Refurbishment Case Study 19

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

# Trial Church Heating: Radiant Panels and Air Source Heat Pump at Kilmelford Church

This case study is published by Historic Environment Scotland, the lead body for the country's historic environment.

This publication is a web publication and is available for free download from the Historic Environment Scotland website:

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This publication should be quoted as:
Historic Environment Scotland
Refurbishment Case Study 19

ISBN 978-1-84917-207-3

## Foreword by Historic Scotland

This case study describes a pilot project on church heating commissioned and managed by the Kilninver and Kilmelford Kirk Session, supported by Historic Scotland. The heating of places of worship has often been a financial burden for all denominations for much of the recent past. While high temperatures are not necessary for the wellbeing of building fabric, warmth and comfort for worshippers is an important consideration, and in this case low temperatures, and resulting discomfort, was an important factor in the on-going usability of the building. This project demonstrates a successful upgrade using largely new technologies.

The heating improvements described here must be seen in the context of an on-going long term process of continual maintenance and fabric repair to the church, without which work on the heating would have been much less cost effective and possibly even pointless. Water ingress, leading to damp masonry, will make any building feel cold, even with adequate heating. Fabric repair work, which commenced many years before the heating upgrade, was an important part of the success of the project. Poor condition of building fabric is not limited to this building; as parts of Scotland become wetter, poorly maintained fabric will fail more quickly and internal conditions will degrade. This church, located in an area of increased precipitation, is handling more water than it did when built, and thus the fabric repairs between 2008 and 2010 were especially timely. Moving forward from sound fabric, and then to building services upgrade was the appropriate step.

The heating options tested in this study progress work started by Historic Scotland on using radiant heat in a domestic context (Technical Paper 14), to heat the contents and linings of a structure with radiant heat as opposed to the air itself. This study on the Church at Kilmelford also shows that combinations of measures may be the most effective when heating buildings of this type. Not only are there tangible improvements in thermal comfort for users and the building fabric; the improvements have generated optimism and hope for the future of this important community asset.

## Project partners

Thanks to The Kilninver and Kilmelford Kirk Session, The Church of Scotland, Andrew McOwan Associates and Hot Heating in Glasgow.

Church of Scotland

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## 1. Introduction

The works described in this case study are largely the end-stage of a programme of repairs that has been long in progress. Problems with building fabric, damp and water ingress prompted a scheme of repairs and work to improve the fabric and interior of the church beginning over 10 years ago and led by the Fabric Convenor. There had been endemic water ingress and damp conditions for many years and repairs were urgent. The work was approached in a logical planned way, starting with repairs to the roof, pointing, masonry and the leaded windows. Some of the defects exhibited were a symptom of the use of the wrong materials, with cement pointing contributing to a wet west gable and other masonry areas. These fabric works were the correct starting point in addressing internal thermal comfort; heating improvements, the subject of this study, were rightly left until the walls were dry. The fabric works were successful, and internal conditions improved considerably. However, dry walls alone do not make warm parishioners and 2013 saw church funds, with support from Historic Scotland, reach a sufficient level to investigate new heating options. Plans for increased use of the church in addition to the regular Sunday services also relied on being able to provide a reasonable level of thermal comfort in the building. Rural places of worship in Scotland face a number of challenges, and the fabric and heating work undertaken in this building play and important part in the wider plans designed to give the property a future as an asset to the community.

## 2. The site

Kilmelford Church sits on an early site; its present form is a small rectangular plan church largely built in 1785 and renovated in 1890 by the local Heritors (Fig. 1). The wall construction is whinstone rubble with sandstone dressings; the roof is a pitched slate roof of west highland slate. A small vestry wing opens to the south. Elements of earlier masonry work are visible in the east gable showing traces of an earlier building. The church is lit by two lancet windows on each side of the nave and two at the east and west ends, with a high level wheel window on the west gable. With the exception of a few memorials, the internal walls are plain. The building is Category 'C' listed.

Fig. 1: *Kilmelford Church viewed from the West; the lime mortar repairs to this elevation were an important first stage in the building upgrade*

Original stained and shellac finished pews line the nave and a mezzanine floor at the West end gives additional seating. The existing heating consisted of a series of 'greenhouse heater' type electric tubes located under each pew, supplemented by four wall mounted domestic electric convectors. These did not give out sufficient heat for services, and proved expensive to run, not least because the inadequate capacity of the system required long periods of pre-heating. As a consequence the inside of the church always felt damp and rarely warm. A significant factor in the poor thermal comfort is the exposed location of the church (the prevailing wind from the south west brings damp air off the sea 700 metres away), and the position of the main entrance on the west gable, gives rise to significant draughts and loss of heat when parishioners enter and leave the building.

Water ingress to the west gable had progressively become worse since the 1970s. Various repairs had been attempted, with extensive use of cement that occasionally gave temporary respite, but ultimately resulted in progressive saturation of the masonry and wall core. This gable, and other areas of the walls were re-pointed in a lime mortar in 2009 (Fig. 2), and works to the roof and some stone repairs resulted in an improvement to the internal conditions as the walls dried out. Although the masonry works of 2009 had assisted in reducing water ingress, de-humidifiers were still needed.

Fig. 2: *Detail of the lime pointing on the west gable; this resulted in much drier masonry*

Other works to the fabric carried out in the post-war period had compromised the ability of the fabric to disperse any water ingress. In addition to the cement described above, the use of oil based paints on plaster, the blocking of the vestry chimney, and poor repairs to the cast iron rain water goods, had resulted in a building that was struggling in the conditions of increased rainfall. The importance of using the correct materials in traditional building repair must be emphasised; it was the correct technical treatment of the masonry that gave the firm base from which to progress to the next stage. Many repairs sought to disguise problems rather than address the cause, and increased rainfall levels in the recent decades has only exaggerated the shortcoming of incorrect repairs.

## 3. Project objectives

The two partners in the project, The Kirk Session and Historic Scotland, were seeking to deliver a pilot that achieved the following:

- Establish and understand existing electricity consumption
- Design and assess the effectiveness of a new radiant heating system
- Procure and install such a system and evaluate its effectiveness
- Develop options for background low level heating suitable for the fabric
- Reconfigure the electricity distribution to accommodate future needs

- Document the process in a refurbishment case study to disseminate the project findings

## 4. Reviewing the heating of the church

Long established dissatisfaction with the existing heating system led the congregation mandated Fabric Convenor to investigate alternative options. Dialogue with Historic Scotland confirmed the project objectives and established an aspiration to investigate the use of radiant heat as the sole means of delivering thermal comfort and low level background heating. This has been used for some time to heat larger spaces and many churches in Scotland are heated in this way. While all congregations are different, some have found this option cost effective. For example, Hobkirk Church in the Scottish Borders (Fig. 3) has used radiant heat for some time; annual heating costs are in the region of £1,500 per annum.

Fig. 3: *Hobkirk Church in the Scottish Borders is heated by radiant panels at cornice level*

The principle of delivering thermal comfort with radiant heat is that the infra-red beam from the heater warms the objects it illuminates rather than the air in between. This is of benefit in buildings where air tightness is harder to achieve, and as the heat gradients between the inside and the outside are lower, the conduction losses through the building fabric are less pronounced. While there was an aspiration to increase use of the church, it was accepted that usage would be variable and likely to be in the region of three days per week. Therefore the fact that radiant heat is effective when used intermittently was also a benefit in these circumstances.

To assist the church in developing options for the trial, an M&E engineer was appointed by the Kirk Session to investigate and present heating options. The careful oversight of the project by the M&E engineer gave an important level of technical input to options, and assurance to the selected measures. It also allowed pre- and post-intervention energy use to be established. After much consideration within the church, a range of radiant heating devices were selected for trial, and samples were obtained in September 2013. During the winter of 2013/2014 parishioners were given the opportunity to experience the different devices. These were: heated seat and seat back cushions trialled on a single pew, radiant panel heater in front of a pew, radiant panel heater mounted under the mezzanine soffit, long wave radiant heaters mounted at high level in the chancel and a low level wall mounted radiant heater in the chancel.

At this time, it was judged by the engineer that this intermittent radiant heating would not supply the low level background heating needed when the church was not in use, and thus not address the need to keep the air reasonably dry. Additional alternative heating measures were considered, and investigations were progressed into the use of an Air Source Heat Pump (ASHP) to give low level heat (16°C) for short periods each day. The radiant heating would then be used to raise temperature or thermal comfort levels during occupied periods only. In some parts of Scotland ASHP's have had a mixed reception, but it was concluded that such systems would be suitable for areas with a relatively mild maritime climate such as Argyll. In addition there was an aspiration to add some form of micro generation to offset the electrical load of the radiant panels and the ASHP.

By the spring of 2014 selections for the radiant panels were completed, and the electrical load for this and the requirements of an ASHP were established. This combined load, and an aspiration to utilise solar panels at some point in the future, obliged the re-configuration of the incoming electrical supply and renewal of the main distribution board in the vestry. This not only improved facilities for micro generation to be fed into the board, but also allowed absolute confidence in the electrical services.

The selected radiant sources were two wallhead level panels mounted on the timber at the base of the roof (Fig. 4), radiant panels mounted on the back of the front ten pews (Fig. 5), and radiant panels mounted on the underside of the mezzanine layer (Fig. 6). The heated cushions on the pews were not selected as worshippers simply became too hot, and the low level wall mounted radiant heater in the chancel was judged to be ineffective. The radiant heating panels were designed and supplied by

Hot Heating in Glasgow. Competitive tenders other aspects of the project works were issued to local electrical contractors. The radiant heaters, air source heat pump, and electrical distribution changes were installed over the summer of 2014.

Fig. 4: *The radiant panels visible middle right, just above wallhead level*

Fig. 5: *The new pew backed radiant panels*

Fig. 6: *The radiant panels underneath the mezzanine layer*

An Oban based electrical contractor with the supplier of the heaters to ensure that the church had a local contact. The siting of the ASHP indoor fan unit was discussed, and a compromise was reached. It was placed at the top of the stairs, with the aim of providing a good air recirculation path up the small spiral staircase (Fig. 7). The pipes and cables were routed under the floor of the mezzanine layer.

Fig. 7: *The fan unit fitted above the mezzanine stairs*

The external unit was located on the NW corner of the church where it was felt to be the least visible place (Fig. 8). The installation, testing and commissioning of all the devices was completed early in September 2014.

Fig. 8: *The external fan unit of the ASHP on the NW corner of the church*

## 5. Commissioning and system management

The heating installation included new automatic controls and these were set so that the radiant panels and high level radiant heaters are switched on automatically one hour before any church event. The ASHP was set to operate automatically for two hours each morning, with the objective of keeping the church interior at about 16°C. While in itself that is a modest temperature, additional heat was easily provided by the radiant heaters, and without this 'pre-warming' from the ASHP it is unlikely that the radiant heaters would have given the required levels of thermal comfort during services and events.

The original convective heating installation was also retained for use during church services with the tubular heaters assisting to combat draughts by providing low level even heat, rising across the floor area of the main worship space.

The improvement in the average temperature in the church was obvious and most parishioners were pleased with the results of the trial.  The panels mounted on the underside of the mezzanine floor proved to be very effective in conveying a sense of welcome to the property, experienced immediately on entering through the front door.

However, system management is important. The success or failure of the improvements will only work if those operating the systems have a full knowledge of all of them and how to control them. For optimum results with the Kilmelford installation there needs to be an understanding that the behind the pews infra-red panels, overhead infra-red panels, convector heaters, the legacy 'green house' heaters and the air conditioning unit can be controlled separately.  Judging the correct amount of heat required before services, to augment the background warmth from the ASHP, is still a learning journey for the Church. It cannot either be 'all on or all off'.  In the summer, it is probably sufficient for the pew radiant panels to work in addition with the programmed timings for the ASHP.  In the winter timings for the ASHP may need to be changed, and the overhead infra-red panels used. Regardless of weather conditions, the continued background warmth provided by the ASHP is important, and must be maintained; it might not save to switch it all off.  For example, while the Fabric Convenor was away in early 2015, one parishioner switched off all the electrical supplies from the breaker switch "to be sure" and as a result the ASHP did not function for a two week period.  The re-warming of the interior after the reconnection of the electrical supply took several days.

## 6. Costs of the work

The costs of the project are summarised in Table 1:

| Item | Cost | VAT | Total |
|---|---|---|---|
| | £ | £ | £ |
| Professional Fees including Building Warrant | 4,850.00 | 970.00 | 5,820.00 |
| Sample radiant panels for trials | 700.00 | 100.00 | 800.00 |
| Supply, installation, testing and commissioning of new high level radiant strip heaters in chancel including power supplies | 1,896.00 | 0.00 | 1,896.00 |
| Removal of redundant electrical installations and general builders work | 248.00 | 50.00 | 298.00 |
| Power supplies to new radiant heaters to backs of pews and mezzanine soffit | 1,444.00 | 289.00 | 1,733.00 |
| Supply, installation, testing and | | | |

| | | | |
|---|---|---|---|
| commissioning of new radiant heaters to backs of pews and mezzanine soffit | 7,613.00 | 1,523.00 | 9,136.00 |
| Power supply to split system heat pump (ASHP) | 229.00 | 46.00 | 275.00 |
| Supply, installation, testing and commissioning of split system heat pump (ASHP) | 3,955.00 | 791.00 | 4,746.00 |
| New distribution board and isolator switch including connection of existing and new circuits | 1,219.00 | 244.00 | 1,463.00 |
| New time controls, contactors and thermostat | 398.00 | 80.00 | 478.00 |
| Upgrading incoming supply and new meter | 1,001.00 | 200.00 | 1,201.00 |
| Builders work for new incoming power supply | 550.00 | 110.00 | 660.00 |
| As fitted drawings and O&M manuals | 194.00 | 39.00 | 233.00 |
| Testing | 323.00 | 65.00 | 388.00 |
| **Total** | **24,620.00** | **4,507.00** | **29,127.00** |

Table 1: *Costs of the work at Kilmelford Church*

Application has been made to the Listed Places of Worship Grant Scheme for the recovery of relevant value added tax. To date £3,504.00 has been recovered, this sum is being used to address comments made by the congregation relating to cold drafts experienced at head height.

## 7. Energy consumption

Energy consumption and fuel bills had been recorded by the Kirk Session and a pre intervention energy consumption baseline was calculated. To allow comparison with post intervention data, and with other churches, this was worked out as kilowatt hours per square metre per year ($kWh/m^2/Y$). In May 2015 the figures were collated and plotted. (Fig. 9)

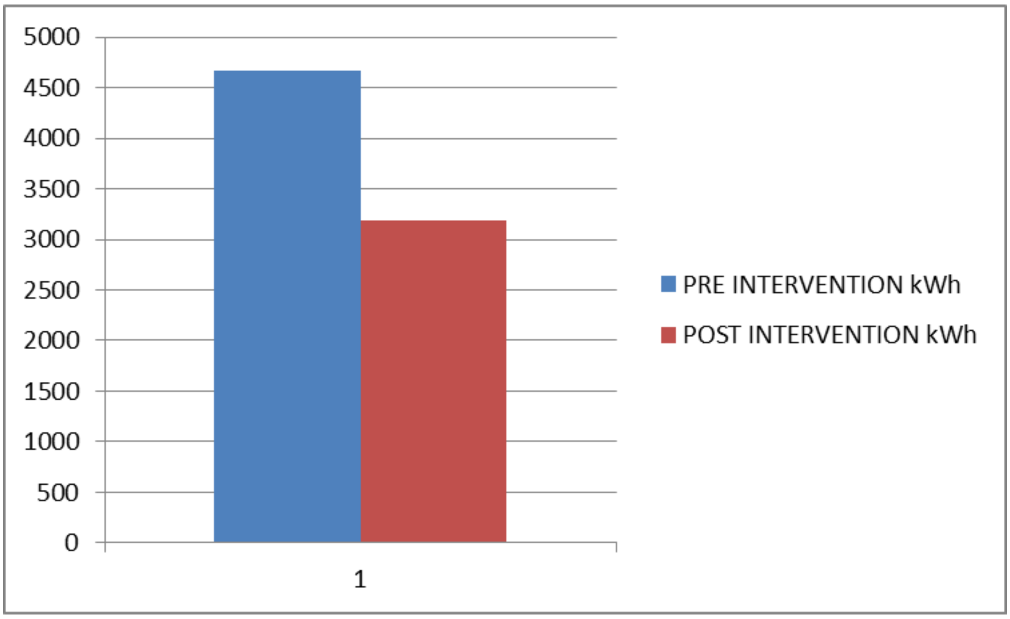


Fig. 9: *Graph showing the pre- and post-intervention energy consumption*

Figure 9 shows that following the intervention, the energy usage of the church has reduced. In the four years before the intervention, energy usage was on average 4674.25 kWh per year, and in the year following the intervention, energy usage was 3185 kWh per year. While more data is required for accurate assessment, initial indications are that the new heating regime has resulted in a saving of approximately £250 per year, whilst also delivering improved thermal comfort and heating to the building fabric.

Compared with the average energy consumption for 16 similar Scottish churches, the post-intervention energy consumption for Kilmelford Church was considerably lower (Fig 10).

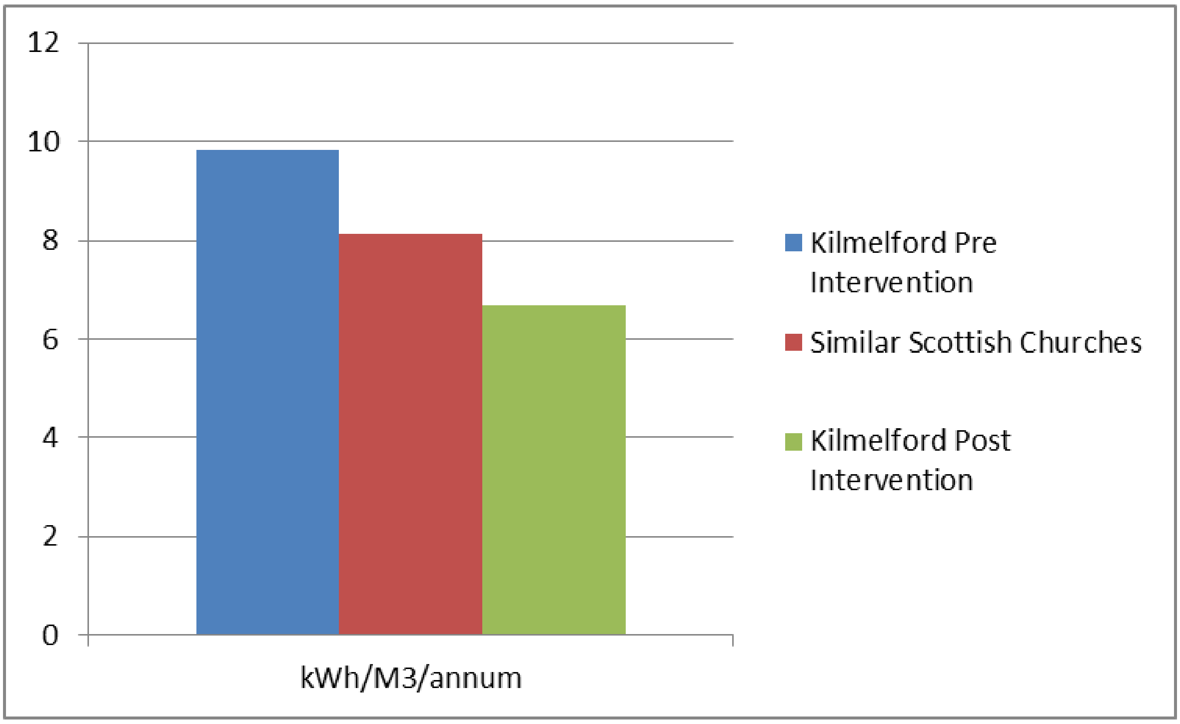


Fig. 10: *Graph showing Kilmelford Church's pre- and post-intervention energy consumption compared with similar Scottish churches*

## 8. Future work

With noticeable benefits in thermal comfort, and reduced bills for the church, the Kirk Session has decided to seek funds to progress the installation of solar panels on the adjacent glebe. A report by the M&E Engineer recommended an installation of 4kW, with an array of 16 panels; a visualisation of this is shown at Figure 11. This would be sufficient to provide electricity for the operation of the ASHP at times when generation levels were above 2.2kW. The surplus generated would be exported to the grid or used to provide some of the power requirements for the radiant heaters when the church is in use. There will be further reductions in electricity costs for the church due to a combination of onsite generation, payments received for exported electricity, and feed in tariff payments of 13.39p/kWh generated.

Fig. 11 *Proposed array of solar panels*

## 9. Other benefits

The modest increase in internal ambient temperature provided by the ASHP means that the internal atmosphere is much drier and more comfortable. The damp smell is entirely gone and the condition of hymn books and other material is much improved. However, the greatest benefit has been to people, and what can be termed the 'improved morale' of the congregation. This has led to greater use by the congregation and the wider community, with musical and other events being held regularly.

## 10. Conclusion

The progressive rehabilitation of Kilmelford Church has been a positive experience for all. It started with a firm understanding of the defects and maintenance requirements of this traditional building back in 2005, and following a period of fabric repairs, consideration was given to improving the building services. The combination of radiant heat and the ASHP has proved to be effective in this building, and has potential for application in other buildings of this type. There have been significant benefits to people and building fabric, and improved perceptions of the church and its future. While the work was costly, the payback times are likely not to be excessive, and possible provision of micro-renewables will bring additional carbon and financial benefits to this rural congregation.

## Further reading


### Historic Scotland Short Guides

Short Guide 1: *Fabric Improvements for Energy Efficiency in Traditional Buildings*, Historic Scotland (2012)

Short Guide 8: *Micro-renewables in the Historic Environment*, Historic Scotland (2014)

### Historical Scotland Technical Papers

Technical Paper 14: *Keeping warm in a cooler house* - *Creating thermal comfort with background heating and local supplementary warmth*, Historic Scotland (2011)

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5 The Pleasance, Edinburgh
*Insulation of coom ceiling, attic space and lightwell*

6 Kildonan, South Uist
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7 Scotstarvit Tower Cottage, Cupar
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8 Garden Bothy, Cumnock
*Upgrades to walls, floors, windows & door*

9 Leighton Library
*Installation of loft insulation*

10 Rothesay
*Installation of insulation and secondary glazing*

11 Newtongrange
*Installation of roof and coom insulation and secondary glazing*

12 Kincardine Castle
*Installation of biomass system*

13 Kirkcudbright
*Conservation works to an 18th century townhouse*

14 Wauchope Mausoleum, Edinburgh
*Interim roofing repairs*

15 Callendar House Stable Block
*Interim repairs to roof, rainwater goods and associated elements*