the roof where the insulation was pressed up against the sarking, described as ‘without interface void’ in Figure 34, shows no significant difference in conditions at the junction when compared to the one ‘with interface void’. This supports the theory that where vapour and capillary active materials are used for insulation, internal humidity is controlled, and the roof is wind and watertight, moisture does not build up.

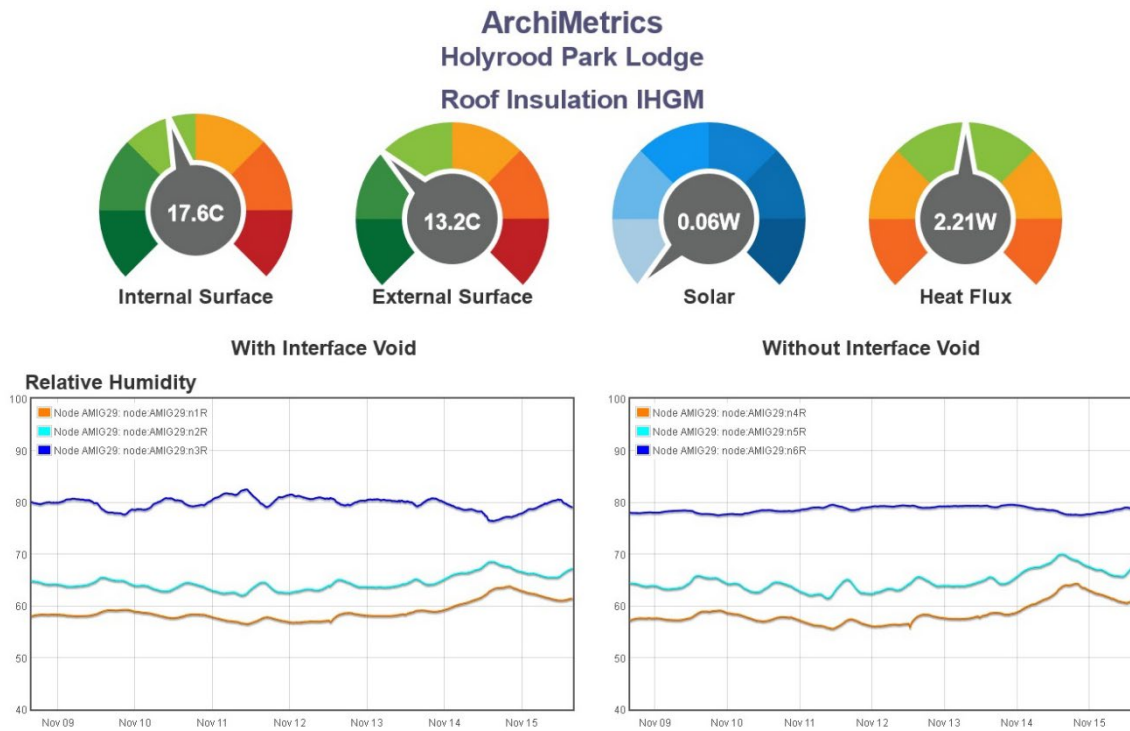


Figure 34. The online dashboard showing the humidity in the roof insulation in the warm roof during November 2018, as well as the average internal and external temperature.

11.4 Air leakage

Air pressure tests were carried out on the refurbished building in February 2019, which included, but not limited to, the standard test methodology. The overall air leakage was an average of 11.25 m³/h/m²; an improvement of 26% from the pre-intervention figure of average 15.29 m³/h/m² measured in January 2017 (Figure 35). During the testing, it was clear that there was still air leaking from the windows and the assessors judged that further window draught proofing would give a still better figure. (By way of comparison, the Scottish Building Standards recommend a maximum air infiltration for new build and conversions of 10m³/h.m² @ 50 Pa.)

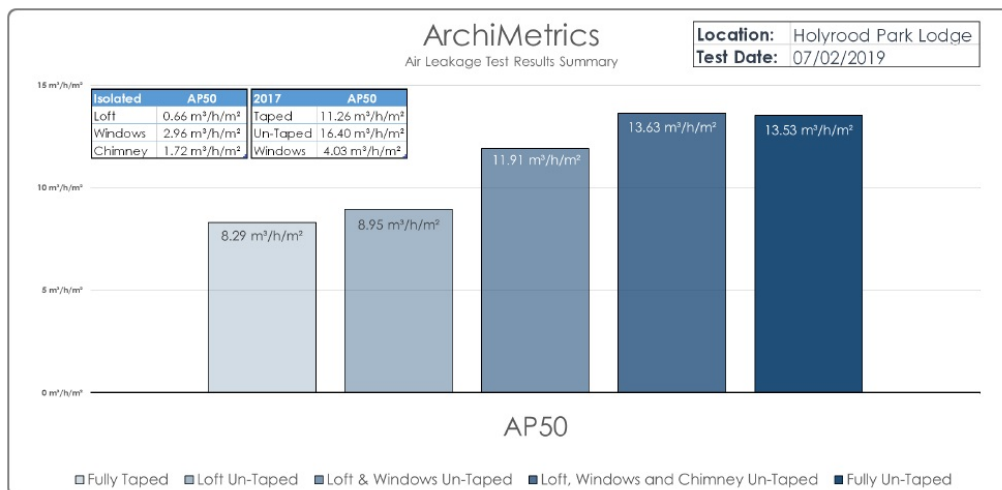


Figure 35. The air pressure test results from February 2019.

11.5 Infrared thermography

As part of the post-intervention assessment, the monitoring team carried out an extensive survey of the building with an IR camera. Overall, the results showed an improvement in the heat retention of the building fabric, but as the building was now properly heated, some areas show more heat loss than before (this is especially noticeable in the corner of the shop by the back door); however, there was a clear improvement in the glazing. Figure 36 shows two of the thermograms where these differences can be clearly seen. A full report on the pre- and post-intervention will be published separately as a HES Technical Paper.

EXTERNAL PRE-REFURBISHMENT					
Date	Time	External Air T	Internal Air T	Wind Speed	Conditions
24 th January	8.20 – 9.05 am	9 °C	18 °C	2.0 m/s	Dry
EXTERNAL POST-REFURBISHMENT					
Date	Time	External Air T	Internal Air T	Wind Speed	Conditions
7 th February	8.45 – 9.25 am	4 °C	15 -20 °C	1.0 m/s	Dry

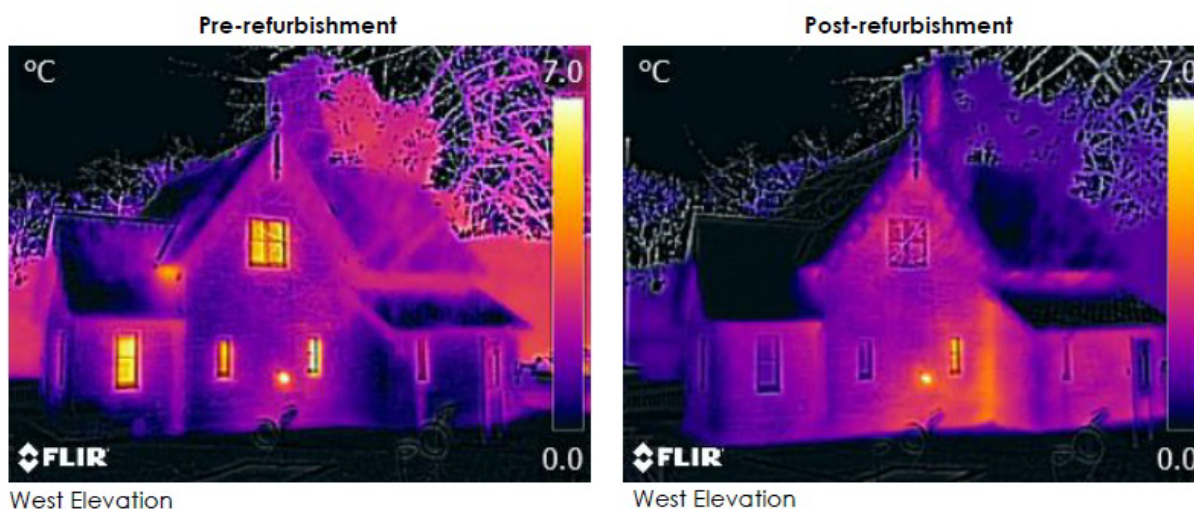


Figure 36. Thermograms of the Lodge pre- and post-refurbishment. There is a clear improvement in the glazing performance.

12. THE ENERGY PERFORMANCE CERTIFICATE (EPC)

12.1 Pre-intervention EPC

An important part of the project was to investigate how the improvement measures affected the EPC rating. Some measures used do not feature directly on the options available in the drop-down menus for EPCs, and this obliges the assessors to make assumptions on the level of detail they put in for the building. This will affect the SAP (Standard Assessment Procedure) score, and therefore the EPC band for the property. In order to better understand the assessment process, an EPC Assessor was commissioned to produce three versions of an EPC for Holyrood Park Lodge. For this, Rd SAP Version 11 was used, released in Sept 2019. The first task was to establish what EPC rating the lodge would have had before the works. This assessment gave the lodge a SAP score or rating of 35, putting the building in Band F of the EPC scale. This poor result is not unexpected and clearly shows the effects on the rating from an absence of insulation in a solid wall property.

An EPC will also give a set of recommendations where improvement can be made. In this case, the three recommended improvements for the Lodge prior to the works, generated by the software, were: floor insulation, coom ceiling and roof insulation, and suspended timber floor insulation. As can be seen from this study, most of these measures were possible for the lodge and were delivered as part of the refurbishment. Additional work was also done, but this did not include floor and roof insulation to the entrance hall.

12.2 Post-intervention EPC

With the works completed, a post-intervention EPC assessment was carried out by the same assessor. This followed all existing Rd SAP conventions and was supplemented by documented evidence on insulation added to parts of the building that would not normally be visible. In this case, the product information on the installed measures, which were retained as part of the Health and Safety File (a requirement of the CDM regulations), were invaluable. The file was handed over to the EPC Assessor, who was able to ascribe the right values to insulation thickness etc. The 'extended data' entry options were selected for the room in the roof data entry. Specifically, this consisted of careful measuring of all the components of the room in the roof: the 'flat ceiling' above, the 'vertical walls', the sloping ceilings of the cooms and the gable walls. It also accounted for all known thicknesses of insulation from the recent refurbishment. Details on the boiler, the heating controls, hot water provision, secondary heating and lighting were also included. The details of the double glazing were entered, as well as chimney details. This new EPC assessment gave a SAP rating of 63, the upper part of EPC Band D (Figure 37). While not ideal, this is a good score for a 19th century building. With

further work, the EPC predicted that a score of 77, the upper part of Band C, could be achieved.

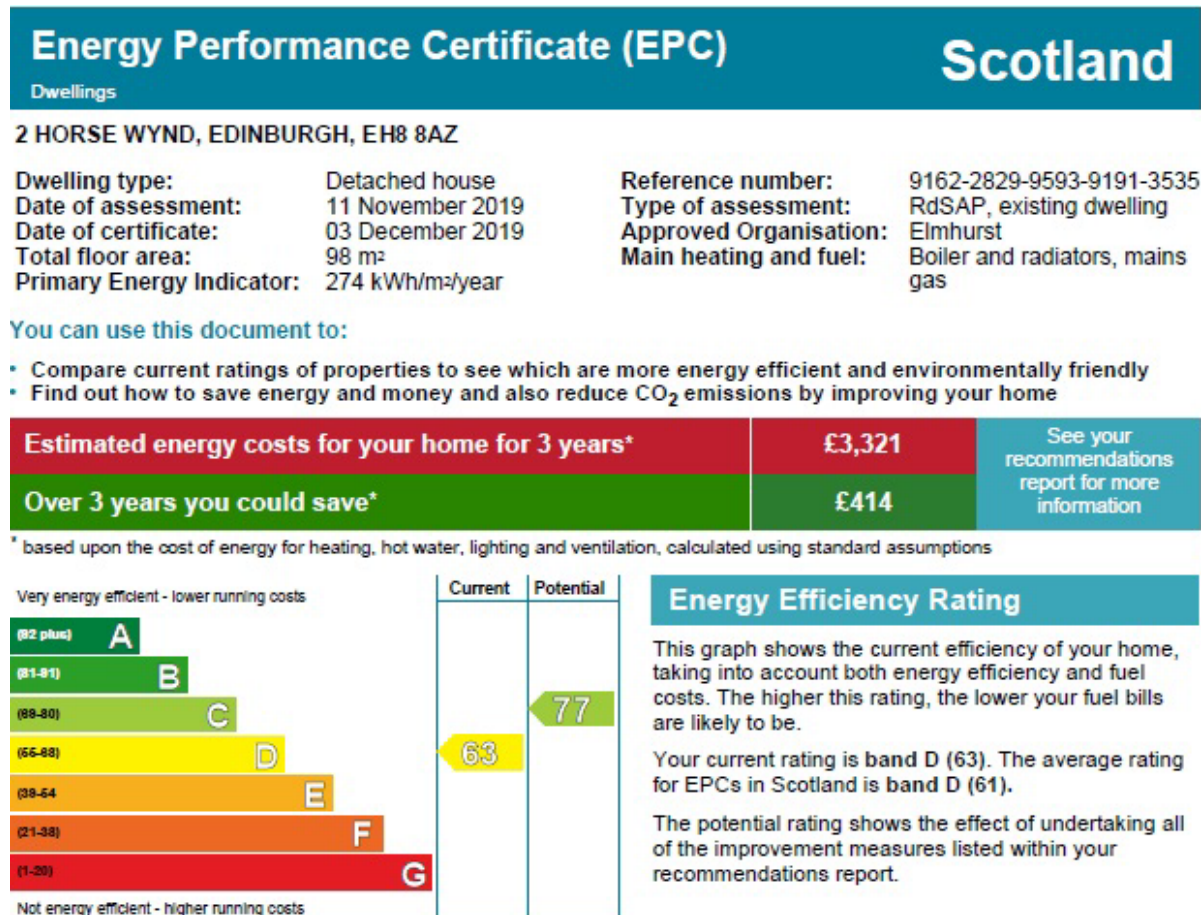


Figure 37. The EPC for the Lodge post refurbishment.

While the score of 63 is a respectable improvement, there were a few details of the refurbishment that would have increased the SAP score into Band C at only modest cost. These were:

- The fixed infrared heating panels were hard wired in; this made it a secondary heating source according to the methodology, which lost 5 SAP points. These points could be regained by making the heaters portable in SAP terms, powered by a plug and fully movable.
- There is no damper in the inset in the hearth in the meeting room. If one was fitted, SAP would recognise the reduced heat loss which would result in an additional 1 point.

These two measures combined would have given a SAP score of 69; an improvement of 6 points and within Band C of the SAP scale. (To note here, that the inset damper for the hearth was indeed reinstated at a later stage, giving the additional SAP point.) That a Category 'B' Listed Building with solid walls can achieve this, is a very positive development and especially given the fact that it could be achieved with minimal effect on

the building fabric and its authenticity. Figure 38 shows the graphic of the EPC, if these details had been attended to:

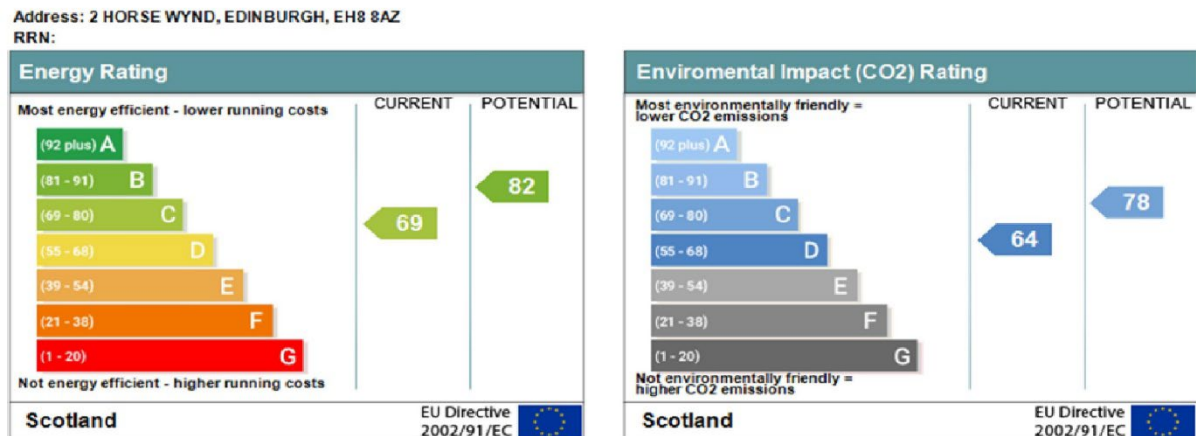


Figure 38. Further Rd SAP score improvements at the Lodge, giving a score of 69.

The Post-Intervention EPC also gave some further improvement options for the fabric: zoned heating controls, solar thermal hot water, additional or thicker insulation in the cooms, and solar PV panels. These measures would give another 14 points, taking the SAP score to 83, the lower part of Band B. This shows the benefits of renewables in taking existing buildings to the upper levels of the EPC bands. Solar thermal and solar PV are both entirely possible at the lodge and may be investigated as part of a later phase. These additional measures would bring the building to compliance with the Energy Efficiency Standards for Social Housing (EESH) due to be brought in by Scottish Government in 2032, when all homes should be Band B where technically and economically feasible.

12.3 A standard EPC

While the EPC results for the lodge were encouraging, it should be noted that here the EPC was generated through the careful use of the Rd SAP software and known details of the improvement measures. This takes time and the cost for the assessment for the Lodge was £450.00. Many EPCs done for traditional buildings are carried out by assessors who may have less time, lower budget and fewer building details; such EPCs are done for less than £100.00. They are only able to enter information on 'things the assessor can see'. To get a feel for how the lodge would be rated, if a simplified non-invasive survey with no product information supplied was done, a further EPC assessment was carried out, which could be called 'worst case'. This assessment gave an Rd SAP Score of 48, an EPC Band E and a reduction of 15 points. This shows that where extensive work has been done to a property, possibly by a previous owner, a more comprehensive survey is needed to ensure the best SAP score is obtained. Many owners comment that they have spent a significant amount of money on the refurbishment of a traditional cottage and there has been only a modest improvement to the EPC Band. This may be, in part, due to an over

hasty EPC. In addition, the dominant factor in an EPC rating for a domestic property is the fuel type.

12.4 Further options for SAP assessment

The EPC uses what is called 'simplified assessment procedure', where a series of assumptions as to building systems, geometry and use are made. The Energy Saving Trust (EST), under their remit to provide energy savings advice to the public, had developed additional software to better model certain types of building. To progress building assessment on older buildings within the SAP protocols, HES worked with EST to refine this variant of the EPC software to work better with older buildings. This mainly included more refurbishment options, and an adjustment of the outputs to only include measures that were technically suitable for the pre-1919 housing stock. The work at the lodge will be used as an example for what might be termed an 'enhanced SAP assessment'. This is planned for Autumn 2020.

13. CONCLUSION

The works at Holyrood Park Lodge have shown that a traditionally constructed listed building can be thermally upgraded in a sensitive and proportionate way, improving its performance, yet respecting the existing historic fabric. During this work, the opportunity was taken to reinstate lost period detail which enhances the building's character and significance. As it is an accessible site, it has been effective in allowing people to view the measures and understand what can be done in other traditional buildings. Traditional approaches to ventilation have been successful, and the building is still warm and comfortable. Extensive building fabric monitoring has been carried out, supporting the results of earlier work by HES on traditional building performance, that careful intervention does not increase hygrothermal risk. This monitoring has shown that there may not always be a necessity for air gaps at insulation junctions, in this context, and there is better understanding on the parameters of fitting roof insulation. The solid wall insulation has proved to be durable and effective, with no significant impact on the hygrothermal performance of the masonry walls post-insulation. This template of refurbishment or selection of measures may be adopted to many other traditional buildings of this type, to bring them up to the standards required under legislation.

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INFORM GUIDES

Our INFORM Guides series provides an overview of a range of topics relating to traditional skills and materials, building defects and the conservation and repair of traditional buildings. The series has over 50 titles covering topics such as: ventilation in traditional houses, maintaining sash and case windows, domestic chimneys and flues, damp causes and solutions improving energy efficiency in traditional buildings, and biological growth on masonry.

All the INFORM Guides are free to download and available from the HES website www.historicenvironment.scot/inform-guides

SHORT GUIDES

Our Short Guides are aimed at practitioners and professionals, but may also be of interest to contractors, home owners and students. The series provides advice on a range of topics relating to traditional buildings and skills.

All the Short Guides are free to download and available from the HES website www.historicenvironment.scot/short-guides

THE ENGINE SHED

The Engine Shed is Scotland's building conservation centre. Run by Historic Environment Scotland, it is a hub for everyone to engage with their built heritage. We offer training and education in traditional buildings, materials and skills. For more information, please see our website at www.engineshed.scot



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Historic Environment Scotland is the lead public body established to investigate, care for and promote Scotland's historic environment.

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