How can we reduce the energy demands of 1 Brookside, a Grade II listed, uninsulated University building?

Introduction

1 Brookside – the building history

"No. 1 Brookside (Grade II listed) is surely one of the loveliest houses in Cambridge. Before it was purchased in 1947, it had been in private ownership. Under the directorship of Humphrey Gilbert-Carter, it became the administrative hub of the Garden. The Cory Library and the Garden Herbarium, both now in the Sainsbury Laboratory, were also housed here. Built in the Regency style around 1832, during the reign of William IV, the house is south-facing with views over the Garden. It is constructed of gault brick with a handsome Welsh slate roof and has a beautiful two-storey semi-circular bay with a decorative ribbed lead overhang shielding the French windows. During the refurbishment in the early 2000s, the lead was stolen but has fortunately been replaced. In 1986 the house was leased to St Catherine's school for twenty-one years and the offices, Cory Library and the Garden Herbarium were transferred to Cory Lodge. In 2007, under the directorship of John Parker, work began on the conversion of the house. It now houses the offices of the Director, Administration, Communications, Development, Finance and Learning teams, as well as Visitor Services."

(Elizabeth Rushden – Botanic Garden Volunteer Guide)

1 Brookside - The building fabric and services

The building walls are approximately 14” solid gault brick with 9” load-bearing brick partition walls plus a small number of stud walls. It has a timber roof structure with slate tiles and suspended timber floors on the ground, first and attic floor levels. There is a brick arched basement space beneath the Learning Office.

Windows are almost all single-glazed sash windows. There is a double-glazed roof light in the roof facing Bateman Street. Doors are a mixture of solid timber panel, glazed and French.

The building measures approximately 23m x 9.5m, so has a 220m^2 footprint. Over the three floors, offices, meeting rooms and circulation spaces amount to an overall footprint of approximately 480m^2 (ground floor, first floor and attic – basement and loft space excluded).

Over the stairwell there is a single-glazed roof lantern which sits within the loft space.

Decorative roof lantern to stairwell viewed from attic space

The building has a Stelrad Ideal Concord CX gas boiler. The oldest service record noted on the boiler is dated 16 August 2000 - it is unknown when it was installed. The heating system is controlled using a compensation controlled heating system. Offices, staffroom, repro room, meeting room and hallway are heated by radiators. The distribution of radiators in the building appears a little erratic, some with one radiator, others with two or more, and not necessarily consistent with the room’s proportions.

There are no extractor fans in the first floor toilets. The smaller first floor toilet has a metal grille which has been painted open and daylight can be seen through it.

Fireplaces are generally boarded up to varying degrees. It is believed that the chimneys are open – with no chimney cushions or chimney caps (wind can be heard blowing down the chimney from fireplaces).

Fireplace in Admin office

1 Brookside – The building use

The building ground floor is divided into a hallway/reception area and stairwell, an office space used by the Learning Team, a small glazed reception office, a meeting room, two toilets and a shop. On the first floor there are five office spaces, one staffroom/kitchen, two toilets and two small rooms used for printing and filing. Office spaces vary in size and numbers of occupants – for example the Administration Office has six occupants, the Director's and Assistant Director's offices have one occupant.

Staff and visitors arrive at the building generally from Bateman Street, via old, double wooden doors. On the Garden side of the building double glazed doors open from a corridor from the reception area onto Brookside Lawn – this door is used frequently by staff during the day to go between offices and the Garden itself. A further double glazed door provides access to the shop from the Garden.

1 Brookside – Current insulation in place

The only evidence of insulation in the building is to be found in the loft space. Approximately 100mm deep fibreglass insulation has been laid between floor joists across approximately 130m2 in the loft. Most buildings have this low-cost measure in place already - it is essentially a minimum provision and falls far short of the 300-400mm depth recommended by Cambridge City Council, "We recommend an extra 200-300mm, which should be laid at a right angle to the layer of insulation below, to limit gaps forming." [*Retrofitting your Home – September 2022 – Cambridge City Council*]

Uninsulated floor in attic

100mm insulation in the attic

An area of 30m2 in the centre of the loft has no insulation. This area is above offices and the central hallway and stairwell circulation space.

There is no insulation in the rafters – the roofing felt laid under the tiles is clearly visible and there are gaps where daylight can be seen in several places.

The partition wall between the loft and stairwell has been insulated with 100mm Ecotherm insulation board.

An attic office and stairwell space occupies approximately 41m2 of the loft. It's impossible to know what insulation is behind the plasterboard ceiling of these spaces, however we will be optimistic and assume 90mm fibreglass insulation (based upon the rafters being 90mm in depth).

Stakeholders

22 staff work in the building 1 Brookside on a full and part time basis. A small number of volunteers also work here, in addition to occasional visiting staff and students.

1 Brookside is likely to present similar structural features and therefore similar challenges to numerous University of Cambridge buildings and also Cambridge residential buildings. Green Impact members from other Cambridge University museums confirmed that they are occupying similar buildings, dealing with similar temperature challenges.

Staff members who work at 1 Brookside on a regular basis were invited to take part in a survey to obtain their thoughts on their comfort levels in the building and interventions they needed to take. 13 responses were received.

Question 1: I consistently worked in a comfortable temperature during the winter period.

Staff were asked to mark on a scale of 0 to 10 whether they agreed with this statement.

Seven people strongly disagreed (rated 0-2). Four people somewhat disagreed (3-4). One member of staff strongly agreed with this statement (9). One respondent did not answer this question.

92% of staff were not working in a comfortable temperature at 1 Brookside at times during the winter.

Question 2: I consistently worked in a comfortable temperature during the summer period.

Staff were asked to mark on a scale of 0 to 10 whether they agreed with this statement.

Five people strongly disagreed (rated 1-2). Four people somewhat disagreed (3-4). One person neither agreed nor disagreed (5). One person somewhat agreed (7). Two people strongly agreed (8).

75% of staff are not working in a comfortable temperature at 1 Brookside at times during the summer.

Question 3: On colder days this winter, at my desk in 1 Brookside, with no additional equipment (e.g. electric heaters), I was:

Staff were asked to choose between Too cold, cool, comfortable, warm and too warm.

Ten people said they were 'Too cold'. Two people said they were 'Cool'. One person said they were 'Comfortable'.

92% of staff are too cold working at 1 Brookside on colder winter days.

Question 4: On milder days this winter, sitting at my desk in 1 Brookside, with no additional

equipment, I was:

Staff were asked to choose between Too cold, cool, comfortable, warm and too warm.

One person said they were 'Too cold'. Three people said they were 'Cool'. Seven people said they were 'Comfortable'. Two people they were 'Warm'.

54% of staff were comfortable, 31% were too cold or cool, 15% were warm.

Question 5: The radiator(s) in my office function(s) correctly.

Staff were asked to mark on a scale of 0 to 10 whether they agreed to this statement.

Three people strongly disagreed (rated 1-2). Three people somewhat disagreed (3). Four people somewhat agreed (6-7). One person strongly agreed (8).

46% of staff do not feel they have radiators that function correctly.

Question 6: My ability to work was impacted by office temperature during the winter period.

Staff were asked to choose between Yes, No and Maybe.

Three members of staff found their ability to work was impacted by office temperatures.
Four members of staff felt their ability to work was maybe impacted by office temperatures.
Six members of staff did not feel their ability to work was impacted by office temperatures.

54% of staff believe their work was or might have been impacted by office temperatures in winter.

Question 7: My ability to work was impacted by office temperature during the summer period.

Staff were asked to choose between Yes, No and Maybe.

Three members of staff found their ability to work was impacted by office temperatures.
Three members of staff felt their ability to work was maybe impacted by office temperatures.
Seven members of staff did not feel their ability to work was impacted by office temperatures.

46% of staff believe their work was or might have been impacted by office temperatures in summer.

Question 8: What interventions did you use (if any) to maintain a comfortable working environment during the winter period (tick all that apply).

Staff were offered the options: None, Coat, Gillet, Extra jumper, Thermals, Blanket, Hat and/or scarf, Fingerless gloves, Warm socks, Hot drink, Electric/blow heater and Other.

No member of staff selected none. 10 wore an extra jumper, 9 made a hot drink, 7 used an electric heater, 6 wore thermals, fingerless gloves and warm socks, 5 wore a coat, 4 wore a hat and/or scarf, three used a blanket and 1 wore a gillet. On average staff used 4.5 interventions to maintain a comfortable environment in the winter.

Question 9: What interventions did you use (if any) to maintain a comfortable working environment during the summer period (tick all that apply).

Staff were offered the options: None, Electric fan, Water spray, Other

8 used an electric fan, 2 used water spray, 2 no interventions, 1 an insulated cold water bottle. On average all staff used at least 1 intervention to maintain a comfortable environment in the summer.

Question 10: I am concerned about the energy loss at 1 Brookside and the corresponding financial impact on the Botanic Gardens

Staff were asked to mark on a scale of 0 to 10 whether they agreed to this statement.

One person strongly disagreed (rated 2). Two people neither agreed nor disagreed (5). Five people somewhat agreed (6-7), four people strongly agreed (8-9). One person did not respond to this question.

69% of staff are concerned or very concerned about the financial impact of the energy loss at 1 Brookside.

Question 11: I am concerned about the energy loss at 1 Brookside and the corresponding environmental impact

Staff were asked to mark on a scale of 0 to 10 whether they agreed to this statement.

One person strongly disagreed (rated 2). Two people neither agreed nor disagreed (5). Two people somewhat agreed (6-7), seven people strongly agreed (8-10). One person did not respond to this question.

69% of staff are concerned or very concerned about the environmental impact of the energy loss at 1 Brookside.

From this survey, we have discovered that

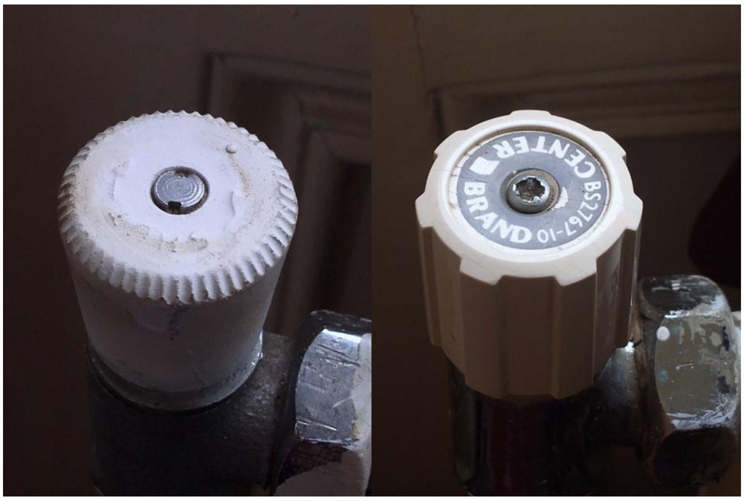
- over 90% of staff were not consistently working in a comfortable temperature during the winter
- on average, people were not consistently working in a comfortable temperature during summer
- staff are concerned about the financial and environmental impact of energy loss in the building (stronger concern was felt for the environmental, rather than the financial, impact)
- staff are using multiple personal interventions to keep warm working in the building in winter
- most people are unable to rely on their radiators functioning well to make their working environment more comfortable
- most people feel their work is being affected by the cold temperatures felt in the office in winter

Project Inception

In a typical year, once the heating has been switched on, it remains on until the spring and milder temperatures allow (this year, it should be noted, the heating was still on as of 5 May 2023).

By 17 October 2022 the heating was switched on in 1 Brookside. On 18 October, the outside temperatures reached 19°C, the heating system appeared to be operating at full steam, the temperature in the building was approximately 24-25°C at 9am, rising to 27°C by the later morning and for the rest of the day. To lower the internal temperatures, windows and (fire) doors were opened and, in some rooms, where radiator valves hadn't seized and could be adjusted, radiators were being turned off.

The Estates Manager attempted to resolve the issue by adjusting the heating system's flow rate, but it was explained that the compensation controlled heating system made it impossible to achieve a long-term satisfactory setting and any adjustments made that day would need to be undone to ensure the building heated sufficiently on colder days.



Examples of seized radiator flow and return valves

With the energy/fuel and climate crises it was felt it should be a priority to bring the building's lack of insulation and antiquated heating system to broader attention. To the CUBG Green Team, it felt just wrong, both from an environmental and a financial viewpoint. A few days later all staff received a timely email from the Pro-Vice Chancellor, calling on staff to set building temperatures to 19°C. This seemed to be a very good idea, however, was it going to be possible, given the building and the heating system we were dealing with?

The idea for this project was conceived.

Data recording

Gas meter readings

Generally gas readings were taken weekly, but where this wasn't possible a reading was taken at the earliest available opportunity.

The first (taken on 13 December 2022) and last (taken on 20 March 2023) gas readings taken for the project

A unit of heat

50 g CO_2e using a solar water-heating panel
244 g CO_2e using a modern (90 per cent efficient) gas boiler[13]
400 g CO_2e using an old, 55 per cent efficient gas boiler
600 g CO_2e from UK grid electricity
1060 g CO_2e from Australian grid electricity

By a 'unit' I mean 1 kilowatt-hour. That is enough to run a 'one-bar' electric fire for 1 hour, or enough to boil about 15 litres of water in an electric kettle.

Extract from Mike Berners Lee - How Bad Are Bananas

In Mike Berners-Lee's book, 'How Bad Are Bananas', he helpfully assesses the impact of a unit of heat. I will assume that we are using an "old, 55 per cent efficient gas boiler" for the purposes of the calculation of gas usage over the winter period – as the Stelrad Ideal Concord CX gas boiler appears to have been installed over 23 years ago.

Over the course of the project (13 December 2022 - 20 March 2023) the building used 3,097 cubic metres of gas, which was used entirely for the heating of the building (the building has no hot water except in the kitchen and this is generated by an electric water heater). This roughly translates into 35,190 kilowatt-hours (using theenergyshop.com's Gas Meter Reading Calculator).

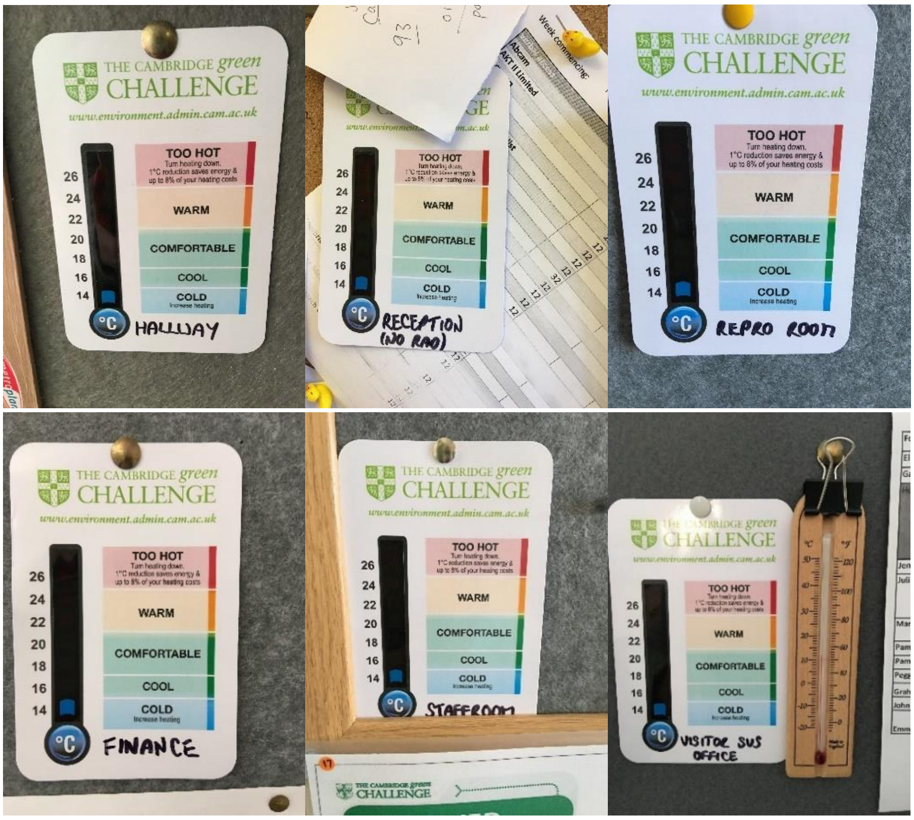
Using Mike Berners Lee's 400g CO_2e calculation, this equates to 14 tonnes of CO_2e emissions for just this one building's heating over the course of the project. It should be noted that this doesn't include CO_2e emissions created by the use of electric heaters on colder days to raise temperatures in many rooms. Using the value of 9.34p as the gas unit price/kWh (britishbusinessenergy.co.uk), this equates to a cost of £3,286 for the gas consumed – this is the cost of gas consumption only, and excludes any additional supplier standing charges.

Were a "modern (90% efficient) gas boiler" installed, Mike Berners Lee's figures suggest an immediate potential reduction of 5½ tonnes could be achieved, reducing the CO_2e emissions to 8.584 tonnes.

If we take an average daily gas consumption for the building, and take the energy consumption back to 17 October 2022 (to 20 March – so a five month period) when the heating was switched on, this increases to 22.5 tonnes of CO_2e emissions, and £5,274 of cost.

With the heating still on at 1 Brookside on 5 May, it would be a shame not to look at these even more complete figures for the building's heating impact, both financial and environmental, over the entire autumn-spring period. It is estimated that 27,634 kg of CO_2e were emitted. The cost for the gas consumed would have been £6,453, based upon the abovementioned assumptions.

Temperature readings



Thermometer readings taken on 16 December when the actual temperature was 11 degrees

"The Cambridge *green* Challenge" liquid crystal themometers were kindly provided by the Sustainability department. These were placed in:

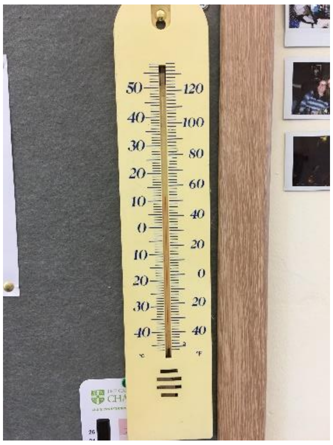
Room	Floor	Occupancy	Radiator	Supplementary heating?
Reception area	Ground	one occupant	None	Electric heater
Hallway	Ground	circulation space	1 radiator	
Learning Team office (plus additional thermometer)	Ground	varies but up to five occupants	2 radiators	Electric heater
Visitor Services office (plus additional thermometer)	First	varies but up to three occupants	1 radiator	Electric heater
Admin office	First	six occupants	3 radiators	
Finance office	First	four occupants	2 radiators	Electric heater
Staffroom/kitchen	First	varies	2 radiators	
Marketing/development office	Attic	varies but up to four occupants	2 radiators	Electric heater

Positioning of thermometers in the building

The thermometers are only able to measure between 14 and 26 degrees which limited our capacity to take measurements when temperatures were outside these limits.

Internal temperatures were recorded daily initially by staff. Some staff members added their own thermometers adjacent to the thermometer cards to provide more accurate readings. Temperatures were recorded in an excel spreadsheet, but it quickly became apparent that, on days with similar weather, the data was very repetitive. Data recording therefore happened weekly or when temperatures dramatically changed, to provide representational data for the building under varying conditions. Extra efforts were also made to record temperatures on unusually cold and mild days to note the building's heating system's response to these temperatures.

It was found that internal temperatures could vary dramatically during the course of a day. Days would frequently start with rooms being cold/cool. The rooms would then reach a comfortable temperature (some offices with just radiators and some offices with additional help from electric heaters) after a number of hours. At this point, rather than the radiators reacting to the comfortable temperatures being reached, they would instead continue to warm the rooms further. By mid-afternoon, rooms frequently became too warm and doors (and also windows occasionally) were opened in order to obtain a comfortable temperature again.



The lowest internal temperature recorded in the building was on 16 December. The internal temperature was 11°C – this was recorded on a thermometer placed by the Learning Team (as the Gambridge *green* Challenge thermometers could not record below 16°C); the external temperature that day ranged between 0.4°C max and -8.4°C min. The image to the left shows this temperature reading. The staff member working in the Learning Office on this day noted: "The day it was absolutely freezing in here and I went home: you just can't even think in temperatures like that, sat down. It's not reasonable to expect staff to work in a coat and with another coat over their knees – especially when they know that at home they have a lovely warm house! The university had not provided me with a laptop so I couldn't work from home (I don't own my own computer). I feel like all the policies such as turning heating on later in the year are made with only a thought of new buildings. Our office is almost double height and if it gets cold it takes forever to warm up. Old buildings need to be constantly warmed at a low level so they don't store cold. I had several days in here where it was so cold I ended up tensing my body for hours which sets off pain from my arthritis."

The minimum workplace temperature noted on the HSE website (https://www.hse.gov.uk/temperature/employer/the-law.htm) is 16°C, or 13 degrees "if much of the work involves rigorous physical effort." As this is an administrative office, the 16°C limit should apply. To be able to continue working in these conditions staff had to wear outdoor clothes, coats, hats, scarves etc.. in order not to freeze.

Staff engagement

Staff working in 1 Brookside were sent a communication at the commencement of the project, providing them with an outline of the project's aims and an excel spreadsheet into which they could input temperature readings. Some staff members added their own thermometers to the thermometer cards to provide more accurate readings.

Readings were taken by staff members from either the liquid crystal thermometers or, where available, their mercury thermometers and entered into the spreadsheet. The Green Team also regularly recorded the room temperatures, and the process of touring the rooms provided an opportunity to engage with staff about the issues they were experiencing: too cold, too hot, radiator controls not working, the number of layers of clothing required to be comfortable etc. These visits also gave the Green Team the opportunity to observe the interest staff were paying to their management of the room temperatures over the winter months.

Staff were also invited to provide additional comments in the shared excel document. Staff interest in the document readings noticeably increased in the colder weather conditions – this is when the mercury thermometers with wider temperature reading capabilities appeared in the offices.

Sharing of best practice was initially to happen via email. However, in the end the communication happened verbally. It was feared communicating via email would have seemed officious and would have given staff a negative relationship with the project. Informal chats were found to be a better way to communicate about alternative ways to try to achieve a comfortable temperature in the office. Best practice solutions included:

- Closing doors to warm rooms up
- opening doors (not windows) on milder days when internal temperatures became too warm
- Radiators were turned on and off by staff as temperatures fluctuated, if the valves could be moved – people interacting with what controls were available

Conversations occurred frequently between staff members about managing building temperatures and difficulty of balancing heat retention with room ventilation and cooling.

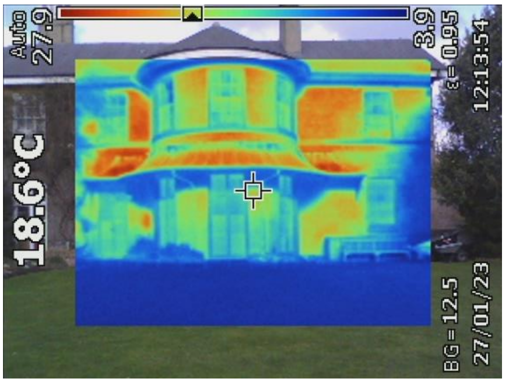
Heating a room to everyone's satisfaction is complicated. Some people want a warmer room, others cooler. People sitting next to radiators are exposed to the direct heat whereas those further away don't benefit from the heat until after it has been circulated through the room over time. People sitting in cold draughts experienced even colder temperatures.

Ventilation became an issue on colder days, as CO_2 levels rose 300% over a few hours. No windows in the building have vents.

Thermal Imaging Camera

The camera borrowed was a Fluke TiR105, loaned by Cambridge Carbon Footprint. The camera has not been recently calibrated so temperatures displayed cannot be relied upon to be exact, but temperature ranges can be. So whilst the maximum and minimum temperatures on the building were read by the camera as 27.9 and 3.9°C, the 26° variation would be correct, whilst the temperatures may not be.

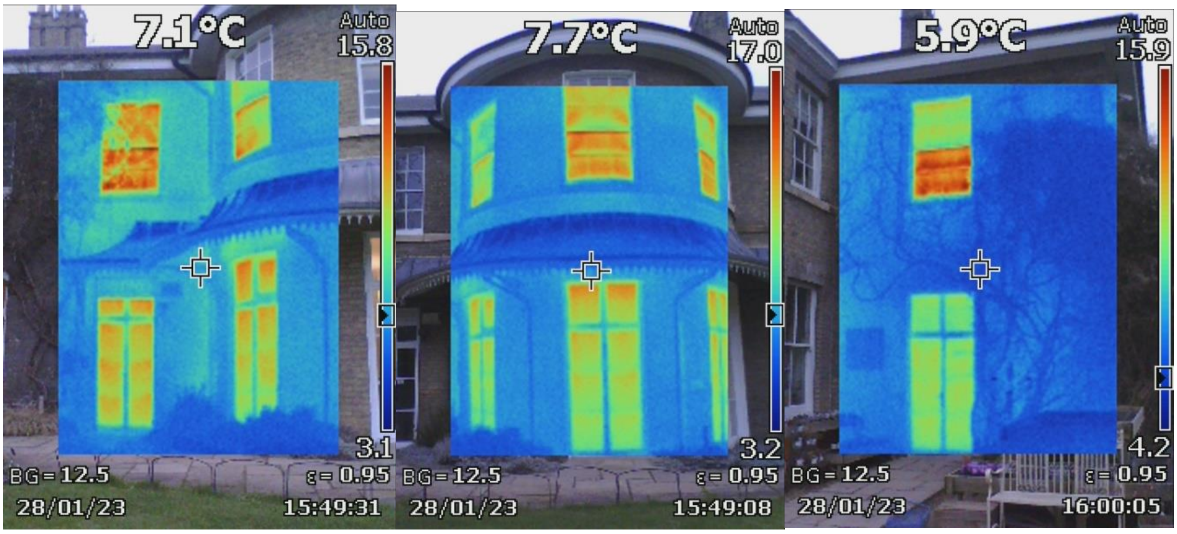
The carmera was borrowed on 27 January, a sunny day. By the time the camera was sufficiently charged the building exterior had warmed significantly in the sunshine, providing images showing



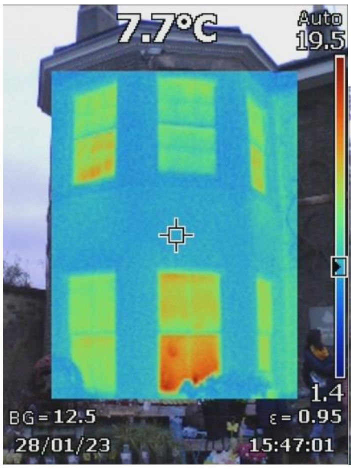
the bricks reaching toasty 27°C temperatures on a relatively cool day of 7.5°C. It was interesting as a perspective on how vulnerable building fabric is to heating in summer heat, exacerbating internal temperatures further. Taking thermal images in office spaces was found to be impractical sadly, due to the interference of hot spots created by electrical equipment, plugs, sockets and lighting.

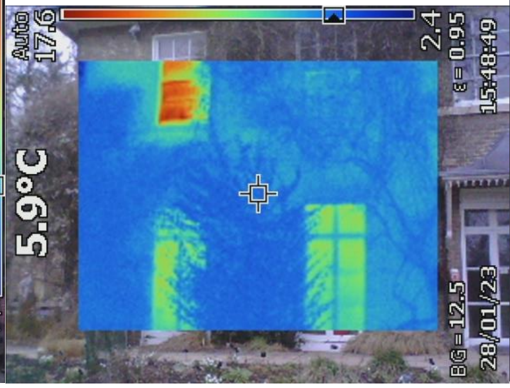
Thankfully Saturday 28 January was cloudy and around 6.5°C, so better images could be collected – images were taken between 3.30-4.30pm. The photos clearly show windows as being the main source of heat loss in the building. In the images taken, you can see hotspots on all windows, where the highest temperatures are recorded. Coldspots may be seen on metal items (gutters and canopy) and should be ignored as metal responds differently to thermal imaging. To a lesser degree, walls are also shown as leaking heat, particularly where radiators are located internally.

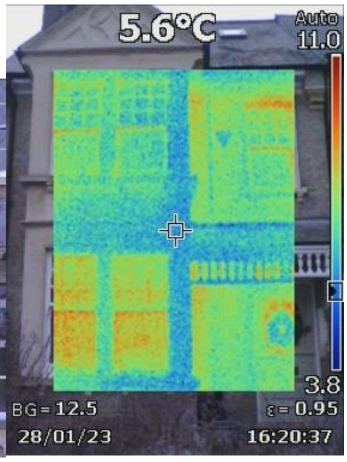
External images taken with a Thermal Imaging Camera show that the biggest cause of heat loss in the building is through its windows. This is through a combination of single-glazing and lack of draught-proofing.



Heat can be seen leaking predominantly through windows, and also to a lesser extent through walls

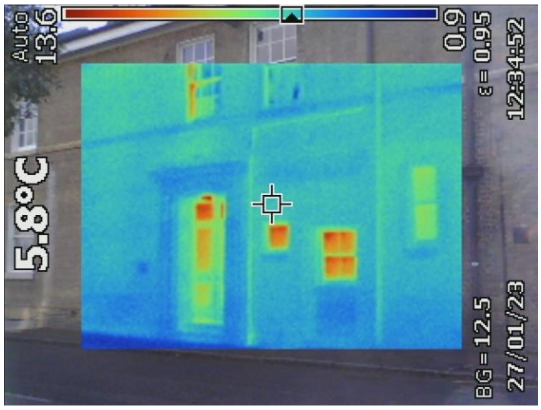




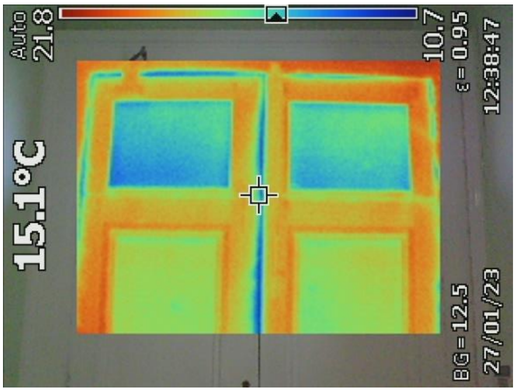


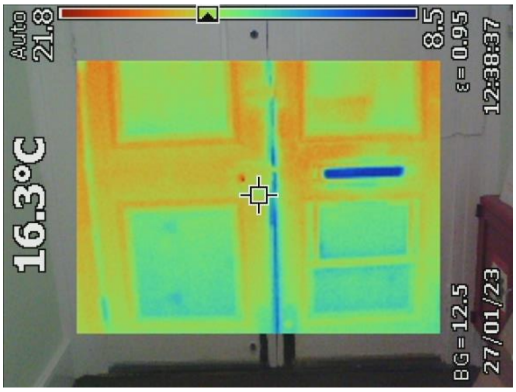
The two left-hand images show 1 Brookside. Here you can see heat escaping through windows and glazed doors, with hot spots shown on the warmest windows. Hotspots are shown as 19.5°C and 17.6°C, with coldspots as 1.4°C and 2.4°C. For contrast, an image on the right shows a house (on same day, similar time, with same camera) with slim double glazing, where the hot spots measure 11°C, and the coldspots 3.8°C.

Again, in this image of the Bateman Street side of the building, you can see heat leaking mostly through windows but also through walls and roof

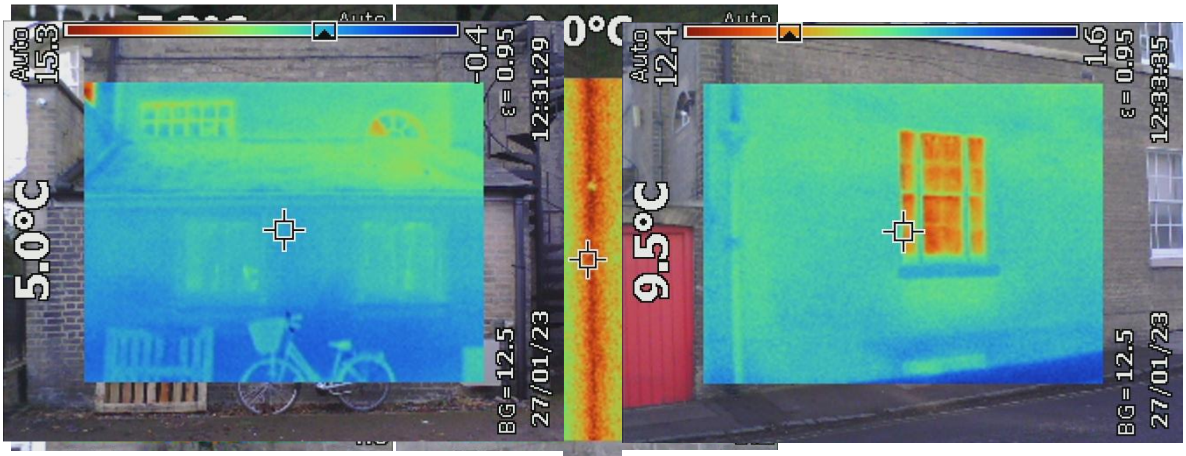


Main entrance from exterior, with heat loss seen through single glazing and wood panelling of door and windows





Internal images of the main entrance doors to 1 Brookside, with single glazing and no draught proofing



This image shows heat loss through the roof and ground

Here heat can be seen leaking at the junctions of the building's wall with the curved bay structure around the ground floor meeting room

This image shows heat escaping from window but also warm spot under the window where a

ed

A cold draught showing under internal (MCB board) cupboard in stairwell

The thermal imaging camera images showed the largest cause of heat loss was through the single-glazed (mainly sash) windows. Due to the scale of the windows heat loss, readings of other heat loss, through walls behind radiators for instance was less distinctive, but nevertheless discernible. There were also significant draughts around doors.

An Anecdotal Story

This from a staff member working in our neighbour building, The Hayloft, located a few yards from 1 Brookside and in a very similar state of repair.

"Having recently had the lead stolen off the roofs in The Hayloft and Brookside, estates brought roofing contractors in to replace the lead and repair the roof. It was found that the wood under the tiles above the Hayloft kitchen was rotten so the roof was replaced. Scaffolding was erected, the roofing contractors dutifully removed the old roof, replaced the wood and started the retiling. But as work progressed, we noticed that the cavity under the roof was completely devoid of any insulation. We naturally assumed insulation would be added towards the end of the build. As it came to completion, we casually asked the contractors if they were going to put insulation in. "Oh no", they replied. "Insulation comes under the remit of the Sustainability Department; we've been contracted by Estates which is separate".

And we watched with dismay as they sealed the roof.

University bureaucracy once again providing layers of red tape to the detriment of our environment."

Retrofit costs compared with financial and environmental savings

Insulation options	Installation cost	Detached house savings £/year	Detached house savings kgCO2/year	Source	Payback in years
Double glazing	£ 22,500.00	£ 585.00	990	energy savings trust	38.46
Loft insulation	£ 1,095.00	£ 483.75	821.25	energy savings trust	2.26
Underfloor insulation	£ 2,900.00	£ 270.00	465	energy savings trust	10.74
Radiator reflector panels	£ 50.00	£ 100.00	200	https://www.thegreenage.co.uk	0.50
Draught proofing	£ 500.00	£ 90.00	180	energy savings trust	5.56

The Energy Savings Trust provides cost estimates for carrying out various energy saving measures on a property. These have been used to provide the above approximate costs for installing double-glazing, loft and underfloor insulation and draught proofing at 1 Brookside. The Energy Savings Trust also estimates the financial and environmental savings per year achieved by installing these measures, together with the number of years it would take to recuperate the costs. The above table shows that loft insulation, draught proofing and radiator reflector panels provide low cost options that achieve a sizeable payback in financial and environmental savings, paying for themselves in 0.5 - 5.6 years.

Insulation of doors and windows

The thermal images taken on 28 January suggest that the double/triple glazing and draught proofing of windows and doors would achieve the biggest reduction in energy loss (and therefore CO_2e emissions) for the building. The Energy Savings Trust also identifies this as the largest financial and environmental saving measure. A 'typical' house would be expected to lose 10% of heat via the windows. Due to their age and absence of draught-proofing, it can reasonably be expected that the windows in 1 Brookside lose more than this. Whilst double glazing is expensive, considering staff discomfort, the expense may be considered to be worth it. Staff sitting close to leaky windows are experiencing constant cold draughts throughout the winter months; these staff are often to be found wearing coats and hats even on milder winter days, when staff sitting in the same room but further from the windows are in t-shirts.

The existing timber windows may not be able to structurally support double glazed units (even slimline ones) meaning new timber windows would need to be constructed at additional cost. Windows and doors around the curved bay section of the building are themselves curved – double-glazed curved units would cost significantly more than standard flat units. Secondary glazing may provide a suitable alternative to double glazing in which case. Cambridge City Council Conservation Officers have indicated that this would be an acceptable measure on listed buildings.

Thermal images also showed cold draughts entering the building via external doors which currently have no draught-proofing and some of which contain single-glazed units. Images also showed cold draughts entering the building via internal cupboard doors which, again, have no draught-proofing.

"Up to a quarter of heat losses can be due to a leaky building. Remedying this could save more energy than fitting new windows, and at a much lower cost." (*Cambridge City Council - Retrofitting your home*).

"Research has shown draught-proofing can reduce air leakage from windows by between 33% and 50%, therefore significantly reducing the heating requirement needed for the room" *(Historic England - Energy Efficiency and Historic Buildings)*

The external door leading to Brookside Lawn is frequently left open – staff often need to carry recycling receptacles and other large items through it – it has no self-closing mechanism. When workmen fitted carpet tiles in the building in January 2023, the door was almost constantly left open by them, despite external temperatures of around 4°C. It's not possible to quantify the energy loss here, but fitting a door-closer could solve this problem and reduce the associated energy loss significantly.

Insulation of loft and underfloor

The installation of insulation across the entire attic space, to the recommended depth of 300-400mm would make a substantial contribution to containing energy within the building. Currently approximately 130m^2 of the roof space is insulated with just 100mm of insulation, leaving 30m^2 with no insulation whatsoever. The space is used for storage so additional batons and boards would be required to raise the level of the floor to provide sufficient depth for the insulation.

The building has an unheated basement, therefore fitting underfloor insulation between the ground floor joists would be relatively simple.

Radiators

Issues with radiator valves were identified in several rooms in the building. The common issue was that the radiator controls had seized, making any adjustment either extremely difficult or impossible. *"Just to confirm that we are unable to turn off/adjust the two radiators in our office. [the Estates Team] have looked at them and were unable to adjust them." Finance office staff member*. Replacement with thermostatic valves would ensure that comfortable temperatures were maintained without the need for intervention from staff members on milder days.

On warmer days, where radiators could be adjusted, the corresponding reduction in temperature of the radiator units was slow – replacement of the radiator units themselves should possibly be considered.

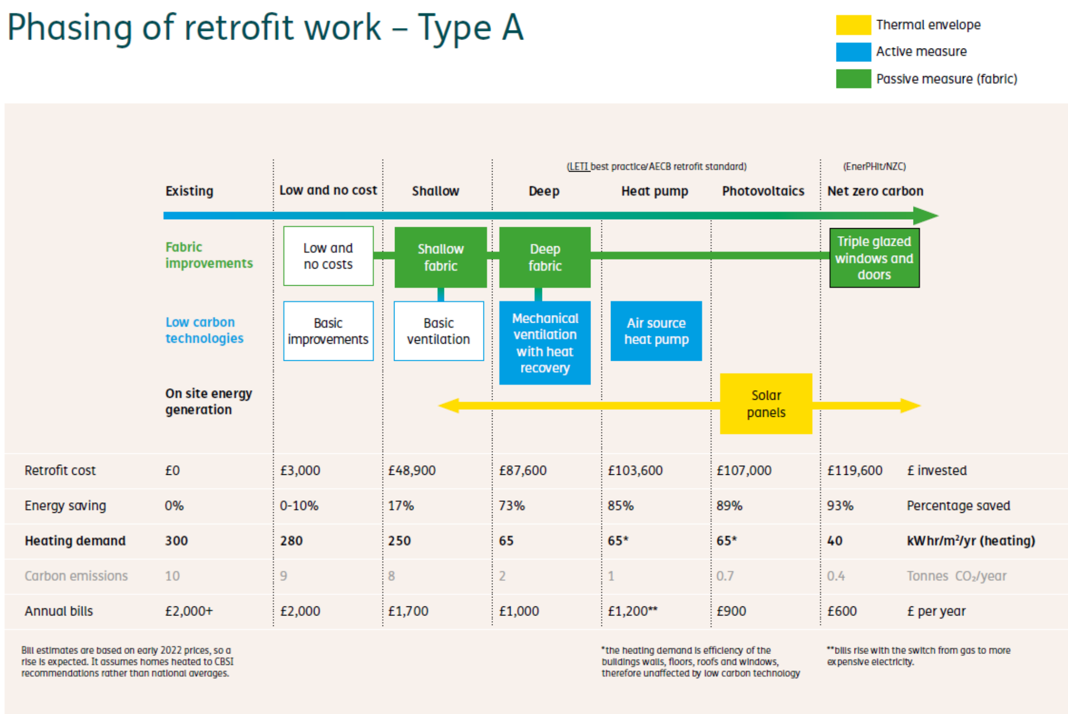
Furthermore, some parts of the building's heating system is on a single loop (daisy-chain style), other parts are set up with the more usual flow and return pipework. This may affect the radiator performance in parts of the building, but to remedy it would require significant upheaval.

Radiator reflector panels are a low cost measure which pay for themselves very quickly and do not need to be installed by a professional.

The Heating System

It's unclear however, once insulation and draught exclusion measures are installed, whether the building's gas consumption would actually decrease, as the heating system does not indicate that it is effectively responding to internal heating needs being met. The building has an outdoor weather compensation-controlled heating system. In mild weather the radiators are nevertheless still hot, even when the room temperatures exceed 24°C. On the afternoon on 30 March, with external temperatures a balmy 19°C, the radiators in 1 Brookside were still pumping out heat as though it was cold outside. This would suggest that the control system is not functioning correctly or efficiently. Were the system commissioned correctly by a professional compensation controlled heating system engineer, there would inevitably be a reduction in energy wastage (e.g. when windows are opened to cool rooms down). It is impossible to quantify how much energy is being lost in this way – through building over-heating, and heat escaping through opened windows. A telephone-directory sized manual is currently provided for our Estates Team to make system adjustments.

Even if all of the above actions were taken, it's likely that, on extremely cold days, the building will not achieve a comfortable temperature due to lack of wall insulation. Nevertheless these numerous retrofit solutions would reduce the building's energy consumption and improve the comfort of the staff working here, enabling it to reach warmer temperature more quickly and efficiently on colder days than it currently manages, which will in turn ensure that staff are more comfortable and their work less likely to be affected by colder weather.



Cambridge City Council - Retrofitting your home

Cambridge City Council have published a document, *Retrofitting your home (September 2022)*, which provides advice to Cambridge residents living in typical Cambridge buildings. 1 Brookside compares closest to the building they label "House type A – Large historical townhouse". The typical size of this house is described as 72m^2 (assuming the residence is a duplex apartment). 1 Brookside's floor space is 480m^2 –for the purpose of translating these costs and using this information for 1 Brookside, we have multiplied the estimate by a factor of 4.

The result looks something like this:

Existing	Low and no cost	Shallow	Deep	Heat pump	Photovoltaics	Net zero carbon
£ -	£ 12,000.00	£195,600.00	£350,400.00	£414,400.00	£ 428,000.00	£ 478,400.00

With the cost and environmental savings looking something like this:

Description	Gas m3	kWhs	kg co2e emissions based upon old inefficient boiler	Gas Consumption Cost	% decrease	kg co2e emissions based upon new efficient boiler	Gas Consumption Cost 2	% decrease 2
Total Usage Oct - May	6080.59	69086	27634	£ 6,452.61	0%	16857	£ 3,936.09	39%
After low cost and shallow measures		57341	22936	£ 5,355.66	17%	13991	£ 3,159.84	49%
After deep measures		18653				4551	£ 1,742.20	84%

Low-cost measures for 1 Brookside - cost estimate £12,000 – 0-10% energy saving

- Correct commissioning of heating system
- Fit low energy lighting and appliances
- Improved heating controls – thermostatic radiator valves
- Fit draught strips to windows and doors
- Draught-seal fireplaces
- Cap chimneys
- Radiator reflector panels
- Self-closing mechanism to Brookside Lawn door
- Seal holes (grille in first floor toilet)

- Extractor fans to toilets

Shallow measures for 1 Brookside – cost estimate £195,600 – 17% energy saving:

- Top-up loft (and, if required, roof) insulation and insulate where currently no loft insulation
- Underfloor insulation (ground floor)
- Demand control ventilation
- Internal wall insulation (considerable upheaval)

A quick recap of our starting point - a current estimated 27.6 tonnes CO_2e emissions and annual cost of £6,452 for gas consumption at 1 Brookside over one winter.

With these low cost and shallow measures, Cambridge Council's Retrofit guide suggests that energy savings could be as much as 17%, so reducing the CO_2e emissions to 22.9 tonnes and annual costs to £5,355.

If a 90% efficient boiler (244g CO_2e emissions per unit of heat) replaced the 55% efficient boiler (400g CO_2e emissions per unit of heat), in addition to the above low cost and shallow measures and their associated 17% energy saving, the CO_2e emissions would be reduced to 14 tonnes and annual costs to £3,160.

Deep measures for 1 Brookside – cost estimate £350,400 – 73% energy saving:

- Double/triple/secondary glazing to windows
- External wall insulation
- Improved performance external doors
- MVHR

With these deep measures, Cambridge Council's Retrofit guide suggests that energy savings could be as much as 73%, and assuming a 90% efficient boiler replaced the 55% efficient one, the CO_2e emissions would be reduced to 4.5 tonnes and annual costs to £1,742.

It suggests it would cost approximately £½ million to make 1 Brookside 'Net Zero'.

Other measures:

- It may be beneficial for the university to stipulate not only maximum temperatures for heating in winter but also minimum temperatures for cooling in summer, not that 1 Brookside enjoys the advantages of air conditioning.
- When any building works are undertaken, all retrofit opportunities presented should be considered as part of the works.
- Sustainability should be elevated to align with or possibly (given the urgency and greater need) supersede building health and safety considerations. As H&S building requirements have been systematically accommodated over the years, the same should be done for retrofit needs.

Conclusion

As Mike Berners-Lee states, "The worst option by far was to do nothing and leave the old house leaking energy like a sieve". In his scenario, which relates to a cottage in Scotland, he looks at the alternative options of knocking the cottage down and starting again, which worked at about 80 tonnes CO_2e based upon the climate change impact over a 100-year period. He goes on "the winning option was to refurbish the old house, because the carbon investment of doing this was just

8 tonnes CO_2e compared with 80 tonnes, and even the highest-specification home could not catch up this advantage over the 100-year period."

The older buildings within the University estate would benefit from prioritisation of retrofitting work and an increase in retrofitting capability among contractors. Unfortunately it appears that these buildings have not received attention in this respect for some years. The scaling up therefore would need to be dramatic, to cope with implementation of all the low-cost options plus some or even all of the medium and high cost options.

Organisations like South Seeds (who make available a team of handymen to the local community in Glasgow to work on old buildings with smaller projects such as draught-proofing) provide an example of the kind of facility the University could initially offer to deal specifically with these needs in the older University buildings over the winter months.

Currently 1 Brookside is an example of "the worst option" though. The consequence of this is that it is leaking energy "like a sieve".

In anticipation of extreme weather in coming years, and with memories of extreme heat and cold experienced in only the past 12 months, the University could set a minimum and maximum safe working temperatures for staff. Opinions differed about what is a "comfortable" temperature. Having the directive from the Pro Vice Chancellor was helpful in creating a target temperature in all rooms, helping deflate disagreements where these may have arisen.

Sustainability needs to be given the same importance as Health and Safety in regard to building projects. Even at 1 Brookside internal doors have been fitted with intumescent strips for health and safety reasons. The same should be the case for external doors and windows being fitted with draught-proofing for sustainability.