Energy Efficiency and Decarbonisation Case Study

Keelmen's Hospital, Newcastle upon Tyne

Foreword

Keelmen's Hospital was designated as a Grade II* listed building in 1954. It has been vacant and disused since 2009, when it was added to Historic England's Heritage at Risk Register.

The project to repair and reuse Keelmen's Hospital started in the summer of 2023, led by the Tyne & Wear Building Preservation Trust, with Newcastle City Council (building owner) and Historic England as main stakeholders. Other funders joined the project at different stages, including the Architectural Heritage Fund, the National Lottery Heritage Fund and the Swire Trust. The project is a great example of how a heritage building can be reused and adapted to help meet today's housing challenge by providing 20 affordable one-bedroom and two-bedroom apartments.

Historic England's involvement was key to securing a positive change and a sustainable future for Keelmen's Hospital. Our development advice at early design stages was essential to shape the project proposals, and our pre-application guidance was instrumental in securing listed building consent approval. We also advised on energy efficiency strategies and low carbon energy proposals to make sure they follow current conservation practice.

Tyne & Wear Building Preservation Trust played a key role as project manager. They led, challenged and encouraged the design team to develop a thoroughly considered project. Fundamentally, they embraced using a whole building approach, focused on extensive investigations at design stage that contributed to streamlining the technical design phase. Securing funding to undertake these initial surveys was crucial in shaping the project and making it deliverable.

This case study focuses on the decision-making process during the design phase of the project. It demonstrates how energy efficiency and decarbonisation goals can be balanced with protecting and enhancing heritage significance while meeting statutory requirements. It shows how:

- energy efficiency interventions and decarbonisation measures in historic buildings require site-specific, exposure-based solutions
- the decision-making process is as valuable as the technical outcomes
- a process-led approach, rather than a performance-led approach, for designing energy efficiency interventions in historic buildings can minimise risks to the building fabric, its occupants and its heritage significance
- combining heritage values with occupant well-being can justify performance compromises
- a transparent options appraisal and decision-making process builds trust with stakeholders and statutory consultees
- building performance evaluation and material testing aid decision-making and budgeting.

We hope this case study helps practitioners, conservation and sustainability specialists, and building owners and managers to understand how instrumental following a whole building approach is in delivering a tailored, quality and successful repair and reuse project.

Historic England

Summary

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Historic England's case studies

Historic England is collating a suite of case studies on energy efficiency, decarbonisation and climate resilience. These case studies are part of an ongoing dialogue on the reuse and adaptation of historic and traditional buildings, as well as on the adaptation of the historic environment to climate change risks. They should not be seen as advice, specifications or recommendations, but rather as unique responses to a particular project. We hope the case studies demonstrate examples of decision-making processes that follow an evidence-led approach to interventions.

Historic England is grateful to all the partners who have been willing to put forward a case study. Please remember, a perfect project does not exist.

If you have a project you think could contribute to this series, please contact us at conservation@historicengland.org.uk

Front cover: Aerial view of Keelmen's Hospital, 2024 © Steve Brocks, Newcastle City Council.

Executive summary

Keelmen's Hospital is a Grade II* listed building in Newcastle upon Tyne, built in 1701 as an almshouse for sick and ageing keelmen and their families.

Vacant and on Historic England's Heritage at Risk Register since 2009, the building is being brought back into use as 20 affordable residential apartments through a partnership between Tyne & Wear Building Preservation Trust and Newcastle City Council, supported by the National Lottery Heritage Fund, Historic England and others.

The project demonstrates how a sensitive, evidence-led approach to energy efficiency and decarbonisation can be applied to a complex historic building, eliminating fossil fuel reliance, improving thermal comfort and achieving an Energy Performance Certificate (EPC)[1] rating of C, all without undue harm to the building's heritage significance.

Key outcomes

- A fossil fuel-free development, with grid and renewable electricity as the sole energy source, delivered through a centralised air source heat pump system.
- Individual apartments targeting an EPC rating of C, aiming to meet potential future Domestic Minimum Energy Efficiency Standards.[2]
- Timber casement windows with standard double glazing, selected after a systematic appraisal optimising thermal and acoustic performance while minimising harm to significance.
- Tailored internal wall insulation, informed by rigorous dynamic hygrothermal simulations and material testing, applied sensitively across different elevations to manage moisture risk without compromising the historic fabric and a healthy indoor environment.
- Solar photovoltaic (PV) panels on inner courtyard roof slopes, chosen for their low visual impact on the wider heritage setting, and to keep energy affordable for residents.
- A design process built on transparency and clear justification, which secured the support of planning and heritage consultees.

Approach

Throughout the project, the design team adopted a rigorous comparative analysis methodology. Rather than applying generic standards or solutions, each intervention was assessed against a carefully defined set of criteria encompassing technical performance, heritage significance, moisture risk, resident well-being, long-term maintenance and cost. This process enabled the team to justify every decision made, and to demonstrate to Historic England, the local conservation officer and the planning authority that the chosen solutions represent the least harmful, most proportionate options available.

Contents

1. Glossary

For ease of reference, definitions of terms, abbreviations and names that are used in the text are included below:

Delphin is the commercial hygrothermal simulation software package used in this project. There are other commercial software packages, such as WUFI®Pro.

Domestic Minimum Energy Efficiency Standards (MEES) Regulations set a minimum energy efficiency EPC rating of E for all domestic private rented properties from April 2020.

Energy Performance Certificates (EPCs) are the government's system for assessing and reporting the energy performance of buildings. For residential buildings, the current headline EPC rating is largely based on the modelled cost of energy use and is shown on an A–G scale.

Glazing bars were introduced in *c.* the 17th century, when glass manufacturing could produce only small glass panes and structural glazing bars were used to create larger window surfaces. The size and profile of original glazing bars can be a good guide to the age of a window, since the glazing bars varied greatly over time as glass technology developed. In this document:

- **true glazing bars** are structural elements that physically separate and hold individual panes of glass in a multi-paned window. Other literature refers to them as 'through glazing bars'.
- **stuck-on or applied glazing bars** are applied to the surface of a single sheet of glass to resemble a multi-paned window. They vary in application method and appearance (for example, they can be bonded or clipped-on).

Hygrothermal simulation software dynamically models how heat and moisture move through building elements over time under changing internal and external environmental conditions (BS EN 15026:2023).

The **keelmen** of Tyne & Wear worked on shallow-draught keels transporting coal from the banks of both rivers to the colliers that sailed to the east end of London.

An **MEP engineer** is responsible for mechanical, electrical and plumbing services.

Standard Assessment Procedure (SAP)[3] is the current government's method for calculating the energy performance of dwellings and obtaining an EPC.

U-value is the measurement of the rate of heat loss through a building element. The lower the U-value, the less heat is lost through that building element. U-values are expressed in W/m^2K.

2. Project overview

Location

Keelmen's Hospital is located to the east of the centre of Newcastle upon Tyne. The building occupies an elevated position north of the River Tyne, sitting between a modern office development and the Grade II listed Salvation Army Men's Palace. Immediately to the rear is the Grade II listed Industrial Worker's Dwellings at Garth Heads.

Figure 1: South-east elevation of Keelmen's Hospital, 1879. © Newcastle Libraries.

The building

Keelmen's Hospital was built in 1701 as an almshouse to house sick and ageing keelmen and their families. The keelmen continued to use the building until Newcastle Corporation took over its management towards the end of the 19th century. A major restoration in the 1970s caused the loss of much historic fabric.

The building comprises a cloister of 50 chambers, designed around an internal courtyard that provided a safe outdoor space for its occupants. It was built in English garden wall bond brick, with pantile roofs and lead-clad dome above the tower. On the south wing, there are two dormers with ornate brickwork, and both the south and north wings end in east and west gables.

Figure 2: South-east and north-east elevations during building works, 1973. © Newcastle Libraries.

Keelmen's Hospital was designated at Grade II* in 1954 (list entry number 1024902). The building was used as student accommodation from the early 1990s to 2009, but has been unoccupied since then. In 2009, Keelmen's Hospital was added to Historic England's Heritage at Risk Register. Despite security measures being in place, it has suffered from trespass, vandalism and lead theft.

The roof covering is in reasonable condition, except where it has been affected by repeated lead theft and subsequent water ingress has led to the collapse of some first-floor ceilings. The external walls are also in reasonable condition, albeit suffering from localised water ingress due to overgrown vegetation and blocked gutters.

Project details

Supported by the National Lottery Heritage Fund, Historic England and others, Tyne & Wear Building Preservation Trust and Newcastle City Council joined forces to progress plans for the repair and reuse of the historic building.

In 2023, a design team was appointed to prepare a conservation management plan and a feasibility study. They concluded that Keelmen's Hospital could be converted into 20 affordable residential apartments without undue impact on the building's heritage significance. Planning and listed building consent approvals[4] were granted in July 2025, with Building Regulations approval in August 2025.

Following further successful grant funding applications, construction work started in April 2026.

Figure 3: South-east elevation of Keelmen's Hospital, 2025. © Maya Polenz.

Table 1: Project team, timescale and budget

Design team		Specialist consultants	
JDDK Architects Ltd	Project architect	Greengauge Building Energy Consultants	
Maya Polenz	Heritage consultant	Skillington Workshop Ltd	
Thornton-Firkin LLP	Quantity surveyor	Vindomora Solutions Ltd	
JC Consulting Ltd	Structural engineer	**Delivery details and ownership**	
Screen and Forster Services Design Consultancy Ltd	MEP engineer	October 2023 to December 2027 £10.2m	Project delivery timescale and budget
CK21 Ltd	Principal designer	Newcastle City Council	Building owner
Newcastle City Council Landscape Design Team	Landscape architects	Tyne & Wear Building Preservation Trust	Project manager and leaseholder

Building's significance

Keelmen's Hospital holds moderate to high evidential, historical and communal value as a local landmark and the last building directly attributable to the keelmen. As a large late 17th-century almshouse in a prominent setting, it holds high aesthetic and historic value. The original plan and surviving fabric carry strong evidential value of past social housing standards.

Energy efficiency and decarbonisation strategy

The overall project aim is to return the building to residential use for affordable housing, while protecting its heritage significance. The client asked for a design that would be financially viable to deliver and that would ensure low operational costs to support long-term sustainability and affordability. The brief was, therefore, to enhance thermal performance, eliminate reliance on fossil fuels, and incorporate on-site renewable energy generation. Individual apartments are to achieve an EPC rating of C, aiming to meet potential future government's Domestic Minimum Energy Efficiency Standards.

3. Window replacement

One of the earliest detailed engravings from *c.* 1820 shows the south-east elevation of Keelmen's Hospital with outward-opening casement windows, protected by external shutters at ground level. Each opening contained two leaded lights. The left-hand light appears to be a casement and the right-hand a fixed light, with the central mullion forming part of the frame. Such a window type still exists in Alderman Fenwick's House, one of two other surviving late 17th-century brick buildings in the east of Newcastle – the John George Joicey Museum being the second (formerly listed as the Holy Jesus Hospital).

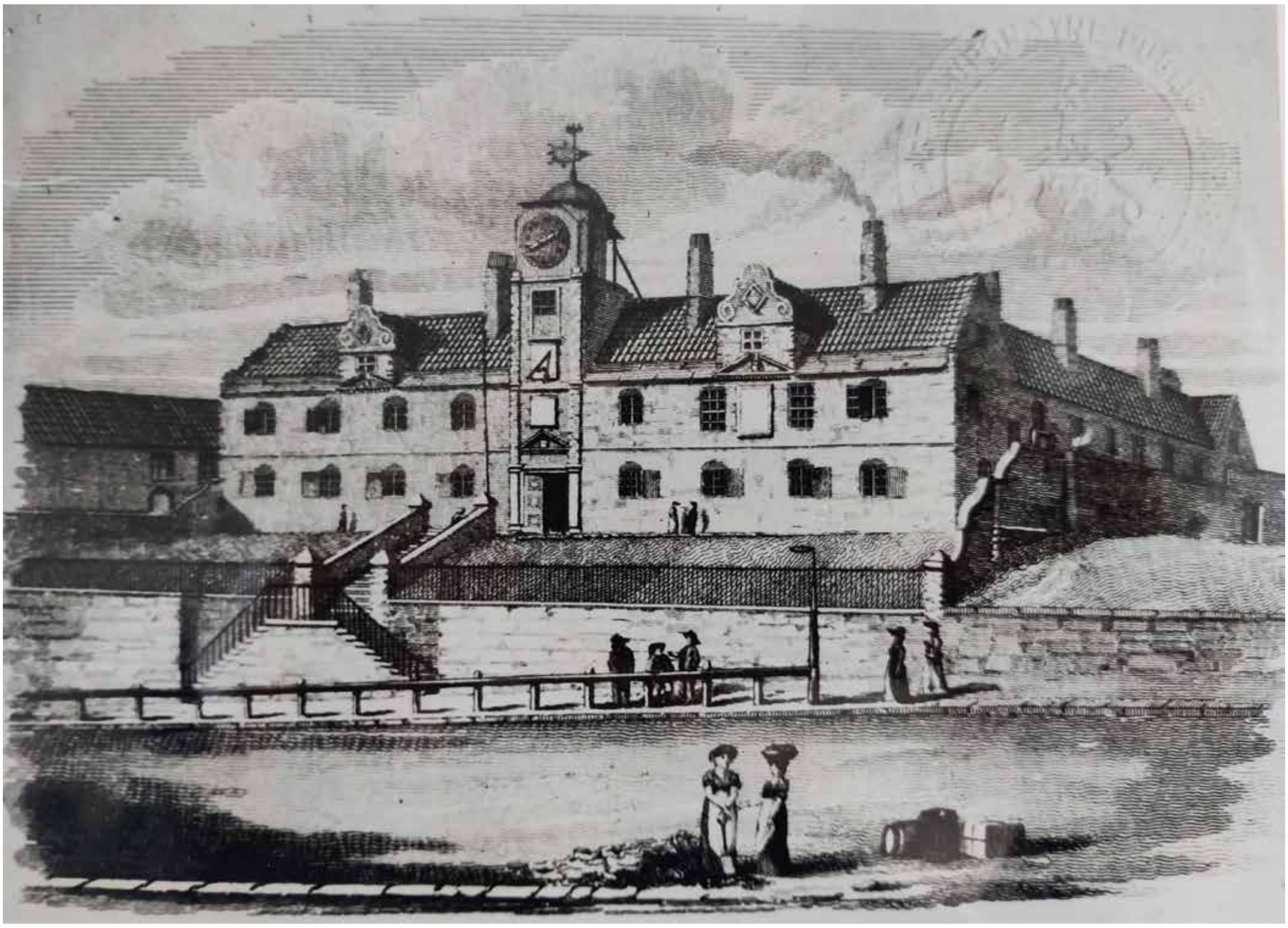

Figure 4: Engraving of the south-east elevation of Keelmen's Hospital, 1820s. © TWAM DX972/45.

From the late 18th century onwards, original windows were replaced with sash windows to increase ventilation and daylight. By the late 19th century, photographs show only sash windows, alongside enlarged openings intended to improve internal daylight.

Major restoration works in 1973 replaced all the windows with outward-opening timber casements. These are of very slim construction and are in extremely poor condition following nearly two decades of neglect after the building became unoccupied in 2009. They have neutral heritage significance.

Figure 5: South-east elevation of Keelmen’s Hospital, 1969 (pre-1973 works). © Newcastle Libraries.

Figure 6: Condition of window pre-development, 2023. © JDDK Architects Ltd.

Window replacement options

The design team produced a detailed schedule of replacement options, covering opening type, frame material, glazing type and window layout. Options were assessed in relation to maintenance, durability, acoustic and thermal performance, fire escape requirements, daylighting and the impact on heritage significance. Overheating due to excess solar gains was not considered a risk given the window-to-wall ratio. A full pros-and-cons analysis was compiled to support the planning and listed building consent applications.

Opening type

Casement or vertical sliding sash openings were considered. Casements were chosen because they offer better performance across most of the assessment criteria. Also, early evidence suggests the original windows were casements.

Frame material

Selecting the frame material required thorough consideration, especially for the windows along the south-east elevation where access is severely constrained by the level drop to City Road. Maintenance in this area requires road closures and scaffolding, which raised concerns about long-term health and safety requirements. The design team explored the following alternatives to timber:

- PVCu, steel, aluminium and glass reinforced plastic (GRP) were rejected due to their bulky profiles, short lifespans, high embodied carbon or incompatibility with the building's heritage character.
- Aluminium-clad timber composites offered clear maintenance benefits, but they were ultimately discounted on heritage grounds. The limited access on one elevation did not justify the associated harm to significance.

Accoya with a factory applied finish was specified. Accoya is modified wood (acetylated fast-grown *Pinus radiata*) of high durability and dimensional stability. It was chosen for being sustainably sourced and because it offered a 50-year warranty for above-ground use. The building owner will adopt safe access procedures for periodic maintenance.

Glazing type

Glazing choices were particularly complex because they directly affect the window layout:

- Single glazing was discarded as an option because of its insufficient thermal and acoustic performance.
- Single glazing with secondary glazing would provide good thermal and acoustic performance. However, this solution would make ventilation challenging because both units must be opened for purge ventilation. If residents did not open both units regularly, they would risk long-term fabric damage and poor indoor air quality. Alternatively, residents would be reliant on mechanical ventilation. Trickle vents would be needed on both frames, making them bulkier.
- Standard double glazing would provide good thermal and acoustic performance. These would contribute to achieving an EPC rating of C without having to reduce the U-values of other fabric elements, which could create moisture risks. However, true glazing bars would result in unacceptably bulky profiles.
- Slim-profile double glazing could incorporate thin true glazing bars. However, thermal and acoustic performance would not be as good as that provided by standard double glazing. U-value

improvements on other building fabric elements would be required to achieve an EPC rating of C. Additionally, there were some concerns about costs and longevity.

- Triple glazing would provide the best thermal and acoustic performance. However, the weight of the glazing units would result in bulky frames. True glazing bars would not be viable with this type of glass, and costs would be too high.

The design team chose standard double glazing because it is a viable and affordable option that does not require upgrading the U-values of other building fabric elements beyond safe moisture risk thresholds to achieve an EPC rating of C.

Window layout

The weight of double-glazed units means that true glazing bars would result in unacceptably bulky profiles. The design team considered two other options:

- Stuck-on or applied glazing bars: These were deemed inappropriate because they are a visually and technically inauthentic solution.
- No glazing bars: This was recognised as a heritage impact. However, standard double glazing without glazing bars would offer the best technical solution for the replacement windows at Keelmen's Hospital, maximising daylight provision and resident well-being, and reducing long-term risk to the historic structure.

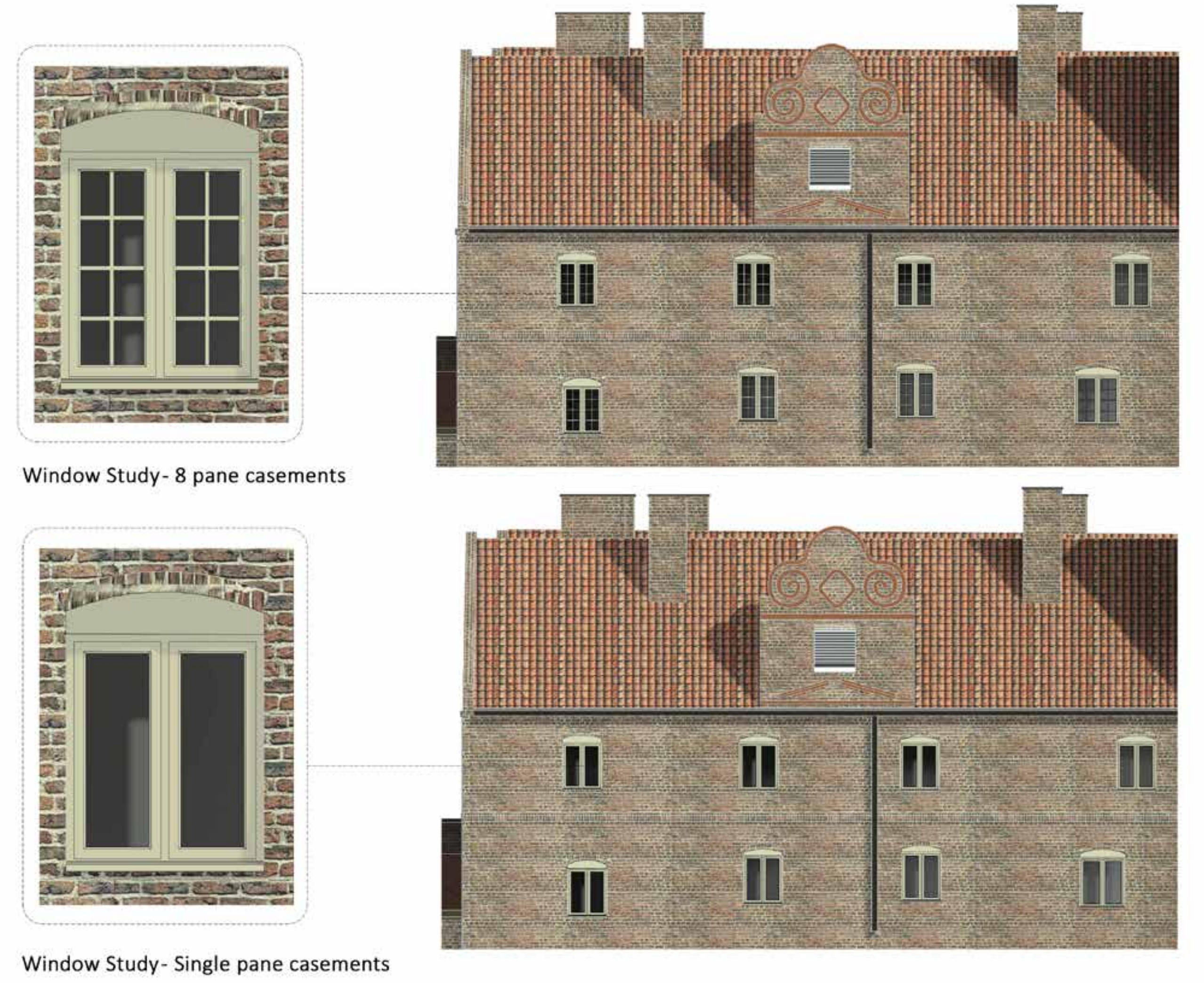

Figure 7: Window layout study. © JDDK Architects Ltd.

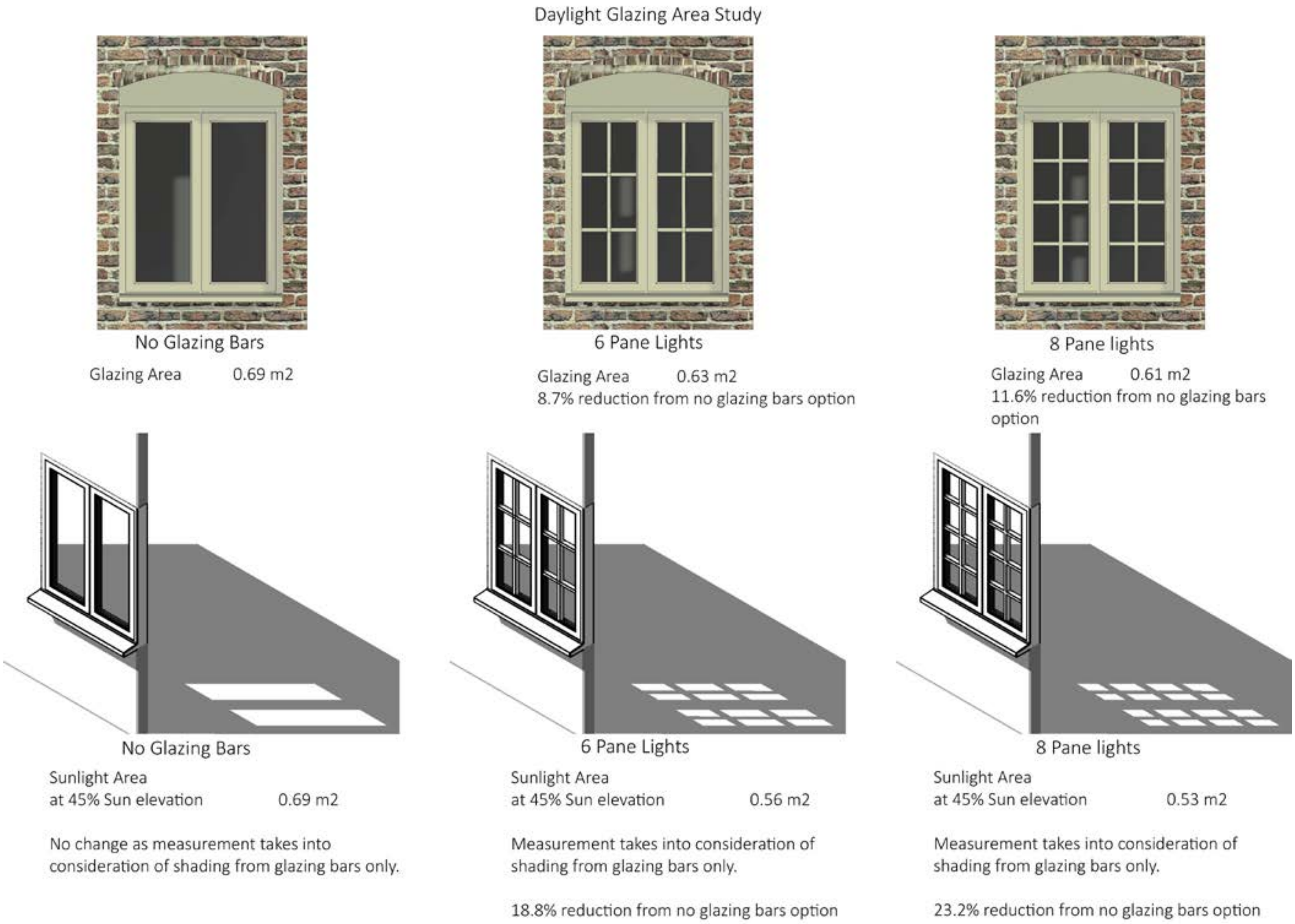

Figure 8: Daylight and sunlight area assessments. © JDDK Architects Ltd.

Window replacement proposal

The final proposal for Keelmen's Hospital is timber side-hung casements, with standard double glazing and no glazing bars. This solution will deliver good thermal and acoustic performance – vital for minimising energy costs – while improving comfort and supporting carbon reduction objectives.

Heritage impact assessment

The building's historic value partly derives from visible layers of change that illustrate evolving standards of accommodation for the poor between 1700 and 1973. The proposed replacement windows allow the retention of the original small window openings while maximising daylight and thermal comfort.

Although the new windows will bring a visual change and will introduce some moderate harm to significance, they will also:

- maintain the highly significant historic form of the building, characterised by very small window-to-wall ratios
- reflect the changes in the setting of the heritage asset, from rural in the early 18th century to urban in the 21st century, resulting in obstruction and lower internal daylight levels

- be a legible contemporary intervention that supports the ongoing residential use and contributes a further layer to the story of changing standards in residential accommodation
- provide adequate daylight levels as well as thermal and acoustic comfort.

Lessons learnt

During the planning consultation, concerns were raised about losing the multi-pane appearance of the windows. However, the transparency of the design process and the clear justification of the moderate harm approach (considering technical performance, heritage implications, maintenance, safety and cost) led to statutory consultees accepting the proposal as a balanced and responsible solution.

Resident well-being was a key purpose of almhouses and was treated as a core conservation consideration. By assessing daylight levels, acoustic comfort and thermal performance alongside heritage considerations, the design team demonstrated that sustaining long-term residential use is itself a heritage benefit. Framing comfort, health and energy affordability as integral to the building's future made it possible to justify technically necessary changes, such as installing double glazing without glazing bars.

4. Internal wall insulation

Energy efficiency interventions to buildings of traditional construction, such as adding thermal insulation to solid walls, carry risks of moisture accumulation, mould growth and decay when inappropriately detailed, specified or installed.

Greengauge Building Energy Consultants were commissioned to undertake a hygrothermal risk analysis at Keelmen's Hospital. The aim was to assess heat and moisture movement within the walls, and to inform the choice of wall linings so as not to put the building fabric at risk or be detrimental to occupants' health.

The key objectives of this hygrothermal risk assessment were to:

- assess the moisture risk associated with internally insulating the external solid walls, comparing four potential internal wall insulation options
- stress-test the proposed internal wall insulation solutions to evaluate their behaviour under potential in-service conditions, such as high internal moisture loads or rain ingress.

Internal wall insulation options

Greengauge used two-dimensional dynamic hygrothermal simulations in Delphin to evaluate the hygrothermal behaviour of four internal wall insulation options:

- Option 1 (O1): Lime-adhered woodfibre (40mm thick)
- Option 2 (O2): Insulating lime plaster (20mm thick) and adhered woodfibre (40mm thick)
- Option 3 (O3): Insulating lime plaster (50mm thick)
- Option 4 (O4): Adhered woodfibre, with a variable diffusion resistance air and vapour control layer (AVCL). Three iterations were tested: two different 40mm panels and one 60mm panel.

The hygrothermal risk assessment investigated the potential for moisture accumulation within the build-up, the decay of embedded timber joist ends and the decay of woodfibre insulation.

Impact of material properties

With permission from the local conservation officer, Greengauge carried out material testing of existing materials to determine their key physical and moisture transport properties and to inform the inputs for the hygrothermal risk assessment. Samples analysed included brick, mortar and internal plaster from the existing external walls, as well as coatings to the inside of the courtyard walls. The measurements included density, reference water content, saturation water content and water absorption coefficient by partial immersion. The site-specific material data informed the selection of representative material inputs to allow a more accurate analysis of the building's performance.

Figure 9: Photographs of material samples tested. Nine samples were selected for full characterisation of density, absorption coefficient, saturation water content and reference water content: seven brick samples from cores C1-C4 (numbers 1, 2, 4, 5 8, 9 and 10); one plaster sample (number 7); one modern mortar joint sample (number 11). Five sets of original mortar fragments were selected for partial characterisation of density, saturation water content and reference water content (numbers 3, 6, 12a, 12b and 12c). © Greengauge.

Analysis of two historic brick samples showed significant differences in water absorption coefficients and saturation water contents. This variability in material properties highlights the importance of sample size, especially when working with historic buildings.

To take into account this variability in brick properties, two brick materials were selected from the Delphin database to represent the two brick types. The modelling compared the hygrothermal responses of the masonry walls assuming both of these brick types in isolation, and also an even mixture of the two brick types in two different arrangements. To be conservative, the hygrothermal risk assessment was based on a mixed brick arrangement, which resulted in higher humidity levels at the assumed position of embedded timber joist ends.

The hygrothermal modelling incorporated the existing gypsum plaster lining on the external walls and the gloss paint on the inside face of the courtyard walls. The design team had initially assumed that these finishes would need to be removed before installing internal wall linings. However, material analysis by Skillington Workshop Ltd revealed the existing gypsum plaster was a lightweight mix, with moisture transport and storage properties similar to those of some lime mixes. The hygrothermal modelling later showed this existing plaster could remain in place without increasing moisture risk. Similarly, the existing gloss paint was found to protect the woodfibre from decay on certain courtyard elevations, while posing no unacceptable decay risk on other elevations.

Impact of orientation

Wall orientation was found to have a significant influence on the hygrothermal conditions of the external walls. The south-west (SW) orientation presents the most severe conditions (due to its high exposure to wind-driven rain), followed by north-west (NW), south-east (SE) and north-east (NE). Average relative humidity in the masonry is reduced by roughly 5 percentage points for each orientation.

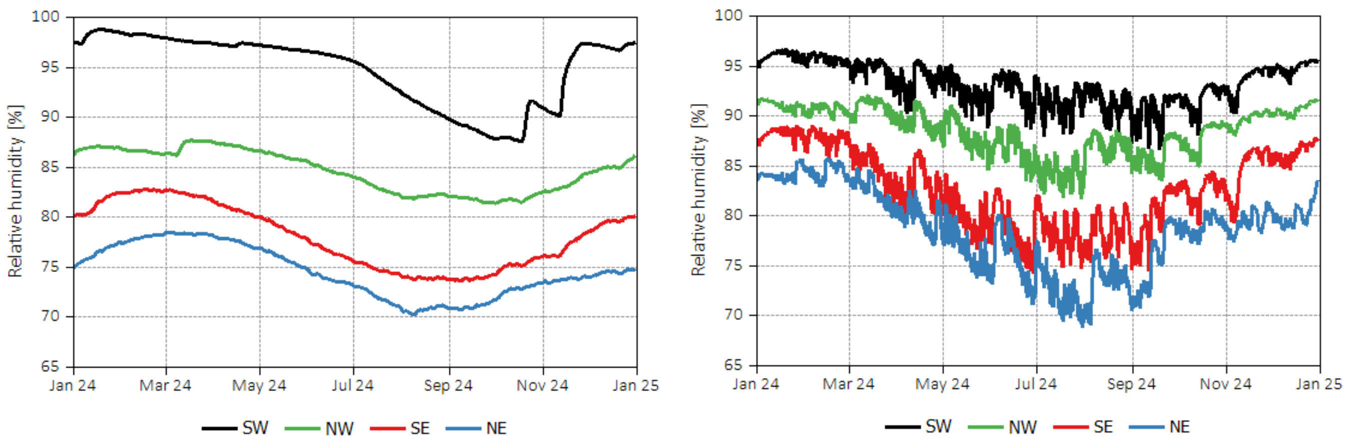

Figure 10: Uninsulated wall – impact of wall orientation: (left) relative humidity at the assumed position of joists ends; (right) average relative humidity within the masonry. © Greengauge.

Greengauge grouped the moisture risk assessments into low, moderate and high risk orientations:

- Low risk: SE and NE (including courtyard with paint)
  All the internal wall insulation options can be used away from embedded timbers with low moisture risk, even under elevated interior moisture loads. With option O4, thicker woodfibre (up to ~80mm) would probably be acceptable.
- Moderate risk: NW (including courtyard with paint)
  O1 is not recommended due to potential woodfibre decay. With continuous mechanical extract ventilation, O2 or O4 with 60mm woodfibre would be acceptable away from timbers. In the absence of controlled ventilation or to prevent risks derived from occupants' use of the system, option O3 would be preferable to avoid the risk of the insulation material decaying. O4 with 40mm woodfibre would also be acceptable and it would have lower moisture risk than O4 with 60mm woodfibre.
- High risk: SW (including courtyard with paint)
  O1, O2 and O4 are not recommended on the south-west elevation because of the elevated risk of woodfibre decay. Non-organic insulation, such as insulating plaster (O3), is preferred. On the south-west courtyard elevation where gloss paint is retained, option O4, with up to 40mm insulation, could be used with a low risk of decay.

Impact on embedded timber joists

The risks of decay for timber joists embedded within the masonry walls depend on wall orientation. Inspecting the condition of existing embedded timber joist ends and repair and maintenance of the walls are recommended before any insulation is applied.

Depending on the condition of the floor joists, for the high and moderate risk walls, a minimal insulation layer between the joist ends (for example, up to 25mm lime-based insulating plaster only) is preferable. This would maintain the insulation layer while minimising decay risk at the joist ends due to cold-bridging. For the low risk walls, up to 40mm woodfibre insulation could be safely continued between the joists.

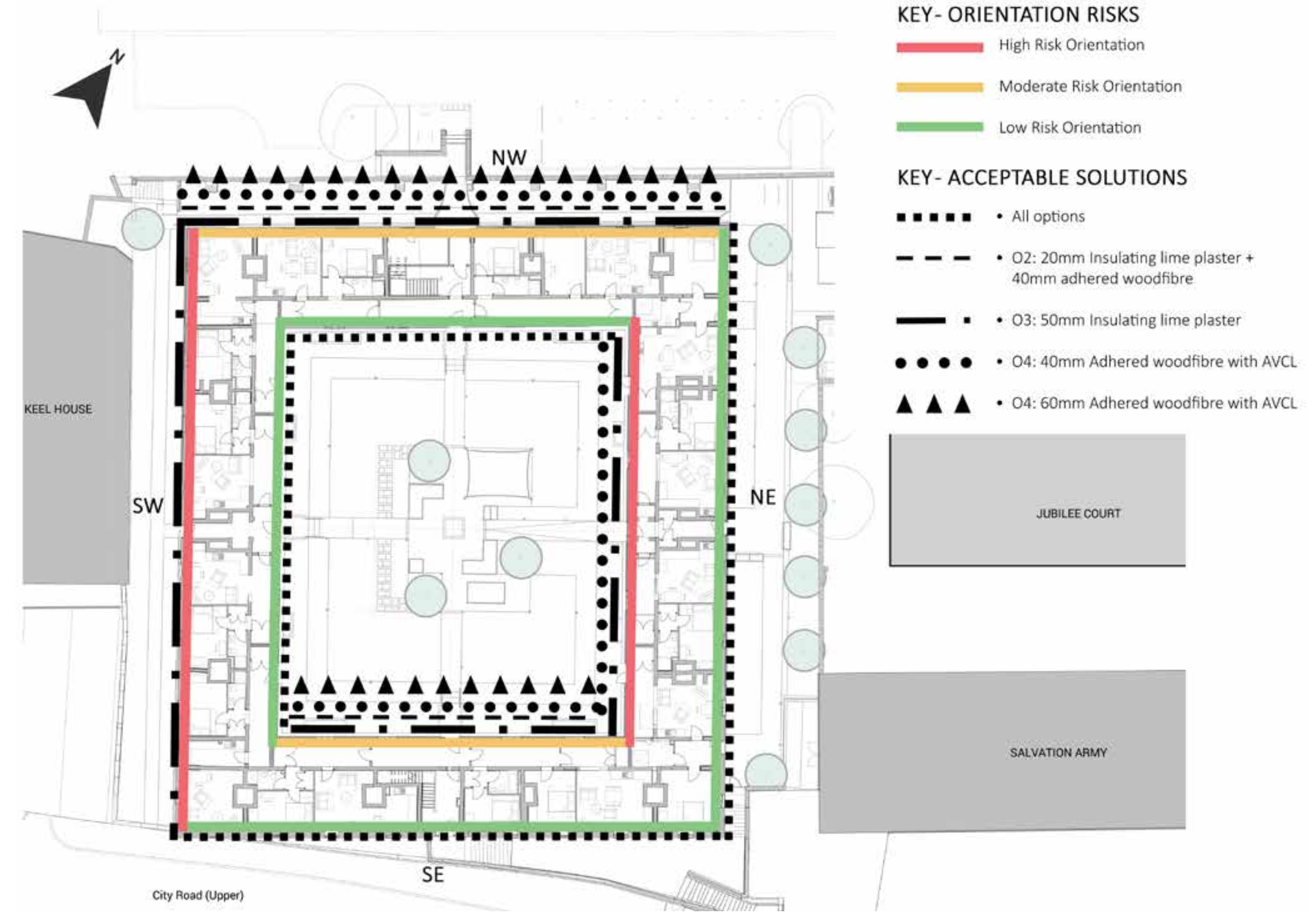

Figure 11: Low, moderate and high risk orientations and acceptable internal wall insulation options according to the hygrothermal risk assessment. © JDDK Architects Ltd.

Internal wall insulation proposals

After Greengauge's assessment, the design team agreed to use woodfibre insulation on all elevations, except the most exposed south-west external facade, where insulating lime plaster will be applied. Using this option throughout the building was discussed. However, it would have required removing the gloss paint from the courtyard walls, risking damaging the underlying brickwork. For this reason, the team proposed two different insulation systems, specifically:

- O3: lime insulating plaster on the high risk south-west external elevation
- O4: adhered woodfibre 40mm thick with variable diffusion resistance AVCL for the other external elevations and all courtyard elevations.

A 40mm woodfibre build-up provides a U-value of 0.5 W/m^2K, which is sufficient to achieve an EPC rating of C. Although the woodfibre insulation thickness could technically have been increased on certain orientations, achieving lower U-values, this solution would rely on continuous mechanical extract ventilation operating perfectly and constantly (that is, residents not intervening with airflow). Otherwise, there would be risks of woodfibre decay and mould growth. Discussions with Historic England and Tyne & Wear Building Preservation Trust concluded this was an unnecessary high risk.

Research from Historic England has shown that while there is some evidence on the benefits and limitations of AVCLs, further research is required to fully understand AVCLs and the impact they have on the performance of building fabric systems, particularly in buildings of traditional construction. At Keelmen's Hospital, using a variable diffusion resistance AVCL was deemed appropriate given the robust site-specific analysis undertaken. Care and due diligence will be critical during the construction phase so that the AVCL is adequately installed and sealed. A service void will facilitate building services installation and future maintenance, while also protecting the AVCL from inadvertent punctures (for example, when hanging a picture on a wall).

Limitations of hygrothermal simulation tools

- Although academic research bodies have tested and analysed the majority of materials within the dynamic hygrothermal simulation software database, only a small percentage of these are UK building materials. As such, most are not directly equivalent to materials used within the UK neither currently nor historically. Materials with the best match were chosen to represent the existing and proposed materials at Keelmen's Hospital and to generate meaningful results. Material characterisation of samples of existing materials was crucial to inform the selection.
- The climate file used was generated externally, and it reflects historic weather data for the project location. There remains some uncertainty about the accuracy of the climate file, due to the nature of the fluctuating climate and also climate change.
- Assumptions about the occupants' behaviour may differ from actual in-use conditions. Simulating potential scenarios with increased moisture loads (moisture stress-testing) is recommended as part of moisture risk assessments.

Lessons learnt

In a heritage setting, internal wall insulation should be treated as a tailored intervention, rather than as a standardised upgrade. Each facade behaves differently depending on its exposure, orientation, construction materials and embedded elements such as joists or lintels. These factors can significantly influence moisture movement, drying potential and long-term durability. They, therefore, require project-specific assessment rather than a one-size-fits-all approach.

Greengauge's study is a robust site-specific analysis that includes material testing, comparisons of various insulation strategies via simulation, orientation-specific risk assessments and stress-testing under additional moisture loads. Rather than relying on generic guidance, the study allowed careful tailoring of the internal wall insulation solutions for this particular building and its future use. Without this thorough analysis, the design team would not have known about the south-west orientation being high risk, since the condition of internal historic fabric did not highlight particular concerns. Also, the team had assumed the existing paint layer and gypsum plaster would need to be removed. However, the modelling showed this is not the case, which will minimise potential harm to the fabric and reduce costs.

5. Building services

The design of building services is a critical consideration in the alteration and continued use of a listed building, as these interventions have the potential to directly affect a building's historic fabric, architectural character and heritage significance.

The design team developed a building services strategy for Keelmen's Hospital to achieve the client's aspirations to:

- deliver a fossil fuel-free development
- minimise energy use
- incorporate renewable energy sources
- reduce the building's carbon footprint
- achieve an EPC rating of C
- make sure systems are easy and intuitive for residents to use
- ensure interventions are limited, sensitive and proportionate, in line with current conservation practice.

Heating system

Gas was available on the site, but the client's strategy focused on grid-supplied and renewable electrical energy as the primary source of fuel. Given the efficiencies of current air source heat pumps and their considerable capital cost advantages over ground source heat pumps – further compounded by significant accessibility restrictions for any plant and equipment into the site – air source heat pumps were identified as the preferred heating solution.

The design team explored air source heat pump options (air to water units), including a centralised heat pump system or an individual air source heat pump for each apartment.

Centralised heat pump system

The centralised provision would provide a low temperature heat network that would feed into individual water heat pumps (water to water units) within each apartment, for space heating and hot water. The benefit of this system is that it would limit heat losses on route from the outside pumps to the apartments. It would also require only one pipework circuit around the building, limiting the amount of digging out of the existing floor slab.

The centralised heat pumps could be located away from the building in a single compound. This would reduce their visual impact on the heritage setting, and noise impact could be dealt with at source by installing an acoustic fence enclosure.

A centralised heat pump system would require horizontal and vertical distribution within the building, which would be readily available in the roof space and via existing vertical chimney risers.

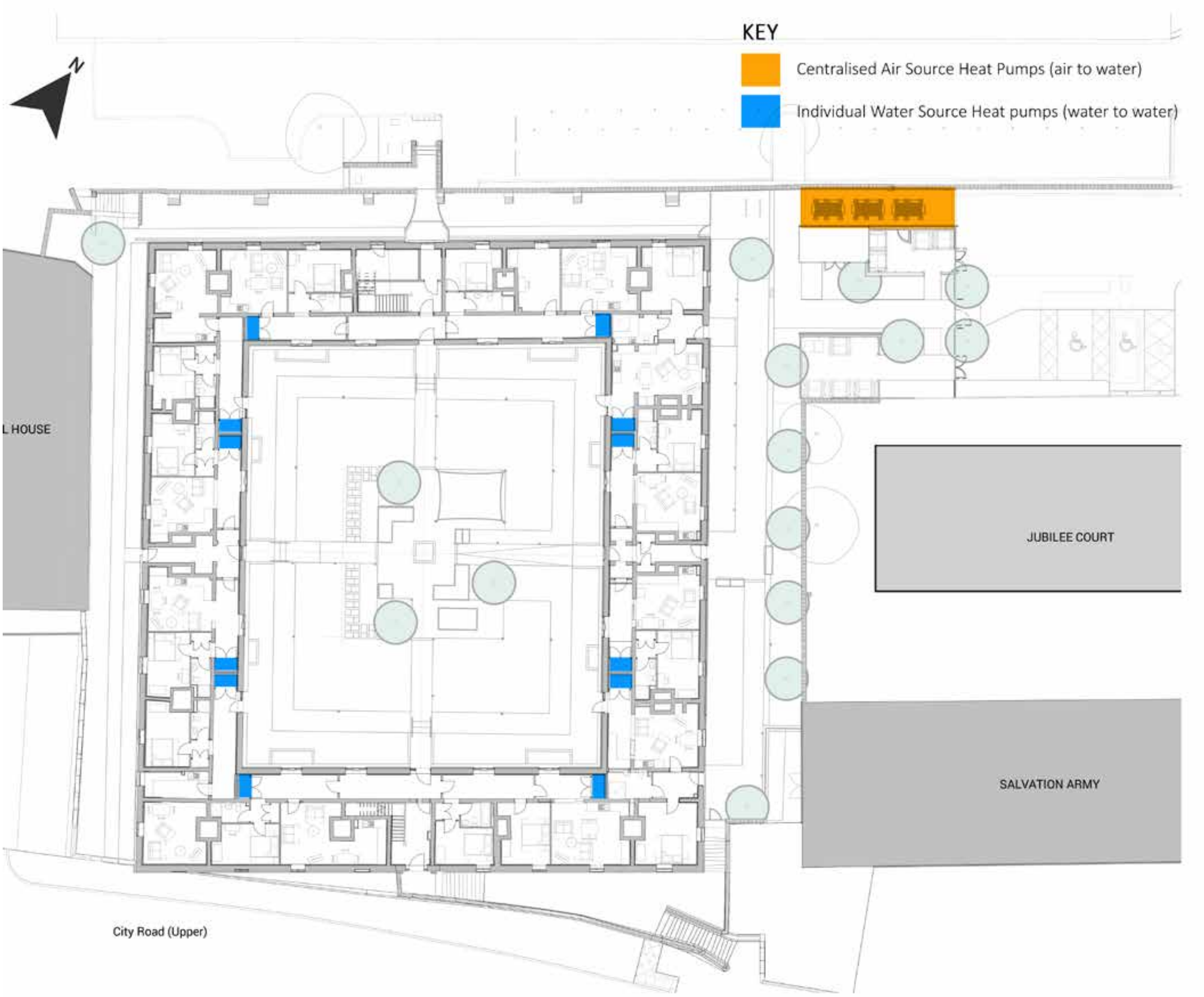

Figure 12: Diagram showing location of external centralised air source heat pump enclosure and internal individual water heat pumps within each apartment. © JDDK Architects Ltd.

Individual air source heat pumps

Twenty individual air source heat pumps would reduce maintenance liability for the landlord. However, this option would be a more challenging solution for Keelmen's Hospital because:

- new distribution routes would be required from each flat to the outside
- longer runs from upper apartments would lead to more heat loss
- individual pumps may cause harm to the heritage setting
- there would be potential for cumulative noise impact.

Heat pumps proposal

A centralised system is to be installed at the north-east corner of the site within a plant compound. This location has limited impact on the heritage setting, minimises noise impact to Keelmen's Hospital and the surrounding neighbouring buildings, and delivers the most efficient heating solution.

Figure 13: CGI image of air source heat pump centralised plant enclosure at new entrance location. © JDDK Architects Ltd.

Heat emitters

Discussions about the heat emitters within the apartments focused on underfloor heating versus radiators.

Underfloor heating

Underfloor heating would pair well with an air source heat pump (air to water system) because both systems operate efficiently at lower flow temperatures. It would also provide more even heat distribution and a gentle radiant warmth across the entire room, although the response time would usually be slower. Another benefit of underfloor heating would be that it would free up wall space and would give residents more flexibility with furniture arrangements, which could be useful in smaller apartments.

However, underfloor heating would need insulation below the heating pipes to minimise heat loss to the ground. The ground-floor construction at Keelmen's Hospital has been replaced with an uninsulated concrete slab in three of the four wings. Floor to ceiling heights are limited, and introducing a new insulated slab while maintaining existing finished floor levels would require excavating the current slab. This prospect raised concerns about potential damage to the surrounding brickwork and the building's structure. Given the challenges of installing ground-floor insulation to the entire solid floor construction, underfloor heating was deemed a suboptimal solution.

Radiators

Radiators can output at a greater range of temperatures, offer the occupants faster heating response times, and allow flexibility on the floor coverings without impacting the effectiveness of the heating system. Additionally, it would be cheaper to install radiators than underfloor heating, and it would be easier to detect and repair leaks.

Heat emitters proposal

The design team ran the Standard Assessment Procedure (SAP) calculations and resolved that a minimum EPC rating of C could be achieved for the majority of the apartments without needing to insulate the entirety of the existing ground-floor construction. Only the corner ground-floor apartments require floor insulation to achieve an EPC rating of C.

The approach of only adding insulation to these four apartments is preferable because it will minimise unnecessary interventions and potential risks to the building fabric. Since the ground-floor construction will be mostly uninsulated, the use of radiators is a more effective and appropriate solution.

Generating renewable energy

The project MEP engineer (responsible for mechanical, electrical and plumbing services) estimated the electrical energy demand and recommended installing PV panels to help with the affordability of the electrified heating system. Each roofscape was assessed for its suitability regarding orientation and effectiveness, and also in terms of the heritage and visual impact the panels may have. The result was a proposal to install PV panels to the southern and westerly facing inner sloping roofs.

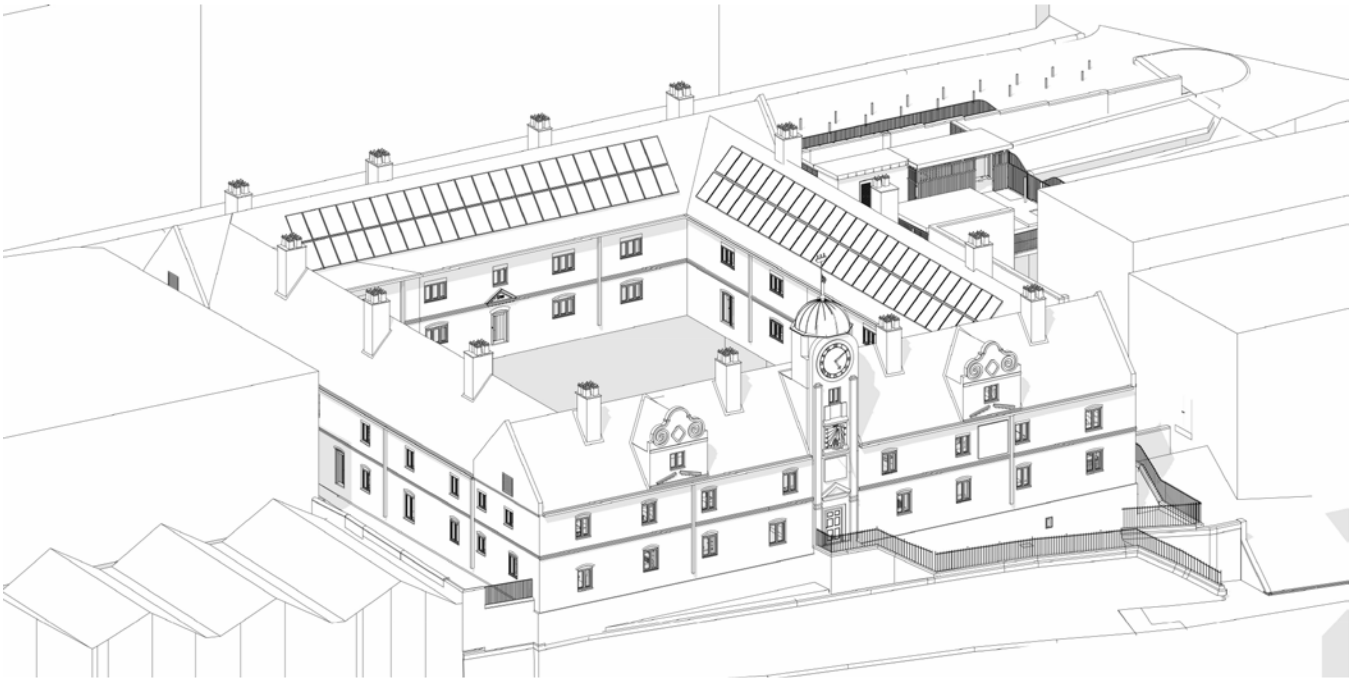

Figure 14: 3D model view showing PV panels to internal courtyard south-east and south-west facing roof slopes © JDDK Architects Ltd.

Water recycling

Water recycling could not be accommodated within the existing building or its immediate setting. Concealed options would have required excavations within the archaeological Hadrian’s Wall World Heritage Site buffer zone and were not pursued.

Ventilation

Ventilation was a major design consideration. Controlling internal humidity levels is key to avoiding condensation risks, particularly where internal wall insulation is proposed.

Standalone reliance on natural intermittent ventilation was discounted at an early stage due to strong evidence that it does not perform sufficiently well in retrofit situations and cannot automatically respond to changes in internal humidity.

Mechanical ventilation

The design team undertook a comparative assessment of two options –mechanical extract ventilation and mechanical ventilation with heat recovery – to determine the most suitable solution for Keelmen's Hospital.

Mechanical extract ventilation

Mechanical extract ventilation would require trickle vents, which could be incorporated within replacement windows.

Mechanical ventilation with heat recovery

Mechanical ventilation with heat recovery would require a significant amount of ductwork to both extract pollutants and moisture from humid areas and provide pre-warmed air to living spaces. Given the low ceiling levels at Keelmen's Hospital, routing this ductwork would be challenging without additional interventions such as bulkheads, which would increase visual impact and disruption to apartments. The higher capital cost and ongoing maintenance requirements associated with MVHR were also key considerations.

Mechanical ventilation proposal

Both systems would provide the benefit of continuous ventilation, enabling the effective removal of pollutants and moisture.

On balance, mechanical extract ventilation is considered the more appropriate solution. It will minimise interventions, costs and impacts on the existing building fabric, while still providing effective humidity control (required alongside the internal wall insulation proposal).

The ventilation units serving the 20 apartments will be located within the loft spaces, with each apartment's ductwork dropping into service risers adjacent to the chimney stacks. Landlord access into the loft space will be enhanced to allow for safe access for maintenance.

Natural cross ventilation

The inclusion of the original inner corridor into most of the apartments will allow natural cross ventilation from the external facade to the courtyard. This will provide extra resilience to the overall ventilation strategy and will give occupants control over their thermal environment, providing a sense of both agency and comfort.

Lessons learnt

The approach taken at Keelmen's Hospital reinforces the importance of carrying out a robust comparative analysis of building services options when working in a listed building.

By systematically assessing potential solutions, the design team has demonstrated that the chosen approach will deliver the required performance while minimising physical intervention and impact on the historic fabric – all balanced against the practical needs of the residents.

Given that the apartments form part of the council's wider affordable housing provision, it is important that the building services are intuitive and easy to operate. User-friendly controls are essential to reduce the risk of misuse that could, unknowingly, cause harm to the historic building fabric. The chosen solution will provide tenants with flexibility to adapt their living environment without compromising the heating system's effectiveness or wider building performance – considerations that may well have led to a different outcome had the building been in private ownership.

The comparative analysis provides clear evidence to stakeholders and statutory authorities that the selected strategy represents the least harmful option, supporting informed decision-making and approvals. Ultimately, this approach will reduce risk, prevent unnecessary loss of historic significance and ensure that services integration is proportionate, justified and aligned with best practice in conservation-led design.

6. Conclusion

The Keelmen's Hospital project illustrates that energy efficiency and decarbonisation objectives are achievable within even the most challenging heritage contexts, provided the approach is rigorous, evidence based and genuinely responsive to the specific characteristics of the building.

The project's central lesson is that there is no one-size-fits-all solution in conservation-led reuse projects. Every building is different, and every facade, material and occupancy scenario presents its own set of risks and opportunities. The commissioning of specialist materials analysis and specialist hygrothermal assessment, as well as the systematic appraisal of options across windows, internal wall insulation, heating system, renewables and ventilation shaped a project that is both technically robust and heritage sensitive. The willingness to adapt proposals in response to evidence, such as retaining existing plaster and paint layers where the hygrothermal risk assessment showed their retention did not pose moisture accumulation risks within the building fabric, was also key.

The comparative analysis process proved valuable not only technically but also strategically. By documenting the full range of options considered and the reasoning behind each decision, the design team was able to build a transparent, well-evidenced case for each intervention. This clarity was instrumental in securing the confidence of heritage consultees and statutory authorities, enabling planning and listed building consent approvals to proceed smoothly. The documentation also provides a clear record that will support the future maintenance and management of the building.

The project reinforces the importance of considering the needs of future residents alongside heritage values. Buildings exist to be used, and the long-term sustainability of Keelmen's Hospital as affordable housing depends on its apartments being well lit, warm, comfortable, economical to heat and easy to manage. By treating energy affordability and resident well-being as integral to the conservation brief, the design team ensured the interventions made will support, rather than undermine, the building's continued significance and use for generations to come.

The Keelmen's Hospital project offers insight into how historic and traditional buildings can be reused thoughtfully, eliminating fossil fuels and meeting modern energy efficiency standards, all while protecting their historic fabric and heritage significance.

7. Endnotes

1 In this case study, EPCs are referred to as a regulatory benchmark. However, recent research has shown that EPCs can significantly underestimate the thermal performance of traditionally constructed buildings (resulting in a poorer rating) and that recommendations made by EPC reports may lead to damaging the character of such buildings, risking fabric deterioration or harming the building users. Government acknowledges EPCs' limitations, including driving unintended outcomes and providing an incomplete picture of energy performance. The need to reform the Energy Performance of Buildings regime was, therefore, recognised and a public consultation was published in December 2024, with a partial response in March 2026. This review is particularly important not only to adequately assess the performance of historic buildings and buildings of traditional construction, but also because EPC ratings are used as the basis for energy efficiency targets for regulatory requirements, such as Domestic Minimum Energy Efficiency Standards for the private rented sector and as an eligibility requirement for funding, such as for the Warm Homes: Social Housing Fund.

2 Government is proposing to raise the Domestic Minimum Energy Efficiency Standard required of privately rented homes in England and Wales from an EPC rating of E to an EPC rating of C by 2030. A public consultation was published in February 2025, with a response in January 2026.

3 Government recognises "longstanding issues with SAP, which are not conducive to the delivery of our housing and climate change objectives" and is currently developing the Home Energy Model, a new calculation methodology that will replace the SAP methodology for the energy rating of homes.

4 Listed building consent application reference 2025/0514/01/LBC and planning application reference 2025/0513/01/DET.

8. Acknowledgements

Contributors

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