PEMBROKE COLLEGE

OLD QUAD

Planning Energy Statement

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ISSUE HISTORY

Issue	Date	Description
P01	22/01/24	Planning
P02	05/02/24	Planning
P03	16/02/24	Planning
P04	27/02/24	Planning

MAX FORDHAM LLP TEAM CONTRIBUTORS

Engineer (Initials)	Role
TB	Director
HRE	Principal Engineer
BM	Project Engineer
KS	Electrical Engineer

INTRODUCTION

Old Quad comprises Grade-I listed buildings. There is a desire to decarbonise Old Quad.

There is also a need to carry out refurbishment as part of the College's Planned Preventative Maintenance Programme.

Some parts of the building envelope are in urgent need of refurbishment or repair, such as the windows. This is an opportunity to improve their performance at the same time.

Many of the spaces within Old Quad currently suffer poor thermal comfort which makes them difficult to use. Attending to the spaces' thermal comfort is desirable and there are various ways to address this.

The existing overall energy consumption and annual carbon footprint of Old Quad is as below.

The main contributor to the building's carbon footprint is space heating. Domestic Hot Water is also significant.

The most important thing for decarbonisation is removal of fossil fuels.

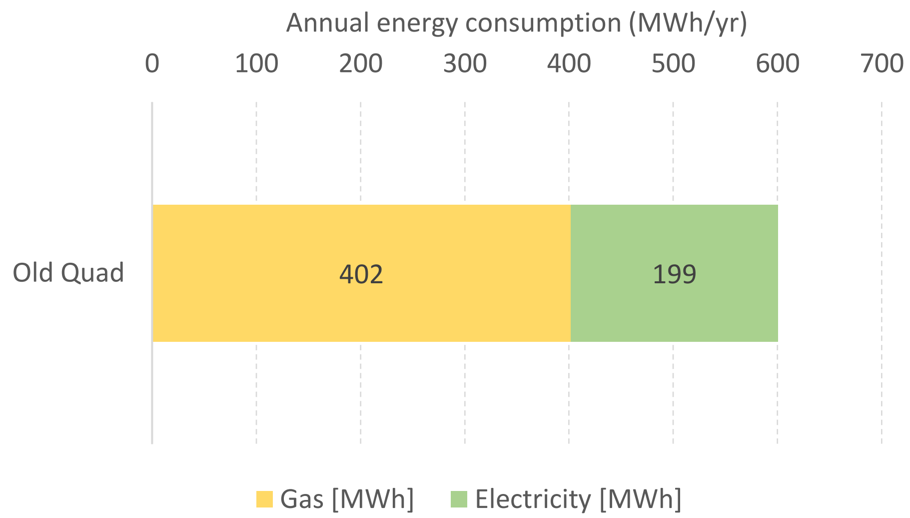
The decarbonisation aims are to:

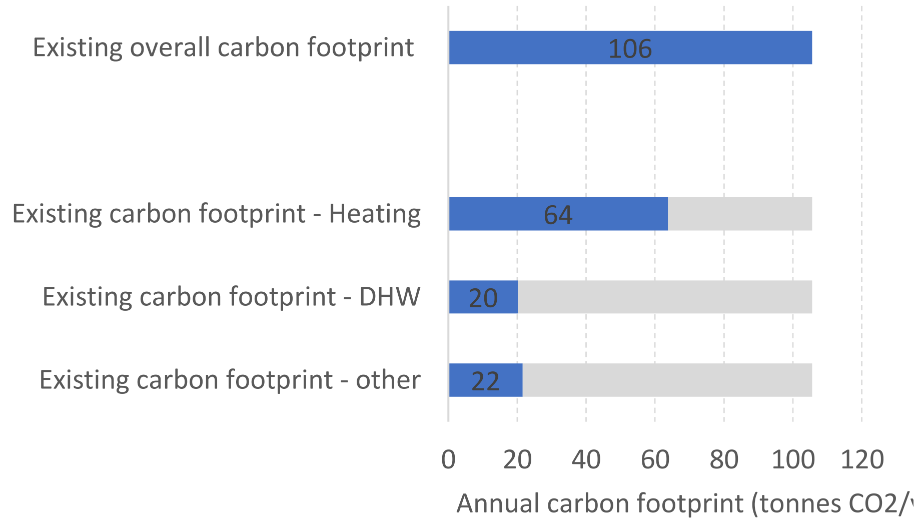
- reduce heat demands with fabric improvements and system rationalisation.
- remove fossil fuels from the buildings and meet all heat loads with decarbonised heat sources (generally heat pumps for space heating and direct electric water heaters for Domestic Hot Water [DHW].
- remove direct electric space heating, extend hydraulic heat pump led space heating systems to serve those areas of the building to reduce electricity demands.

Accommodating decarbonised heat sources, both spatially within the historic estate and technically within the capacity of the available electrical infrastructure is challenging. Fabric improvements are an important way to reduce the required size of decarbonised heat sources.

Refurbishment and preventative maintenance aims are to:

- remove cold water storage tanks from the loft and pressurise the system, improving hygiene of the water supply
- refurbish and extend mechanical extract ventilation systems – to provide background ventilation rates in the spaces
- refurbish and re-wire the aging parts of the existing electrical distribution system, with extensions for feed new decarbonised heat sources
- refurbishment of existing fire alarm systems
- refurbishment of existing lighting installations

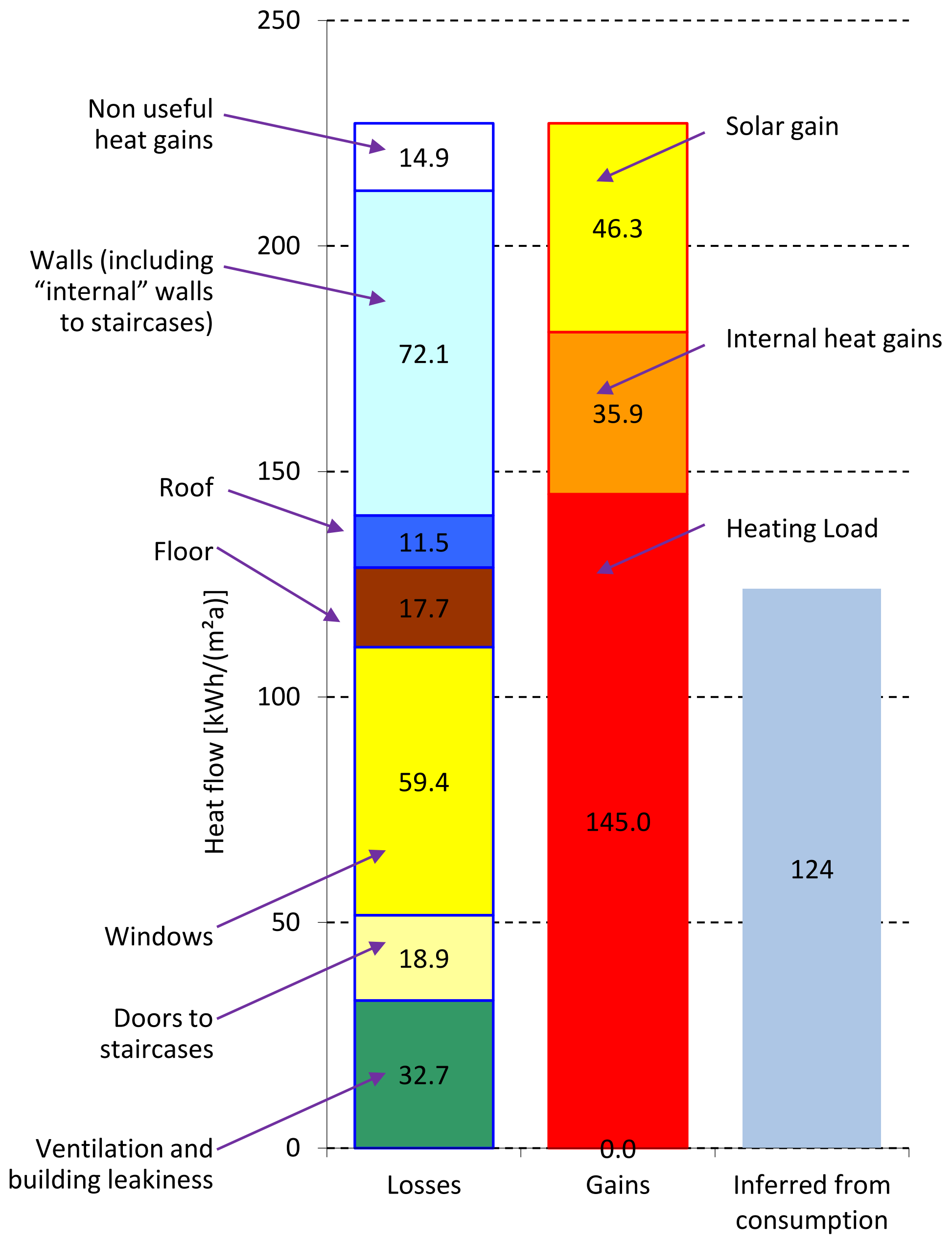


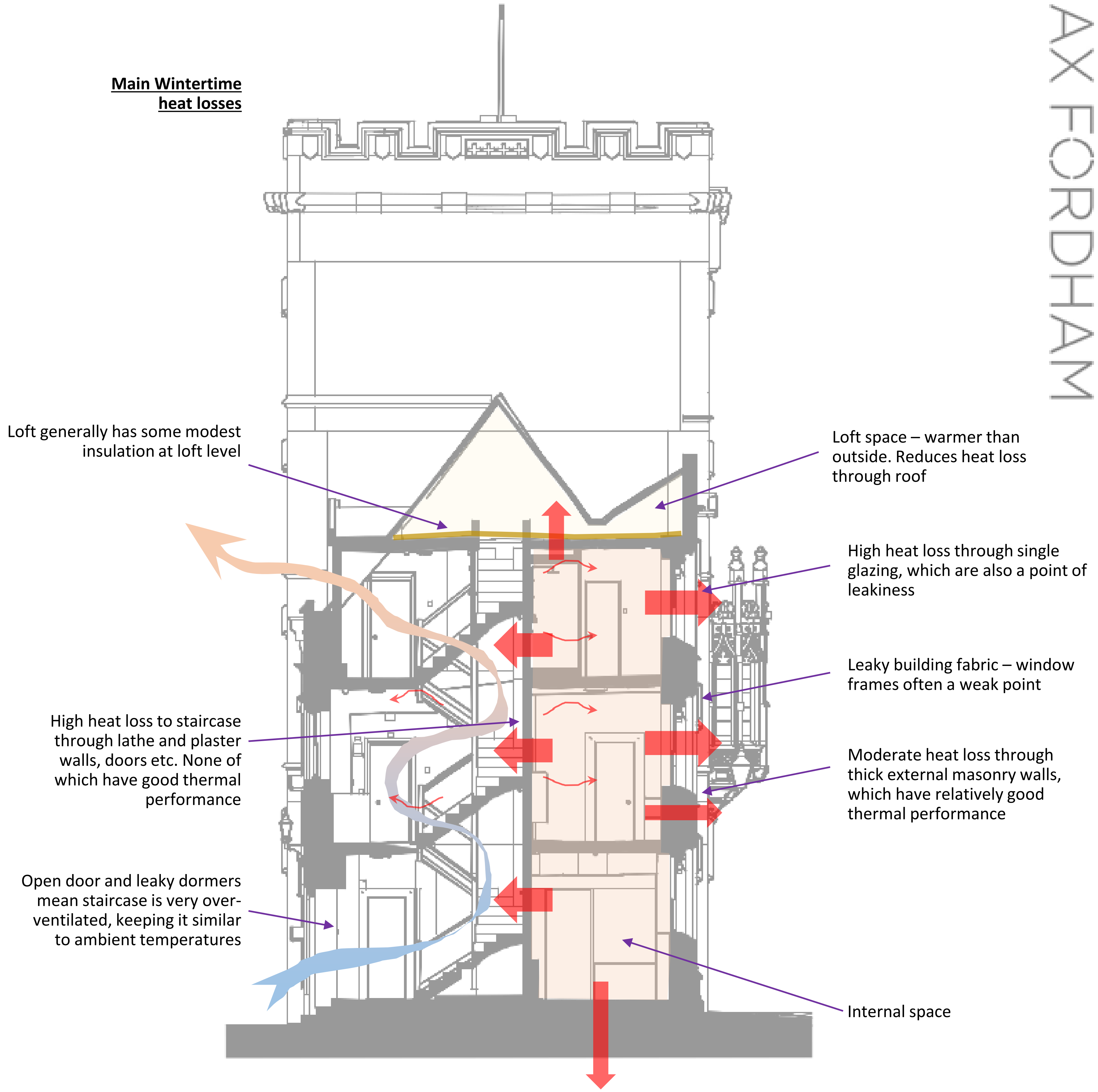


OLD QUAD EXISTING THERMAL PERFORMANCE

The building has been modelled using Passivhaus software to understand its thermal performance. This creates a baseline model, and this has been calibrated reasonably to the annual space heating demand.

This model shows where the main heat losses are and informs where fabric improvements may be beneficial.





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POTENTIAL FABRIC IMPROVEMENTS

There are various fabric improvements which are technically possible. Fabric improvements generally offer many benefits:

- reduced energy demands
- improved thermal comfort
- smaller mechanical installations
- improved solar control in a world which is getting warmer
- (potentially) improved conservation of existing building fabric

Fabric improvements reduce the space heating demands of a building and improve its energy performance.

Where spaces are heated by electric heat pumps, it may be possible to achieve equivalent improvements in energy performance with larger heat emitters (ie radiators), improving the energy efficiency of the system. This will generally be more economic than fabric improvements. Of course, it is also possible to do both. Larger emitters can also help with thermal comfort, but larger emitters alone are unlikely to resolve all aspects of poor thermal performance, such as radiant asymmetry or cold draughts.

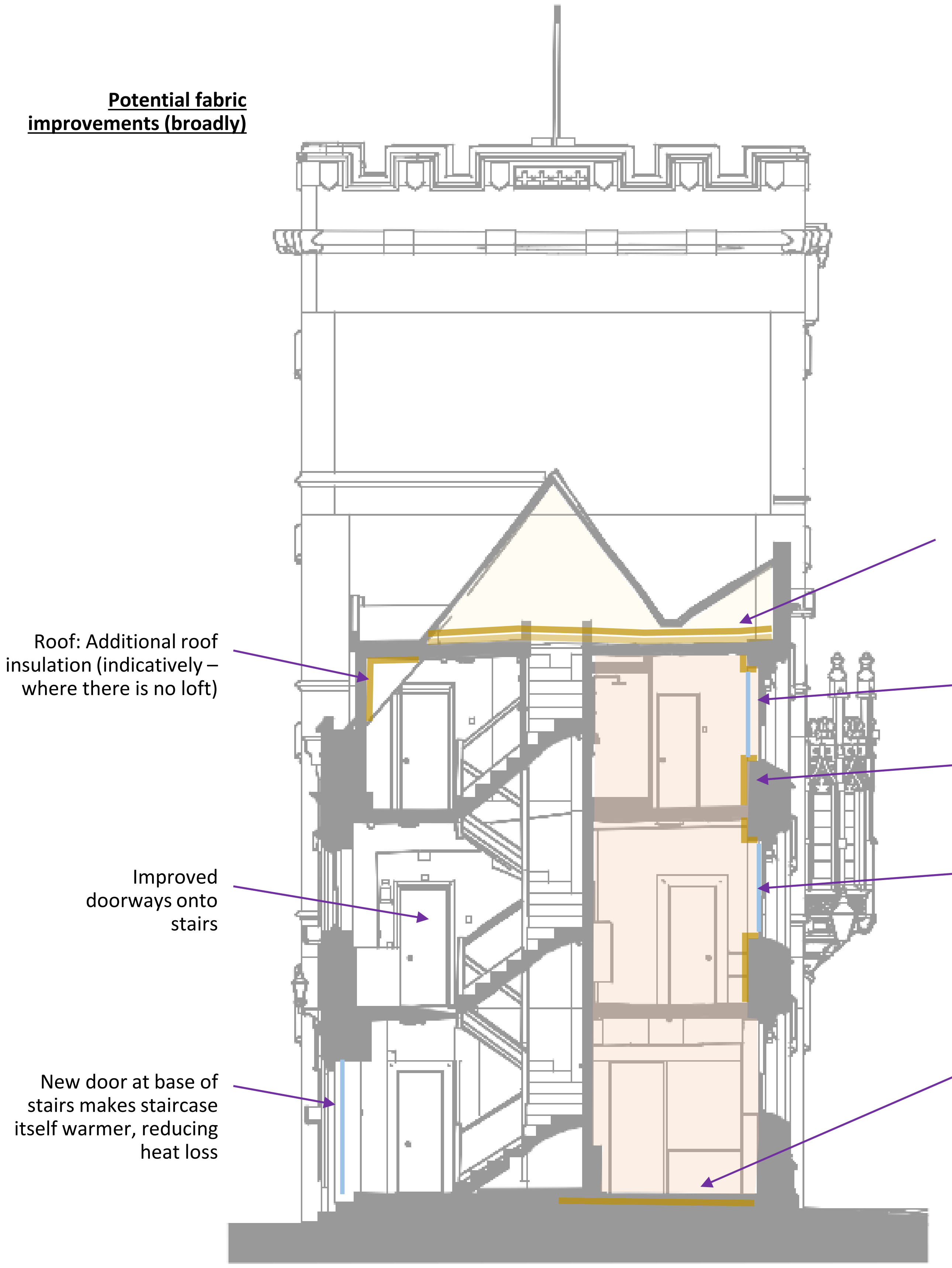
Larger emitters themselves impact the heritage character of the spaces and there is a balance between the heritage impact of fabric improvements and the heritage impact of larger emitters.

Various fabric improvements have been looked at technically. Some fabric improvements improve the longevity of the historic building fabric, for example by protecting areas from condensation.

The full suite of possible measures are:

- Windows
- Doors
- Walls
- Roof
- Floors
- Heat recovery ventilation

We have reviewed various measures with the Heritage Architect. We have not considered heat recovery ventilation because of its high impact into the existing building. The others have been considered in more depth.



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WINDOWS

The windows are the part of Old Quad which are in most urgent need of repair. Improving the thermal performance of the windows as part of refurbishment where possible would be beneficial and economic.

Window upgrades generally improve thermal comfort – a space becomes:

- less draughty
- has a warmer radiant environment as there are less cold surfaces

Where windows are refurbished and repaired, they will generally become more airtight whether their own thermal performance is upgraded or not. The level of airtightness of refurbished windows can be varied by choosing whether to draught strip them or not.

It is generally the intention to repair and refurbish windows.

Windows are often the weakest point in a building's thermal envelope, so window improvements also generally reduce internal surface condensation, albeit in places where it is easily seen.

There are various types of windows and the level of thermal upgrade that may be acceptable in heritage terms is variable.

The original windows are exclusively single glazed and make often make a significant contribution to the heritage of the historic buildings – as set out in the Heritage Statement. In many cases, the glass, the frame and the surrounds all contribute. Replacement of the glass has therefore been discounted as an approach.

This leads to secondary glazing as the main option for thermal improvement. This allows the existing historic glass to remain in situ.

Several secondary glazing options have been ruled out:

- standard dual-pane: Too thick/chunky, will require intrusively thick frames
- triple glazed: Too thick/chunky/heavy, will require intrusively thick frames
- vacuum glass: Spacers are deemed to be too visually obtrusive

This leaves the viable options as single-pane secondary glazing and slimline dual pane secondary glazing (eg Histoglass HD12)

We have assessed three options for window works:

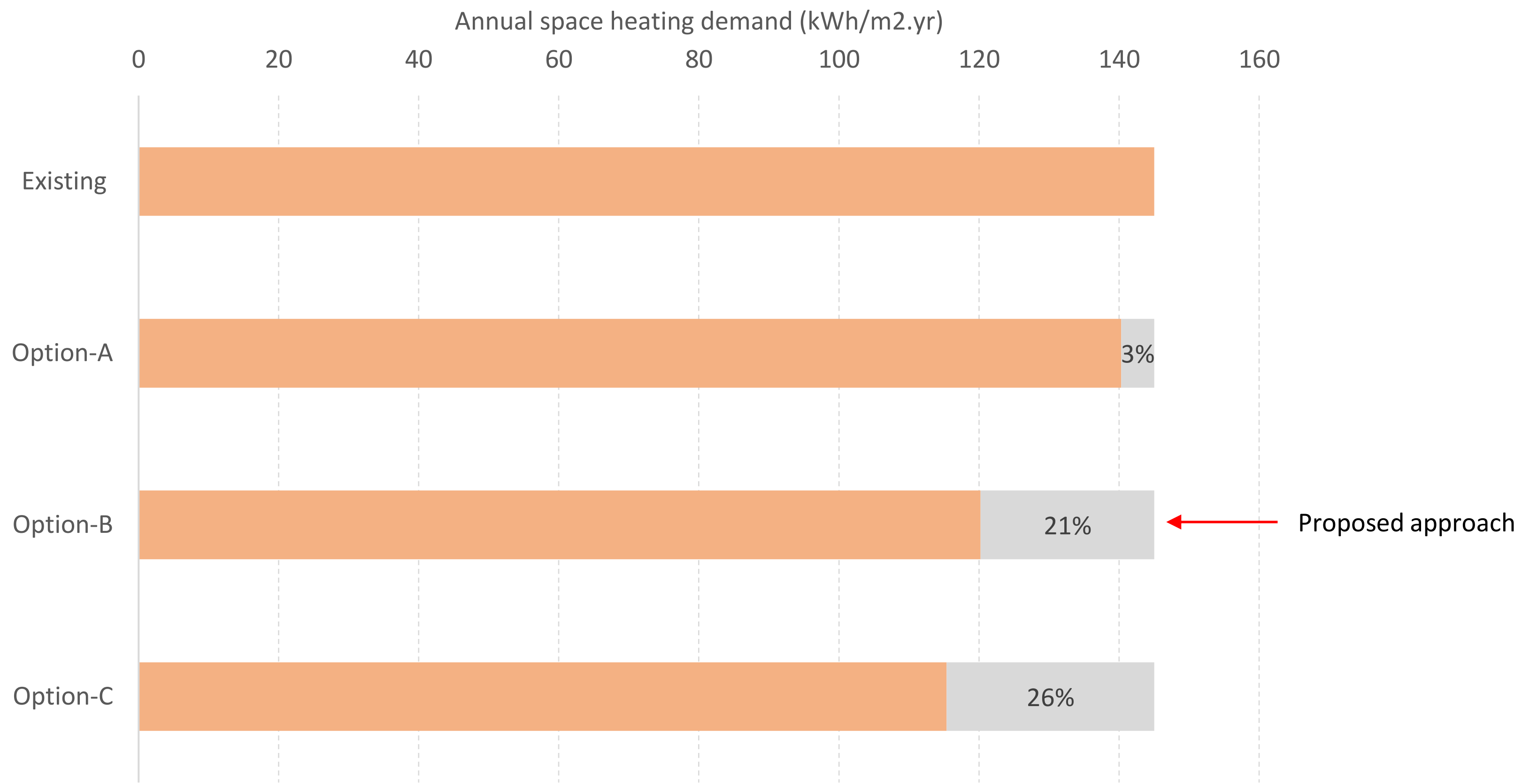
- Option-A – Draught stripping and repair throughout

- Option-B – Draught stripping and repair throughout, with single pane secondary glazing for window types 1-5

- Option-C - Draught stripping and repair throughout, with Histoglass HD12 secondary glazing for window types 1-5

HD12 histoglass offers relatively modest improvements over single-pane secondary glazing yet requires thicker frames. We propose single-pane secondary glazing generally.

There are some windows where implementation would cause too great a harm to the building heritage, such as Broadgates Hall. See the architect's information for the scope of window improvements.



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DOORS - PERFORMANCE

The doorways to the staircases are open. The internal walls between heated rooms and the staircases are not insulated and often made of lathe+plaster which cannot be improved without causing significant heritage harm. The "internal" doors between staircases and spaces have very modest thermal performance and are not particularly airtight.

The staircases themselves have leaky windows at the top, which helps drive ventilation of the staircase through the stack effect. In cold weather, the staircases are as cold as the outside.

There are two broad options to address this.

Option-1: Improve the "internal" doors. All appear to have some heritage value, so we do not consider this to be possible beyond repair and draught stripping. The overventilated staircases remain as they are but their impact is mitigated modestly.

This has modest effect on the thermal performance, as there is still substantial heat loss through the lathe and plaster walls from heated spaces to the staircases.

Option-2. Add new external doors to the bottom of the staircases. This changes the nature of the staircase from external space to unheated lobby. This is much more effective technically.

Additional doors at the base of the staircase have many benefits:

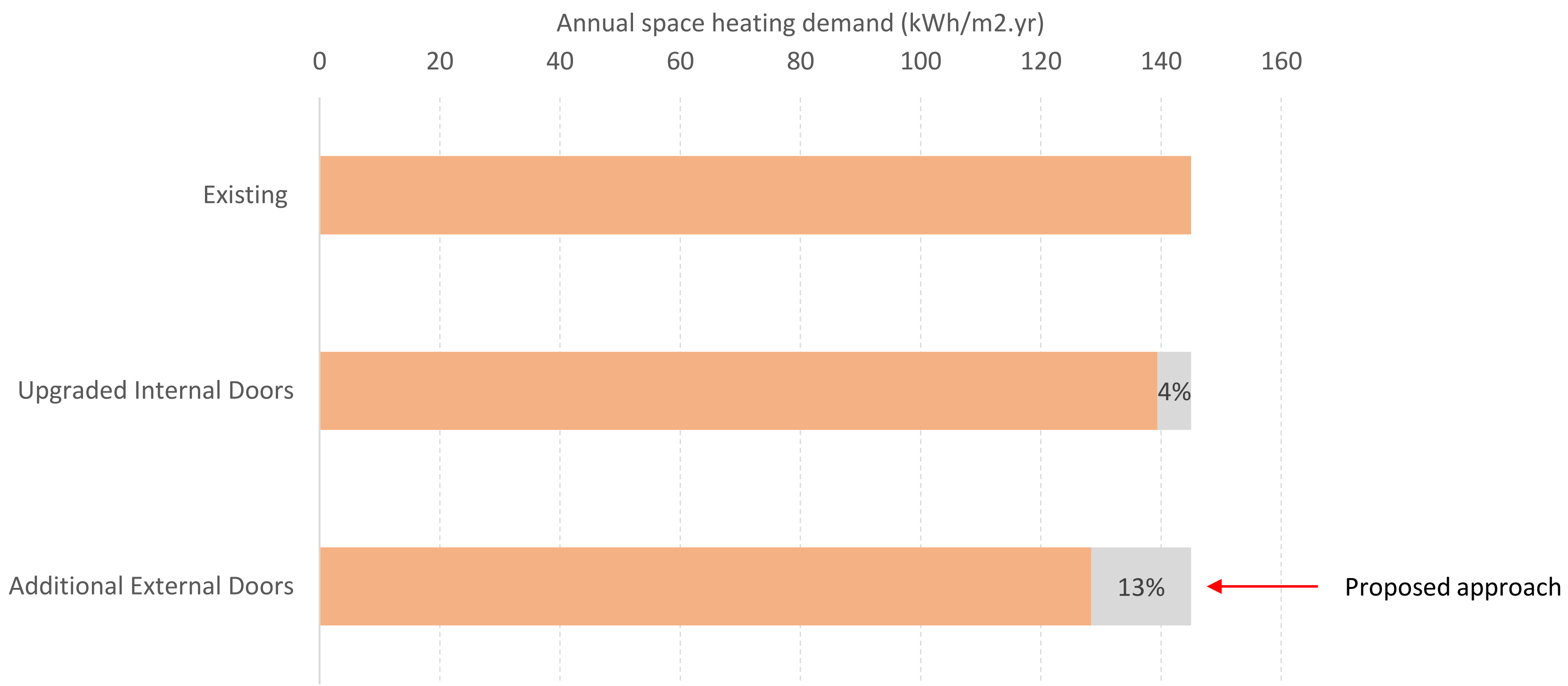
- warmer temperature in the unheated staircase, reducing heat loss from the heated internal spaces
- less draughty in the staircase, reducing draughts through the internal doors making the internal spaces more comfortable
- the staircases themselves become more comfortable

There is a precedent for a new door in Old Quad at Staircase-2.

There is precedent for new doors generally elsewhere in the College (eg, Porters Lodge and those being installed at the Dining Hall).

It is not possible to add new doors to the bottom of all staircases, for example Staircase-7 has some steps which preclude this.

We propose implementation of new doors at the base of staircases where possible due to the significant energy savings this will create compared to upgrading the existing internal doors.



Precedent recent addition of a door to Staircase-2

Precedent addition of a glazed door to a historic entranceway

WALL INSULATION - PERFORMANCE

The buildings in Old Quad generally have modest glazing areas. This means they have a lot of wall area, so the thermal benefit of insulating the wall is substantial.

We have not considered external wall insulation because of the heritage impacts of this intervention.

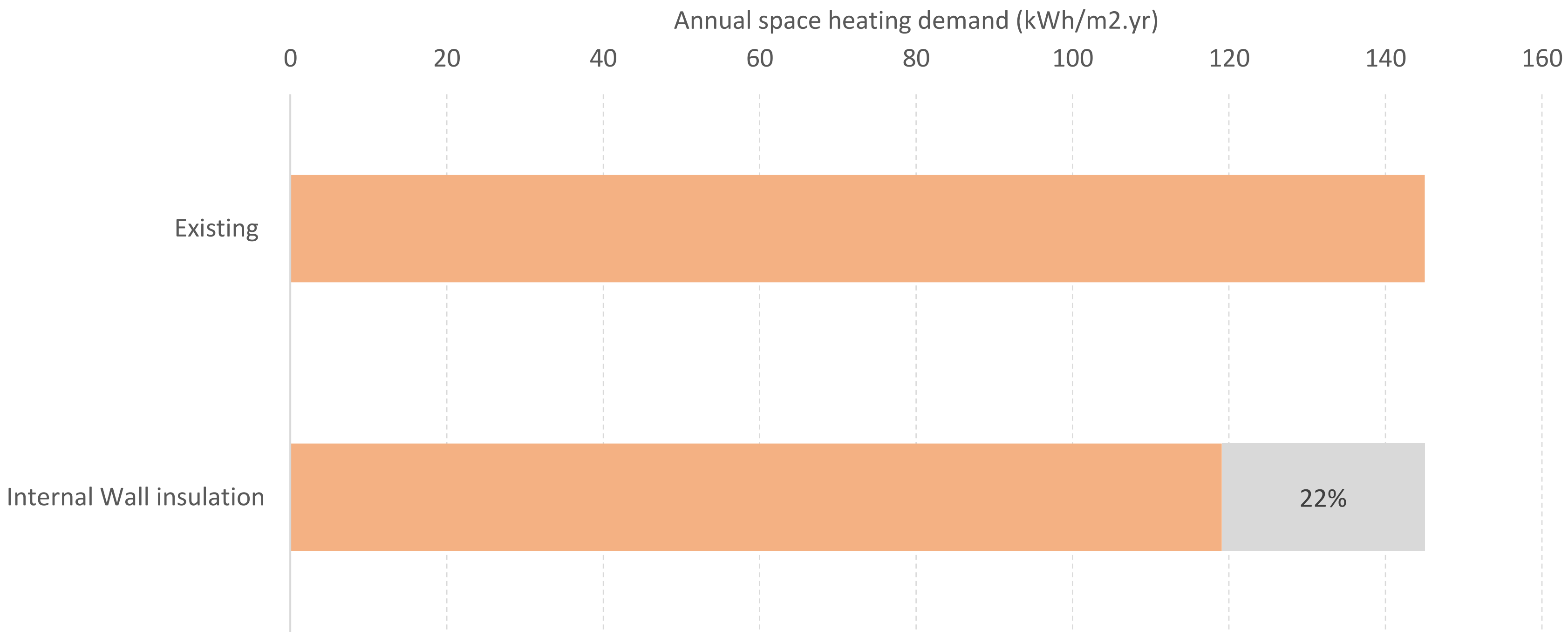
We have considered internal wall insulation, with a moisture-permeable build up. Were it to be implemented, this buildup would need to refined through a process which involves physical testing of the existing walls and is not straightforward.

Indicatively, internal wall insulation offers a reduction in space heating energy use of >20%.

The heritage feasibility will be variable depending on the space and the significance of features such as cornices, skirting boards, window sills, window jambs and the like.

Delivery of internal wall insulation is likely to be a messy, disruptive project.

While the benefit is reasonable, we do not propose progressing internal wall insulation. This is because it is disruptive, high risk and will cause heritage harm where there are historic features.



FABRIC SUMMARY

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	Comfort	Energy use improvement	Building risk	Proposed?
Windows Option-A	Less draughty, comfort improved. Cold surfaces cause downdraft and radiant asymmetry May be scope to introduce solar control to windows.	Moderate	Less uncontrolled air movement, potentially reduced moisture risk	Where option below is not possible
Windows Option-B	Less draughty, comfort improved May be scope to introduce solar control to windows	Good	Less uncontrolled air movement, potentially reduced moisture risk. Can have condensation in void between glazing elements where secondary glazing is added*	Yes
Windows Option-C	Less draughty, comfort improved May be scope to introduce solar control to windows	Best single option considered	Less uncontrolled air movement, potentially reduced moisture risk. Can have condensation in void between glazing elements where secondary glazing More significant risk for building heritage	No
Additional Doors at the base of staircases	Staircases themselves much less draughty.	Depends on use but likely to be very positive.	Less uncontrolled air movement within staircases, reduced moisture risk	Yes
Upgraded internal doors to staircases	Unlikely to have a subjectively noticeable effect	Small	N/A	No
Additional loft insulation	Unlikely to have a subjectively noticeable effect	Small	N/A	Yes
Additional roof insulation	Unlikely to have a subjectively noticeable effect	Very small	Addresses weak points in the envelope where condensation likely to occur	No
Additional floor insulation	May make ground floor spaces less draughty	Small	Could create damp/humid areas if not careful	No
Internal Wall insulation	Changes radiant environment substantially, making spaces more comfortable	Good	Can be high if not carefully designed	No

* The outer windows will not be draught-proofed where we propose to add secondary glazing, so the cavity will have some ventilation. However, if condensation does occur it will be visible and can be addressed immediately.

FABRIC SUMMARY

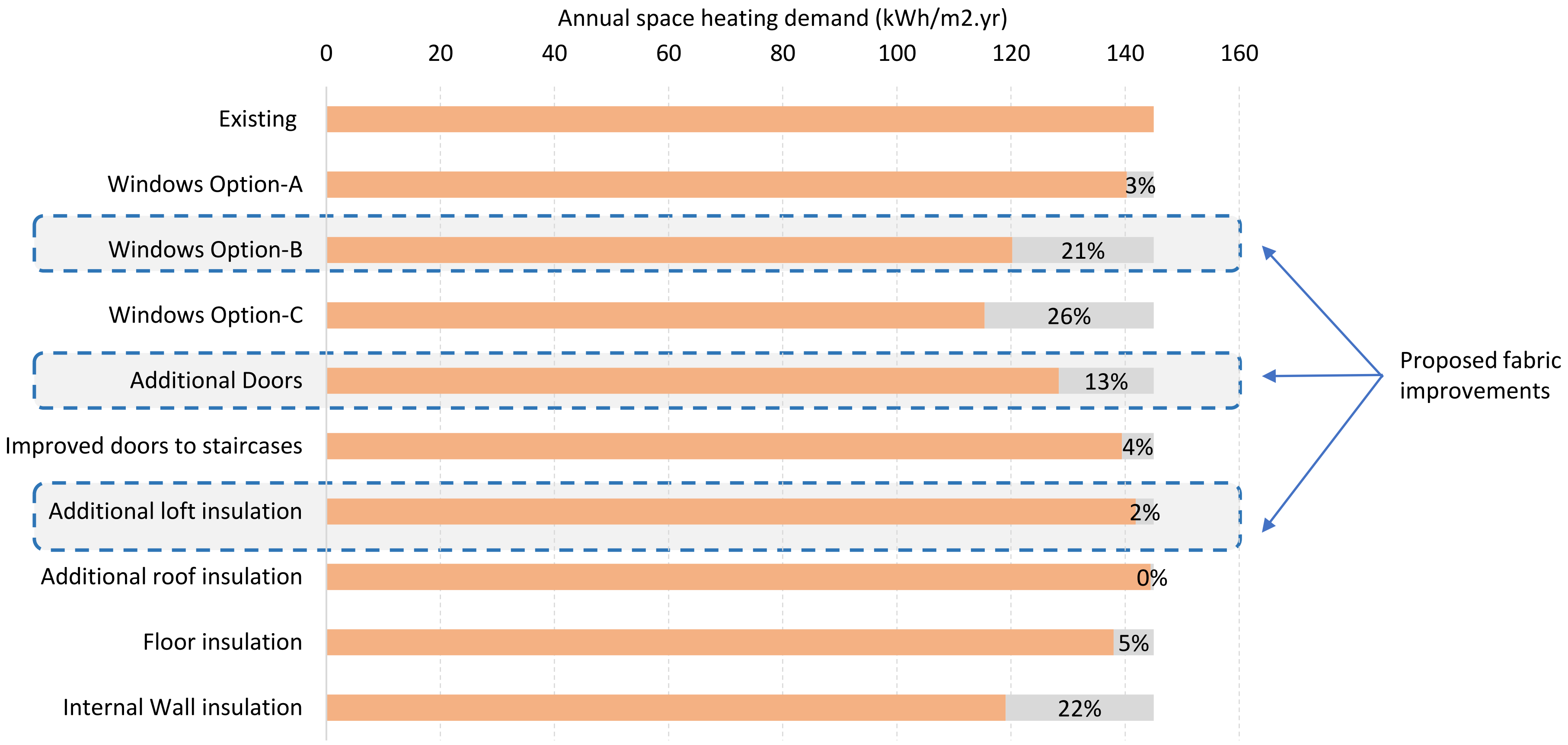
The thermal benefits of the various measures are shown here.

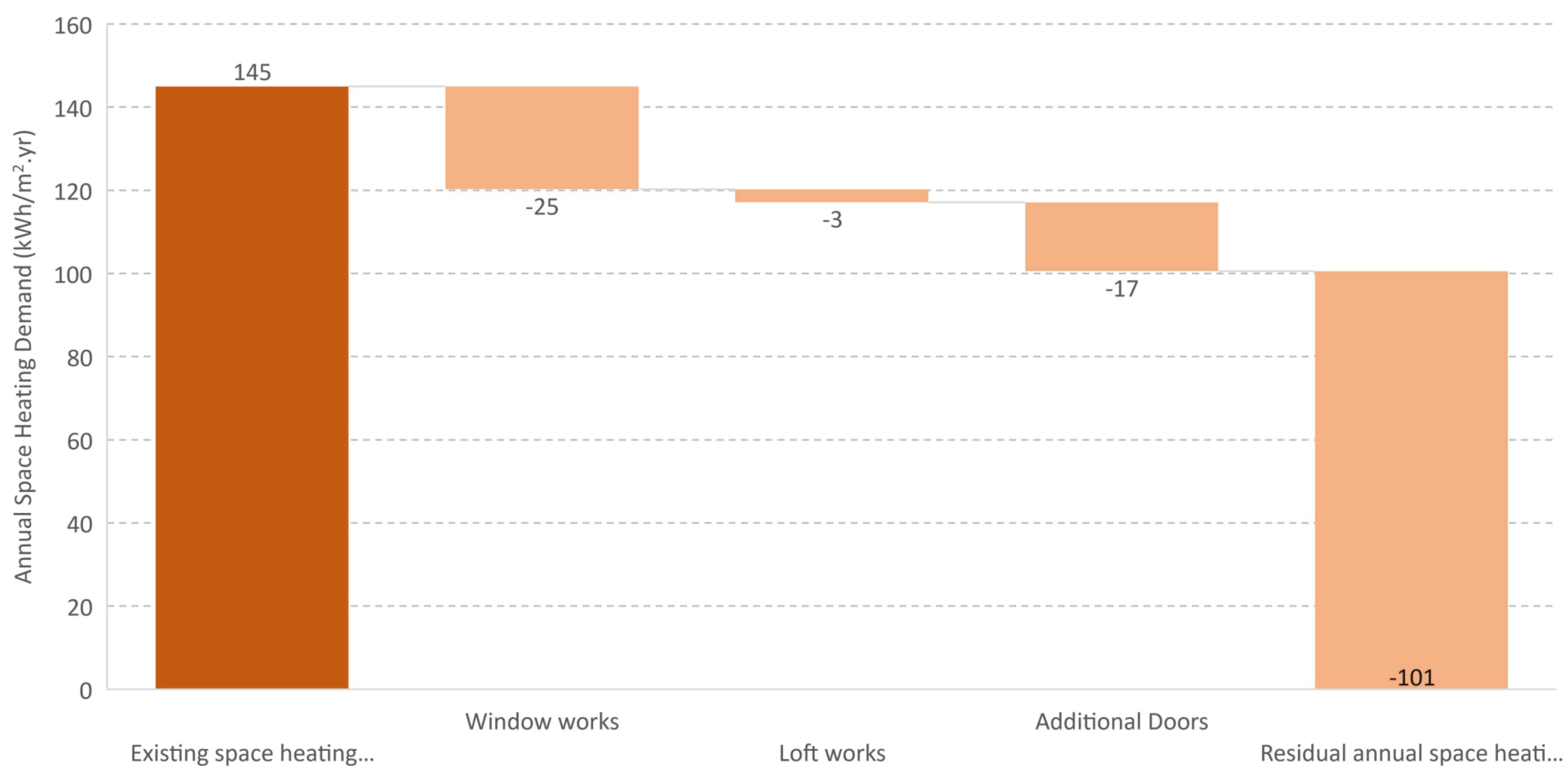
Given the benefits/drawbacks, a proposed holistic fabric scope is as follows:

- additional loft insulation
- window repair and draught stripping generally
- single pane secondary glazing throughout (except for difficult windows in areas such as Broadgates Hall)
- additional loft insulation
- additional doors at the base of staircases (except where this is not possible such as Staircase-7)

Together, these provide a ~30% reduction in annual space heating on the basis of equivalent thermal comfort.

See Architect’s information for full scope of works to windows and doors.





VENTILATION – PROPOSALS

The proposed fabric improvements will increase the buildings' airtightness.

To maintain good air quality, we propose that spaces generally are well ventilated. In some spaces there is a pre-existing need for ventilation upgrade irrespective to changes to the building fabric.

Where there is existing ventilation provision, this will be by refurbishing that ventilation system. Where there is no existing ventilation provision, this will be by adding new extract ventilation provision.

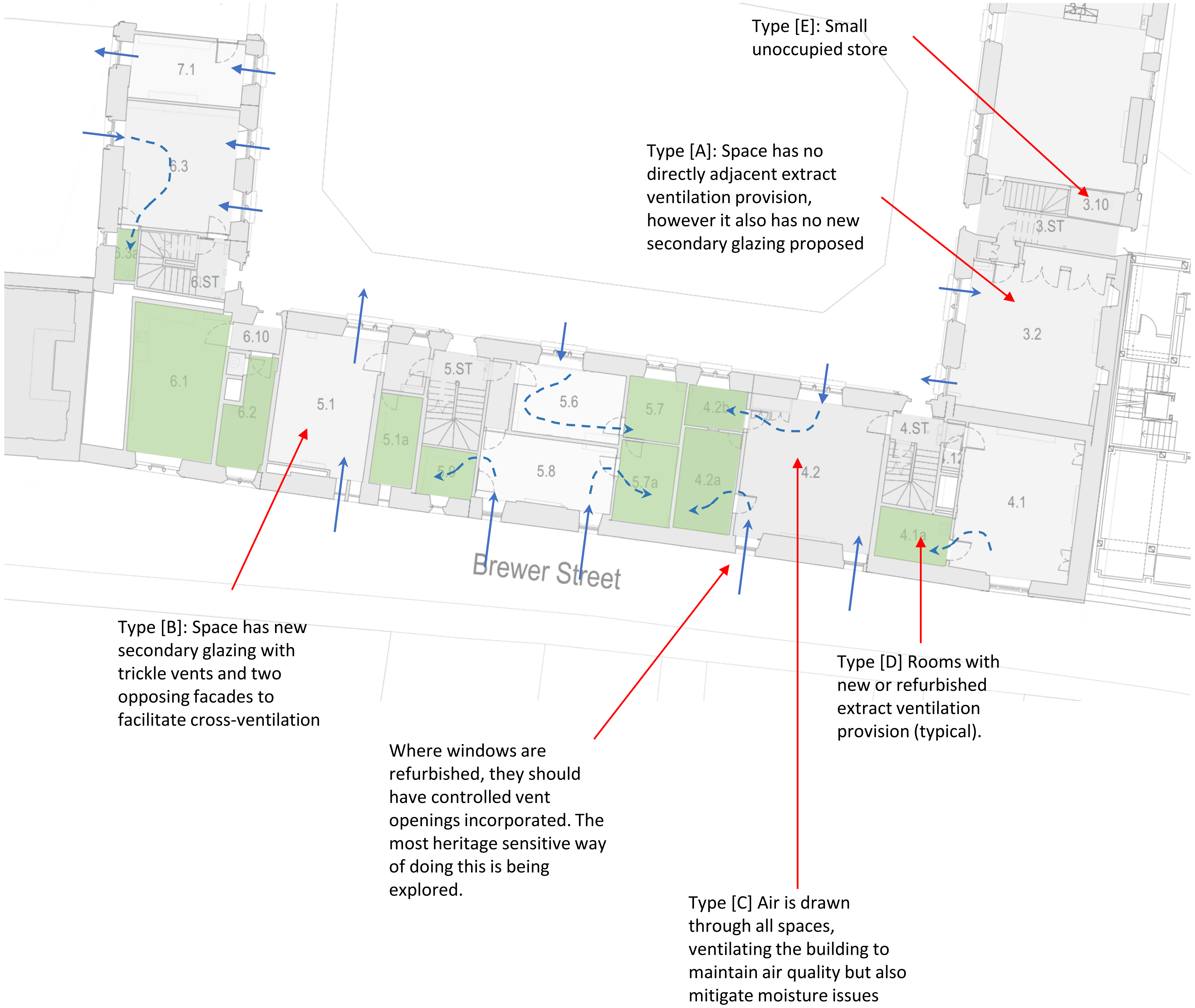
The ventilation pathway for fresh air into the buildings will generally be designed in conjunction with the ventilation strategy such that there is steady airflow through each space in the building. The fans should be running consistently, to provide a controlled background rate of airflow. This maintains good air quality and also helps protect the building fabric.

Generally, where new secondary glazing is proposed, the windows themselves are to remain leaky, whereas the secondary glazing is to have a controlled trickle vent.

This leads to several broad ventilation approaches:

- **Type [A]** spaces where the ventilation provision is unchanged (either because there are external doors or because the existing windows are remaining unchanged
- **Type [B]** spaces where there are new secondary glazing proposals with trickle vents as described above, with multiple facades and appropriate natural cross ventilation
- **Type [C]** spaces where there are new secondary glazing proposals with trickle vents as described above, and an adjacent space with mechanical extract provision
- **Type [D]** spaces where there is mechanical extract provision directly
- **Type [E]** small, unoccupied spaces with no particular moisture load, no existing ventilation provision and no new ventilation provision proposed

See MFLLP M-20100 series drawings for full ventilation proposals



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ELECTRIFICATION OF HEAT

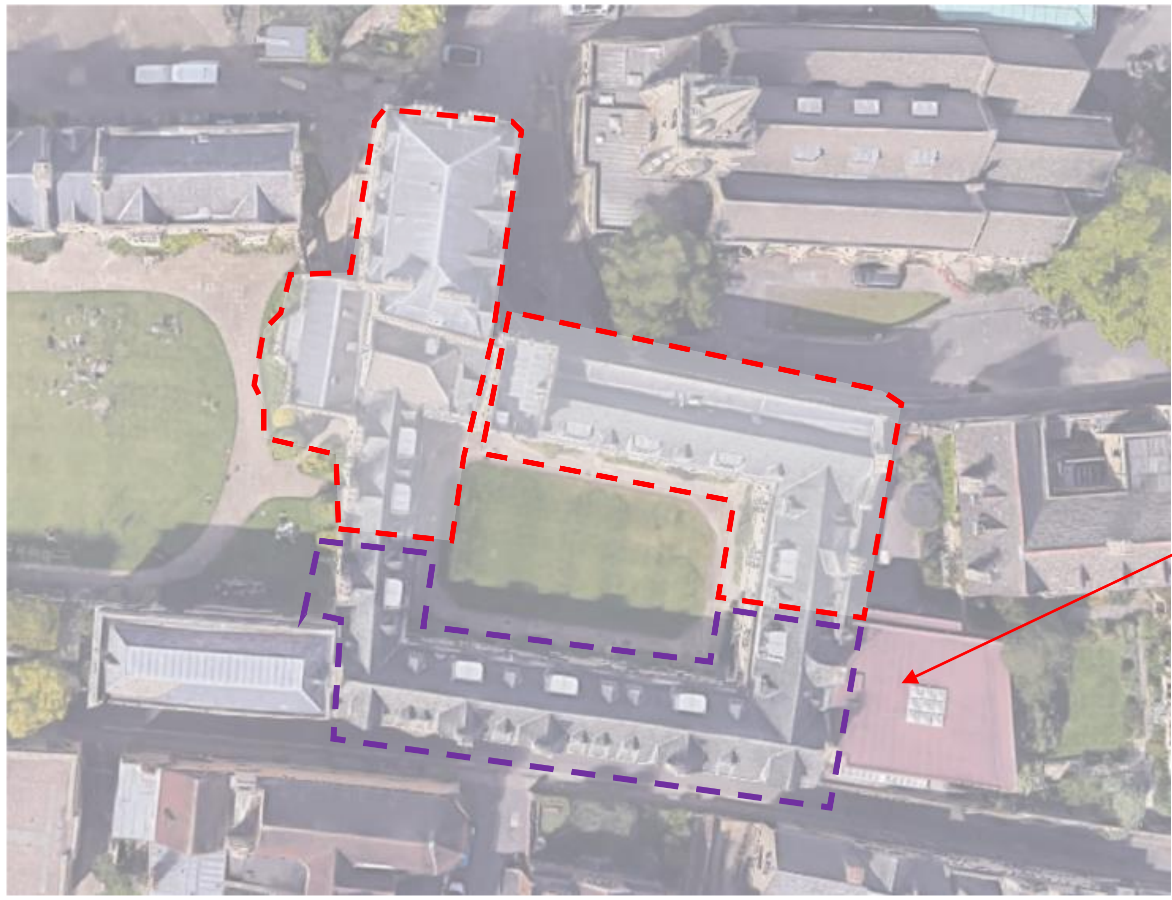
As far as decarbonisation goes, the most important aspect is removing fossil fuels from the buildings and electrifying the provision of heat.

Decarbonisation of the existing gas fired heating systems is a key aim of the project.

Extending wet heating systems:

The areas which are already electrically heated could be considered to be on a decarbonisation pathway already. However, they will have high running costs and put stress on the electrical infrastructure.

Extending wet heating systems and using heat pumps mitigates this and is proposed for Staircases 3-6.



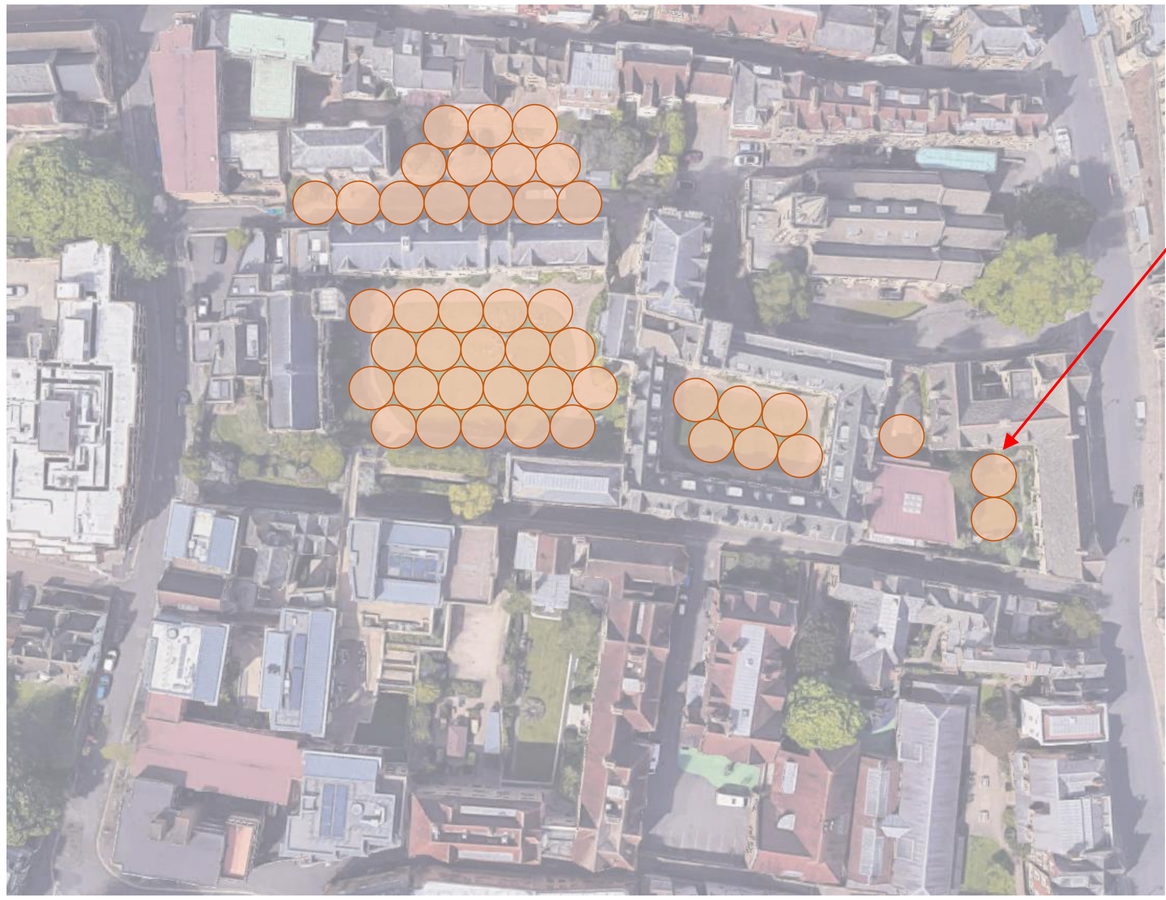
Staircases 3-6 would be an extension of the heating system serving Staircases 1-3, with main distribution pipes routed through the loft and new vertical pipe drops to distribute to spaces.

Sources of heat:

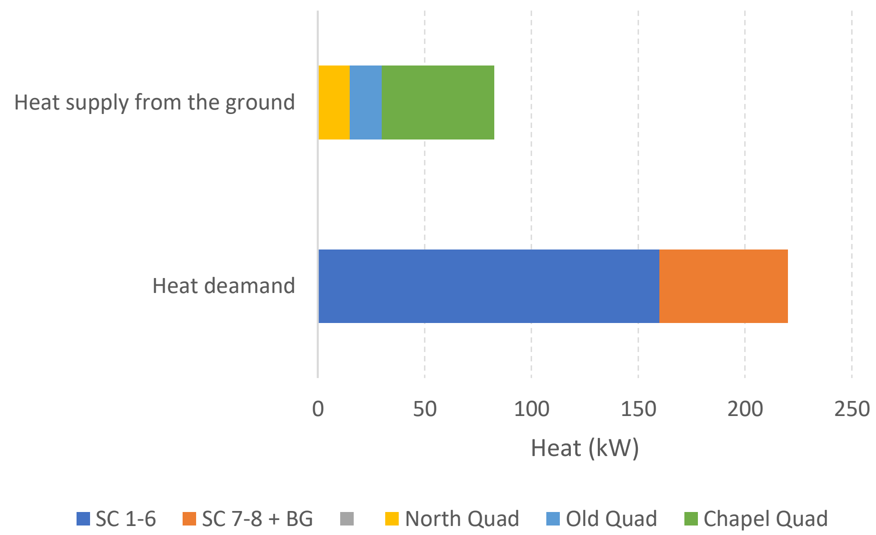
There are two sources of heat available. The ground and the air.

The ground over the whole of North Quad, Old Quad and Chapel Quad offers ~90 kW of heat. This is insufficient and making use of it involves serious archaeological impacts. It is also very expensive. As such, we do not think it is deliverable.

We are proposing air source heat pumps as the means of delivering decarbonised heat.



80m deep Boreholes at 6m spacing



OLD QUAD – RADIATORS

The overall annual efficiency for any particular heat pump led heating system depends on the system temperatures, the external temperatures during the year and the building's load profile.

- Systems are more efficient when it is warmer outside
- Systems are more efficient when the heating system itself is run cooler.

To maximise efficiency, a heating system should be controlled so that the system temperature is minimised while meeting the load at any given time. This maximises efficiency throughout the year and makes a very big difference to the overall performance of the system.

Practically, this means heat emitters should be as big as they reasonably can. This allows them to meet a given load at a lower temperature.

Part of the proposals are larger radiators throughout to maximise heat pump efficiency. The proposed radiator sizes are shown on drawings M-14100. These sizes have been carefully considered to maximise system efficiency while being sensitive to heritage and architecture.

With smaller radiators, the heat pump efficiency will reduce and also their electrical power consumption, putting more stress on the limited electrical infrastructure.

The radiator size does not affect the heat pump size.

See MFLLP drawings M14100 for radiator proposals.

HERITAGE AND DECARBONISATION

There are various aspects to the decarbonisation proposal and these are interlinked.

Fabric improvements reduce both the peak space heating demand and the annual space heating demand.

Larger radiators do not affect the peak space heating demand, but do make heat pumps operate more efficiently and so reduce the peak electrical demand and overall energy use.

Both fabric improvements and radiator size have some architectural / heritage impact and we have looked to optimise and balance these.

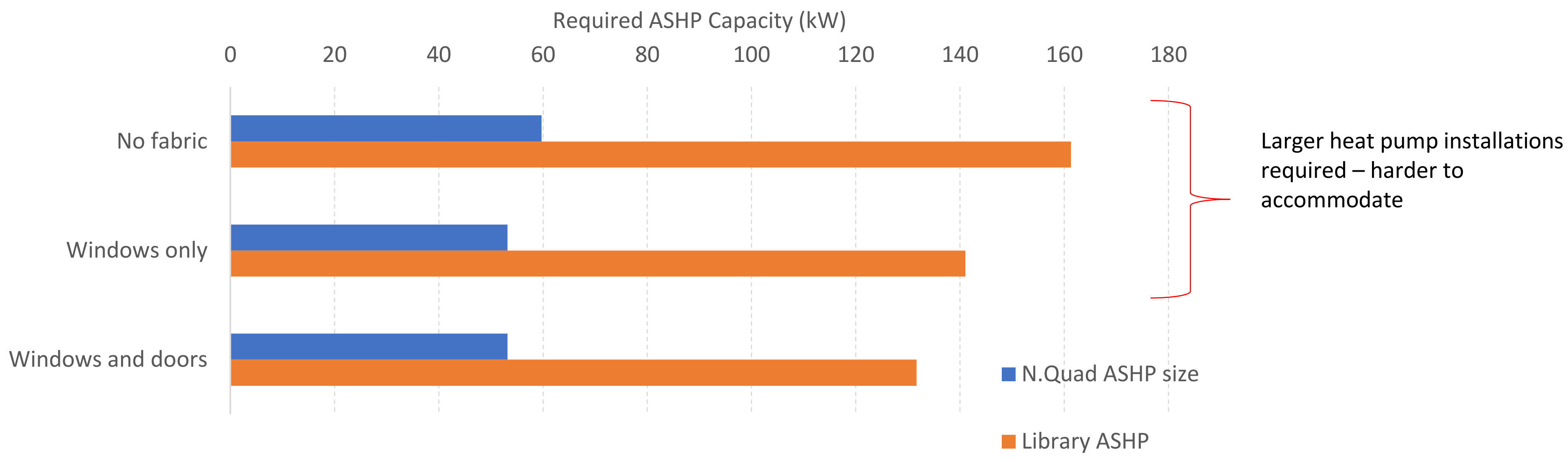
Improved fabric leads to:

- reduced heat pump size (and consequentially, reduced enclosure size)
- reduced required radiator size (all else being equal)
- reduced heat output needed at heat pumps

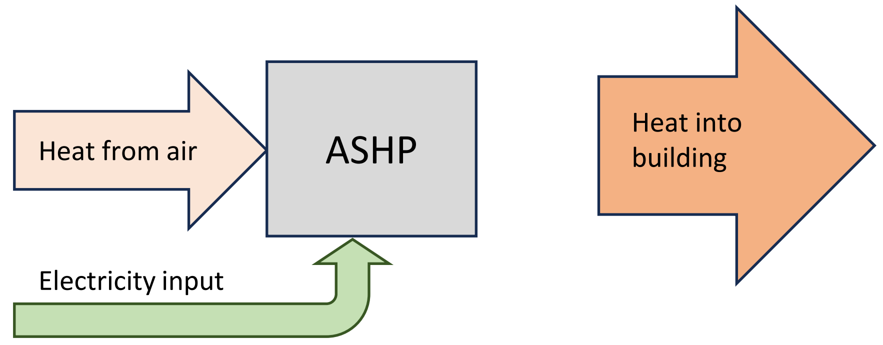
Larger radiators lead to

- reduced electrical consumption at heat pumps

Because fabric improvements reduce the amount of heat required, they are the ONLY thing which reduces the physical size of the heat pumps and their enclosures. Which must be sensitively integrated into the site and its context.

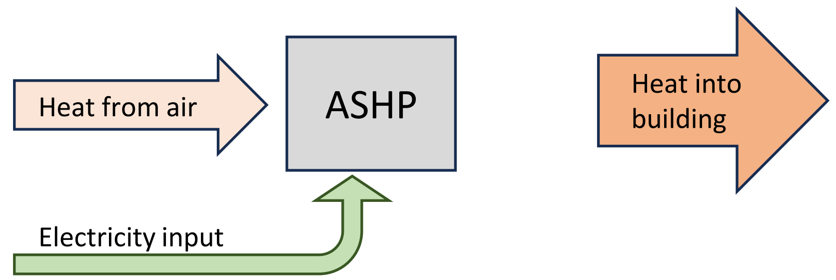


No fabric improvements



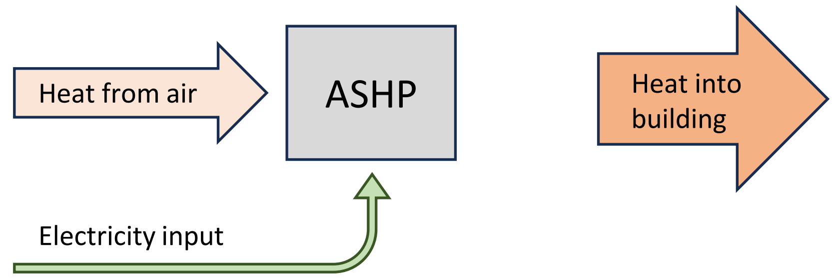
Highest heat demand,
Highest electrical demand,
Largest heat pumps

Proposed fabric improvements, small radiators



Lower heat demand,
Moderate electrical demand,
Smaller heat pumps

Proposed fabric improvements, large radiators



Lower heat demand,
Smallest electrical demand,
Smaller heat pumps

SITING ASHPS - NORTH QUAD

There is a wider estate decarbonisation plan. There are two general heat pump positions for Old Quad:
- North Quad Area
- McGowen Library Roof

What is important for Old Quad is that these two heat pump positions will need to accommodate other buildings' heat pumps in the future. This has been minimised as far as possible by planning to site other ASHPs elsewhere.

In particular:

- the Library Roof area should eventually accommodate ASHPs for the Masters Lodgings and Almshouse

- the N. Quad ASHP area should eventually accommodate ASHPs for SC-18, which has no sensible alternative position.

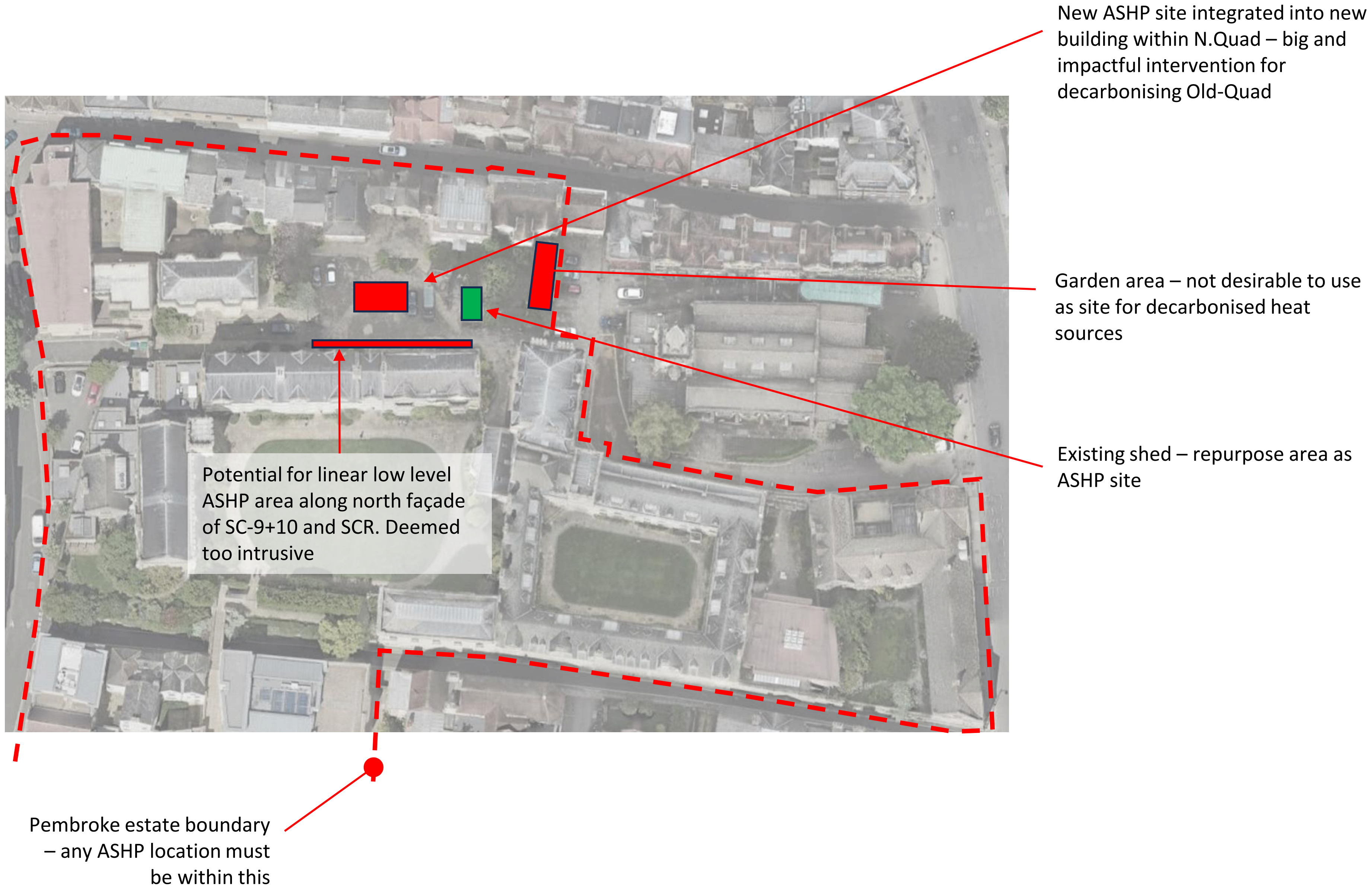
N. Quad Area:

The shed area in North Quad is the only suitable space for decarbonised heat sources for several buildings in the Pembroke Estate.

The area has been reviewed and it is not feasible to install large quantities of ASHPs here. The only future masterplan building which would be served from this plant area is Staircase-18.

Only heat pump plant serving Staircases 7-8 + Broadgates need be accommodated as part of this design, but spatial provision and electrical capacity for the nearby Staircase-18 is provided

Several potential ASHP positions are shown here. The most suitable is the area at the existing garden shed. A proposal for siting ASHPs here has been developed –See Design and Access Statement for further discussion.



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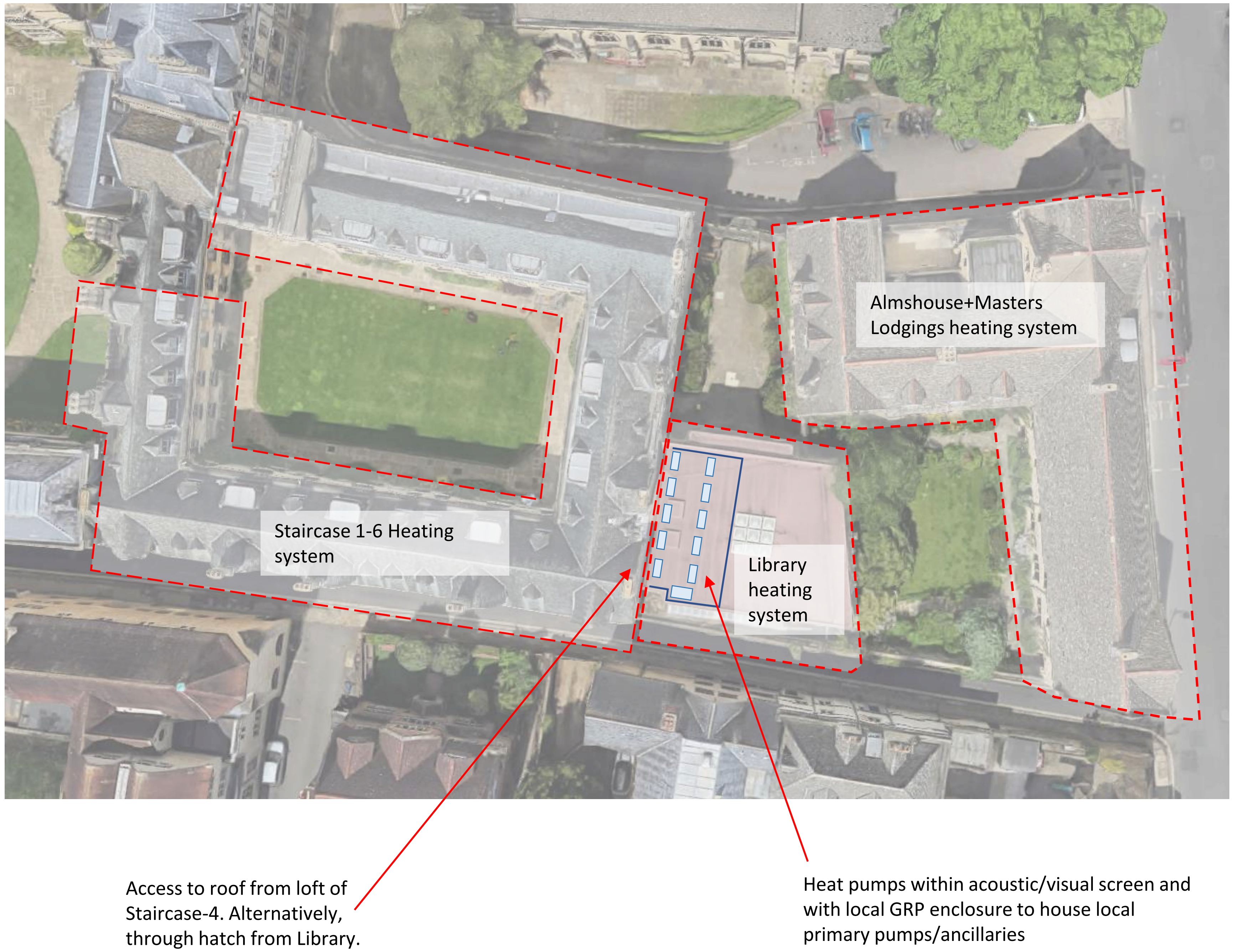
SITING ASHPS - LIBRARY ROOF

The ASHPs required for Old Quad on the Library roof are shown here.

A proposal for siting ASHPs here has been developed – see drawing MXF-LB-02-DR-M-00100 and Design and Access Statement for further detail.



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OLD QUAD – DHW PROVISION AND WATER SERVICES

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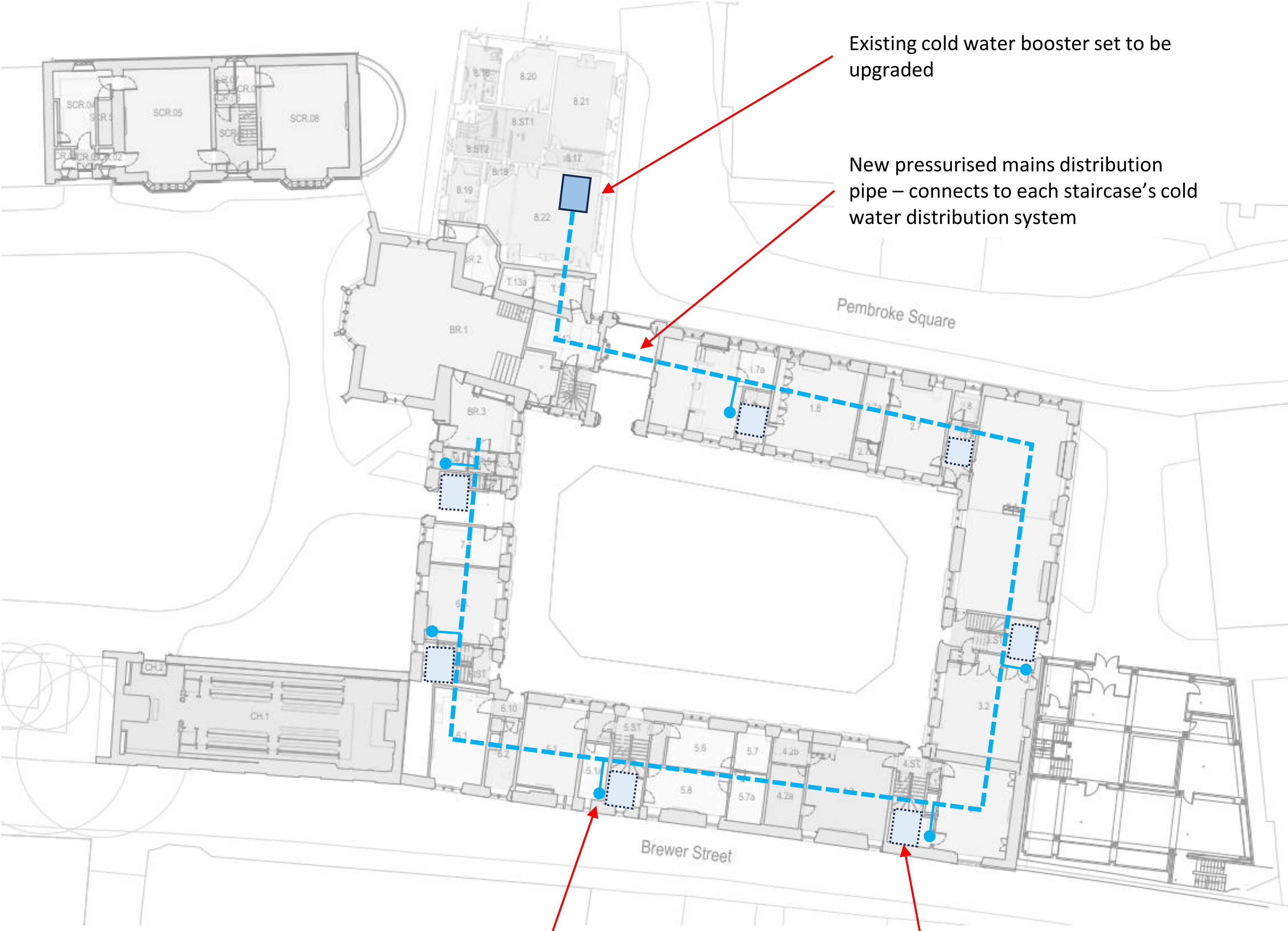
While there is extensive Domestic Hot Water provision within Old Quad, it is largely used only sporadically.

Existing centralised recirculating DHW systems would then be expected to increase the annual demand for heat by a factor of 3 or so.

We propose that DHW is produced locally with direct electric water heaters generally.

See MFLLP P-20100 series drawings for details.



Existing cold water booster set to be upgraded

New pressurised mains distribution pipe – connects to each staircase's cold water distribution system

Loft tanks to be drained and removed (typical)

Boosted CWS to be connected to individual gravity fed systems via pressure reducing valves. Down-service pipes may need to be replaced and increased in size in some places

ELECTRICS

There is a need to provide electrical supplies to new decarbonised heat sources. The Main Quad electrical infrastructure is shown here, with additions anticipated for Old-Quad decarbonised heat sources shown.

See MFLLP drawings M-00100 for further details of the proposed electrical works and routing of cables.

It is necessary that a new cable will need to be taken from PB.02 to the Quad ASHP area. The cable will be sized for all ASHPs in the wider decarbonisation plan in this area

The currently designed route is trenched externally.

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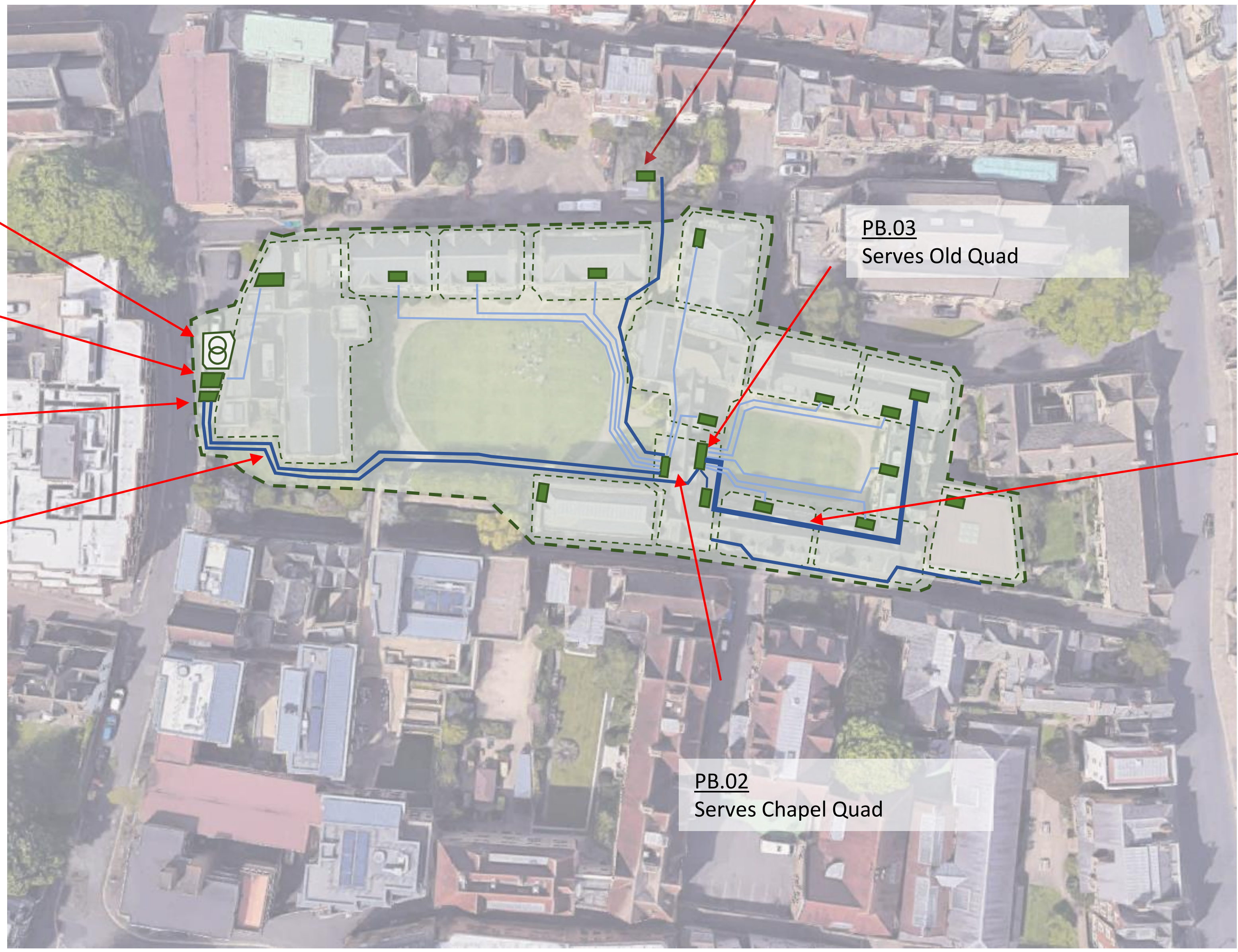
Main site SSE Owned Substation.

Main site switchgear.

PB.01
Serves Dining Hall

Cables from substation to Old Quad panelboards to be upsized



It will be necessary for a new cable will need to be taken from PB.03 to the Library roof, with a new local weatherproof plant area to serve ASHPs. The cable will be sized for all ASHPs in the wider decarbonisation plan in this area.

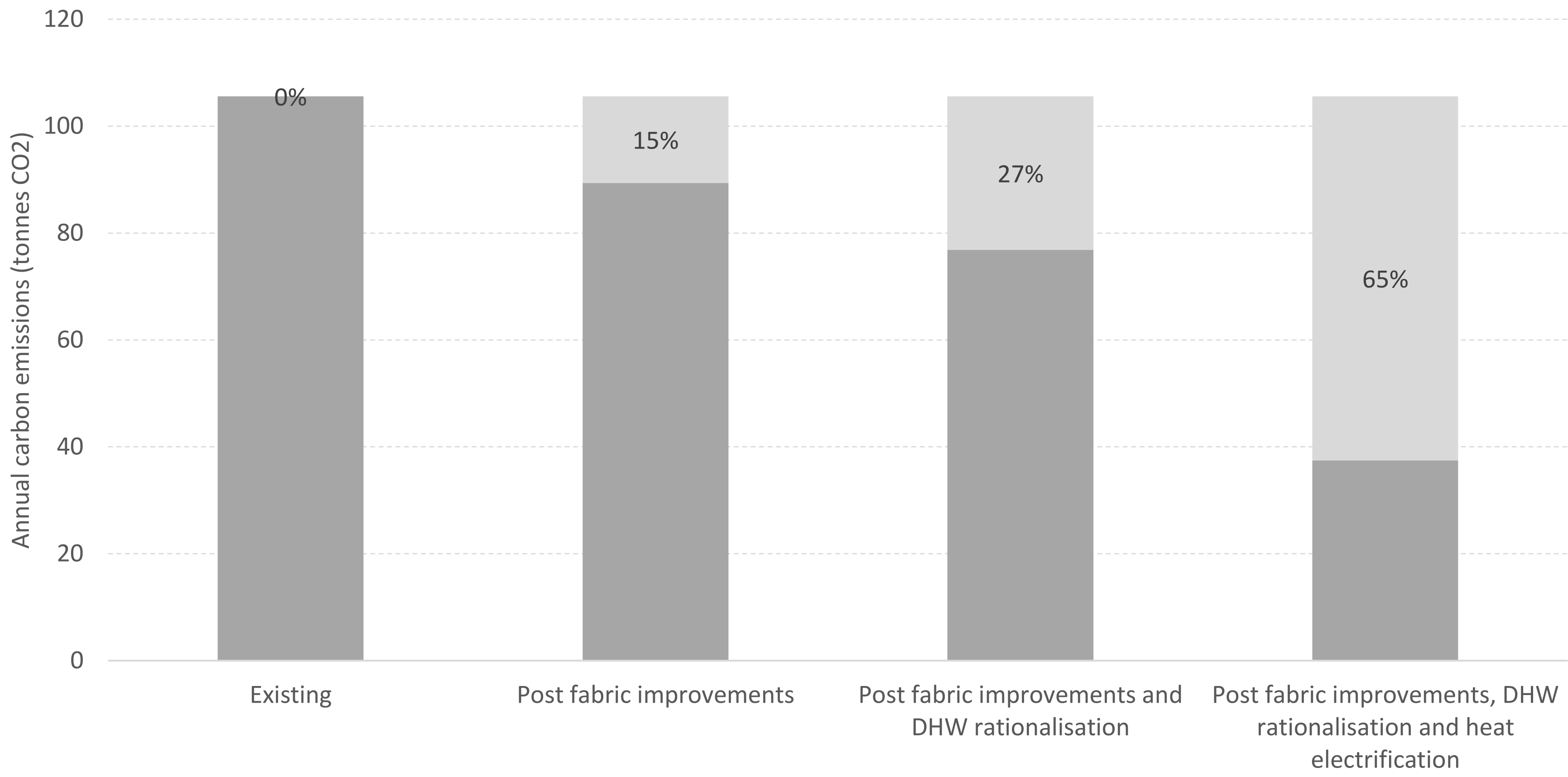
The currently designed route is through the loft above Staircases 3,4,5,6.

DECARBONISATION MEASURES - OVERALL

The overall impact of the decarbonisation measures are shown here.

At current Part-L grid carbon intensities, this reduces the building's carbon emissions by 65%.

However, removing fossil fuels and electrifying all energy loads puts the building on a pathway to decarbonisation as the national grid decarbonises.



Carbon factor - gas	Gas ($KgCO_2$/kWh)	0.21			
Carbon factor - elec	Electricity ($KgCO_2$/kWh)	0.14			
		Annual energy consumption (kWh/yr)	Annual carbon emissions (tonnes CO2/yr)	Percentage reduction from existing carbon footprint	Percentage reduction of measure from previous measure
Existing	Gas	307,395	65		
	Electricity	292,958	41		
	Total		106	0%	0%
After fabric improvements	Gas	251,559	53		
	Electricity	261,126	37		
	Total		89	15%	15%
After DHW rationalisation	Gas	199,452	42		
	Electricity	249,584	35		
	Total		77	27%	14%
After heat electrification	Gas	0	0		
	Electricity	267,468	37		
	Total		37	65%	51%

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