Low carbon heritage buildings

Case studies

ARUP Kirklees Council Leeds City Council YoHrSPACE Yorkshire & Humber Improvement and Efficiency Partnership

Foreword

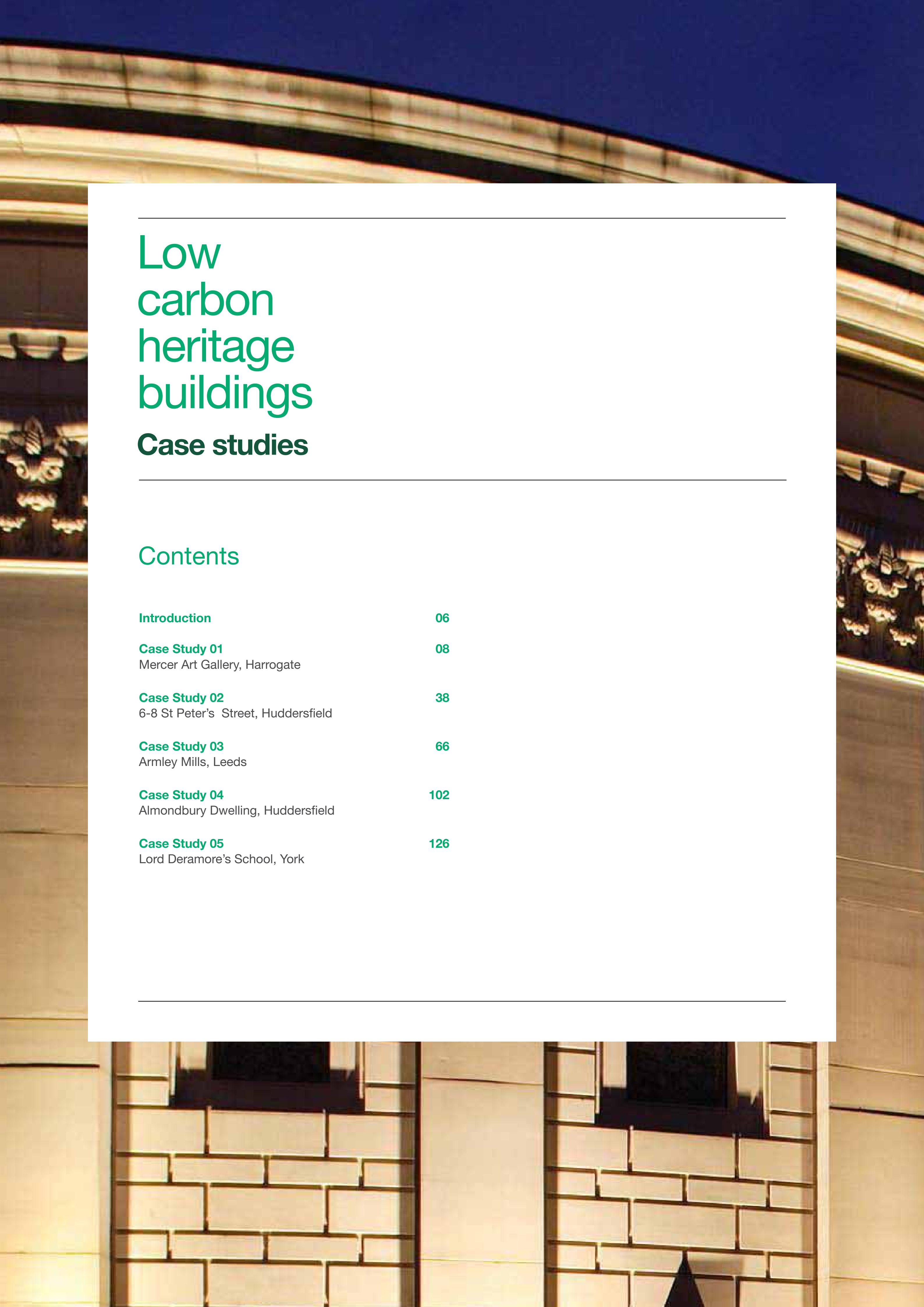
Yorkshire has a multitude of heritage assets with varied constructions and styles that together help to make Yorkshire such a unique and wonderful place.

These case studies are designed to complement the ‘Low carbon heritage buildings: a user guide’ by demonstrating how typical Yorkshire archetypes can be made low carbon without destroying their heritage value.

These are critical publications, proving that low carbon and heritage are not mutually exclusive choices.

Cllr Arthur Barker

Councillor Arthur Barker



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Introduction

Our region's heritage buildings immeasurably enhance the built environment. However, many of them are inefficient in terms of energy use and they are under increasing pressure to contribute to national carbon emissions reduction targets.

Due to their construction and the restrictions placed on the alteration of both designated and non-designated heritage assets, emissions reductions in these buildings are often seen as difficult to achieve. That they are generally harder to treat than more modern building is undeniable, but there is almost always something that can be done.

This document, containing the case studies of five buildings, accompanies a guidance document on low carbon heritage refurbishment. The guidance document describes the process that should be undertaken and provides information and advice on how to carry out each of the steps.

These case studies follow the process laid out in the guidance in order to give real practical examples of the types of carbon reducing interventions possible.

Whilst there are some patterns in the results of the case studies in terms of cost, payback and suitability of interventions, the fact that every heritage building is unique means there is no guarantee that these patterns will apply to other buildings. A detailed study should be carried out for each potential project, not least because accurate and comprehensive justification will necessarily be required by the planning process before permission is granted for work to begin on a heritage asset.

The case study buildings, each of them Grade II or II* listed, are as follows:

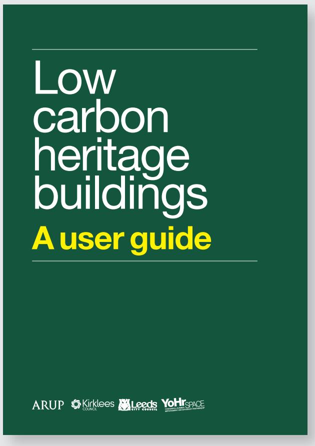
Mercer Gallery, Harrogate
Built in the late 19th century, this building represents not only museums and art galleries that are often located in heritage assets but also Victorian civic and community buildings.

6-8 St. Peters Street, Huddersfield
This mid-19th century Victorian commercial building is representative of many stone-built heritage assets in centres around the region.

Armley Mills, Leeds
Built early in the 19th century, this building, once what was perhaps the world's largest woollen mill, represents the many other former mills and industrial buildings so prevalent in our region.

Almondbury Dwelling, Huddersfield
This early 19th century two-storey stone handloom weaver's cottage is representative of its type and also, from an engineering perspective, the many other solid walled dwellings of the region.

Lord Deramore's School, York
This mid-19th century primary school represents the many brick-built community schools that date from this time, with the small panelled windows being particularly important to the character.



Images from top left:
Mercer Gallery, Harrogate; 6-8 St Peter's Street, Huddersfield; Almondbury Dwelling, Huddersfield; Lord Deramore's School, York; and Armley Mills, Leeds





Case Study 01

Mercer Art Gallery, Harrogate

01 Summary

The Mercer Gallery is a free art gallery in Harrogate owned and operated by Harrogate Borough Council. It is Grade II listed and is a good example of a Victorian civic building, built as assembly rooms and later used as a theatre and council offices before conversion to its current use in 1991.

The aesthetic and architectural value of the building is concentrated on the exterior of the front block facing Swan Road, and in the former assembly hall/ main gallery, which is a space of high significance with coved plaster ceilings and glazed roof lights. Single-glazed arched windows and front entrance doors probably date from c.1875 and are part of the high significance of the principal elevations.

The building is of solid wall construction in sandstone with slate roofs of differing designs including steep French-style pavilion roofs over the front range. In 1991 the Council refurbished the building for art gallery use. The concrete floor structure, basement store, new lift and principal building services date from this time and it is apparent that some energy efficiency measures were introduced including roof insulation and secondary single glazing. The external walls are uninsulated.

The building has been maintained to a reasonably good standard, although there is some disrepair in the external walls and windows. The mechanical and electrical services are relatively simple but since the services were installed in 1991, the central plant has become less efficient and nearing the end of its design life. The building is heated by a gas-fired boiler and radiators with very limited system controls. Lighting is generally by tubular fluorescent fittings. There is no sub-metering of electricity. Domestic hot water is provided from a large and relatively inefficient immersion system in the kitchen.

The emissions from the building are split equally between gas and electricity. Comparison with benchmarks shows that the electricity usage is as expected from a building of this type but a very flat annual profile indicates that the benefits of natural light are not being maximised. The energy used to heat the building is much higher than comparable buildings, being approximately double that expected in a building employing good practice techniques.

There are opportunities to reduce carbon emissions from the building but these are limited by the historic significance of the elaborate interior of the main gallery space which will not allow internal wall insulation. This case study tests the indicative costs and benefits of 21 possible interventions. All of these would provide worthwhile savings in carbon emissions but for some payback is distant, even taking into account the more rapid payback that is likely to result from predicted energy price inflation. They could be considered as part of larger project if funding becomes available.
The following are the most significant recommendations, which could result in substantial annual savings:

- A range of behaviour change related items which can be implemented at minimal cost
- Doubling the existing roof insulation
- Internal insulation of external walls as part of general refurbishment
- Replacement of existing light fittings with low energy equivalents
- Replacement of the domestic hot water system
- Replacement of the existing boilers, pumps and control system
- Installing photovoltaic solar electricity panels to the south facing roof but payback periods may be delayed as a result of probable changes in the Feed-In Tariff.

02 Heritage value and statement of significance

Statement of significance

The Mercer Gallery is a good example of a Victorian civic building, built as assembly rooms and later used as a theatre and council offices. The aesthetic and architectural value of the building is concentrated on the exterior of the front block facing Swan Road, and in the former assembly hall/main gallery, which is a space of high significance.

Single-glazed arched windows and front entrance doors probably date from c.1875 and are part of the high significance of the principal elevations. The entrance foyer and flanking rooms are also significant although these areas have fewer intact architectural features and finishes than the main hall.

The north elevation (left return) is prominent in the townscape and, together withthe frontage, contributes to the character of this part of the conservation area. The basement and ground floor structure were substantially altered/renewed to create a secure art store in c.1990 and have low significance.

The south elevation (right return) and rear elevation are largely hidden from public view and of modest architectural quality; although this area has some historic value, it is of no more than medium significance. The former domestic interiors have been substantially altered for office use and are now of medium significance. The Grade II listing is appropriate for the building (listing reference number 1293862).

Inside the gallery

The interior of the main gallery space probably originates from 1875 and is of high significance.

Summary table

The table below summarises the key building features and their relative significance for ease of reference.

Building feature	Significance	Date
Windows: W front	High	Probably 1875
Windows: N elevation	High	Probably 1875
Windows: S elevation	Medium	Various dates, C19- C20
Windows: E (gallery)	High	c.1875
Windows: E (sashes to offices)	Medium-High	Mid to late C19
Windows: E casements (C20 to offices)	Low	C20, various
Doors: Front entrance	High	Probably 1875
Doors: N, fire/disabled access	Low	1990s
Doors: E elevation yard	Low	1990s
Interior: Main gallery walls and ceiling	High	Probably 1875, restored 1991
Interior: N gallery walls and ceiling	Medium-high	Probably 1875, altered 1990s
Interior: Offices S range	Medium	Mid C19, altered C20
Interior: Offices SE former house	Medium	Mid C19, altered C20
Basement below gallery (store not seen)	Low	C19, altered 1990s
Basement boiler room	Low	C19, altered 1990s
Basement below offices	Not seen	
Crawl space/basement below front block	Not seen	
Roof spaces: Gallery	Not seen	Main gallery roof could be early 1800s, front range probably c.1875
Roof spaces: Former house	Not seen	Mid C19

Arched glazing in gallery space

Single glazed arched windows are part of the high significance of principal elevations.

The building – evolution, description and setting

Building evolution

Harrogate became popular as a spa from the early 19th century with hotels and public facilities built in Low Harrogate, around the hot thermal springs. Assembly rooms were an essential public facility in fashionable late Georgian towns. Plans for an assembly room were produced by the architect John Plaw as early as 1790, but the assembly room on Swan Road was not built until 1806, funded by a subscription launched in 1804.

The building is shown on the 1st edition OS map of c.1850 (1:10560), named as Promenade House. The map suggests that the assembly room at this date included a front block, but the 3-storey house attached to the SE corner of the rear is not shown; this may have been built as a caretaker's house. The house and 2-storey south additions first appear on the OS map for 1892-92 (1:500), but the character of these buildings suggests they may have been built in the third quarter of the 19th century rather than later.

The assembly hall was remodelled by the Harrogate architect Arthur Hiscoe in 1875, around the same time that Hiscoe designed a new market building and other large buildings for the town. The 1875 work probably included rebuilding the front block with pavilion roofs, new fenestration and facing to the north elevation and a new interior to the assembly hall with coved plaster ceiling and glazed roof lights. The 1891-92 OS map names the building as the Town Hall Theatre.

The use of the building has changed over the years and during the second half of the 20th century it was in use for Council offices and known as the Promenade Rooms. In 1991 Harrogate Borough Council refurbished the building for art gallery use, re-named after local artist Sidney Agnew Mercer; the Mercer family was a major donor. The concrete floor structure, basement store and new lift date from this work. The building was awarded a Harrogate Borough Council Design Award in 1992. The north gallery (in the front block) was refurbished in the late 1990s.

The building's fabric and character

The single-storey entrance block faces west; this has a symmetrical 7-bay elevation with central Victorian panelled doors and arched single-glazed windows. The building is constructed in solid carboniferous sandstone masonry, faced in ashlar to the front and north, with dressed, coarser stone to the south and rear. The front range has steep French-style pavilion roofs with fish scale slates to either end, with areas of flat or low-pitched slate roof over the central area.

Behind this the long, rectangular former assembly room is contained under one shallow-pitched hipped roof, possibly retaining the 1806 roof structure. The arched windows to north and west elevations are single glazed timber windows, with side-hung opening lights sealed shut. The secondary glazing is modern. The side doorway on the north elevation has a ramp and serves as a disabled entrance and fire exit; the doors are modern replicas. The staff offices are arranged in the 2-storey lean-to addition on the south side and in the former 3-storey house to the NE corner; windows are single-glazed sashes or casements.

Inside, the main gallery is uninterrupted except for an inserted disabled WC to the SE corner, and a service lift shaft to the NE corner; the latter connects to the basement, which is serviced from a rear yard. The lofty gallery space is lit by arched single-glazed windows along the north elevation and east gable end and via roof lights. The floor structure of the gallery is concrete, renewed during the 1991 refurbishment, but the decorative plaster ceiling with deep coving appears to date from the 1875 phase. The roof space and structure over this has not been seen (inaccessible at time of visit). The domestic-scale interiors of the offices have been re-fitted on several occasions and retain no architectural features of note; most of the joinery and finishes appear to be 20th century, probably renewed for Council office use.

Building setting

The Mercer Gallery is located in Low Harrogate, an area with a concentration of civic and public buildings including the Royal Baths, to the south-east and Council offices to the north. The north elevation of the gallery defines the south side of this part of Crescent Gardens which slopes down to the north. Swan Road is a town centre street lined with a mix of residential, hotel and commercial property, with a fairly dense urban grain, part from the gardens to the NE. The single-storey frontage of the gallery gives it a fairly reticent presence in the street scene, compared with higher buildings close by.

03 Building condition survey

Almost any intervention designed to reduce the emissions of a building will impact on existing building elements and services. It is therefore important to establish their condition to fully understand the implications of the changes being proposed.

The project team undertook a high level, non-intrusive condition survey of the building on the 31st of August 2011. Access to gallery and exhibition spaces was restricted due to an on-going exhibition. It was not possible to access the archives and the loft. A summary of the findings is included below.

Fabric

The building was subject to a major refurbishment in 1991 when it was converted to its current use. It has generally been maintained to a relatively good standard, particularly in the 'front of house' spaces. There are some maintenance issues and there is scope for improvement in thermal performance. However, this would be limited by the need to retain the historically significant elements of the interior of the main gallery space.

Basement external wall

Poor quality re-pointing with cementitious mortar.

Glazing in office

Significant deterioration of window frames in places. Peeling of paint and draught strips not installed.

Main gallery external wall

North elevation in ashlar stone and currently in good condition. Historically significant elevation.

Office elevation

Southern elevation with rooflights above office. Less significant elevation and a number of ventilation louvres installed.

Office circulation

Stairs to first floor office accommodation

Results of building fabric condition survey

Item	Location	Detail	Condition

Roof structure	Main gallery and office	- Traditional pitched and hipped timber structure
		- Slated with clay ridge tile and rolled lead hip detail
		- Marginal void at apex of roof above raised ceiling
		  - 150mm approx mineral wool insulation above ceiling level in 2nd floor office
		  - Assumed similar throughout
			- Generally in good condition
			- Significant undulation to ridge of main gallery
			- Gaps with loose masonry around exposed rafter ends along south elevation
			- No signs of ventilation to roof structure - assumed to ventilate through un-felted roof structure or through breathable felt
			- Felt to office roof

Ceiling	Main gallery	- Flat of ceiling raised above eaves with curved eaves detail to perimeter of gallery space - Elaborate plasterwork detailing - 3no. multi-pane prism lay light with splayed panelled reveal	- Good condition - Recently refurbished
	Office and service spaces	- Gypsum board flat ceiling - Ceiling joists tying rafter ends	- Some cracking and uneven in places - Gaps between insulation lengths - Ceiling joists uncovered by insulation
Walls (exterior)	Main gallery (north and west elevation)	- Ashlar stone with small areas of light weathering to string detail and lower plinth up to cill height (west elevation).	- Good - Light moss growth at lower plinth level
	Office and service spaces (east and south elevations)	- 550mm thick, coursed stone - Various stone infills to previous window openings to rear elevation	- Poor quality patched re-pointing with cementitious mortar - Some stones with degraded faces and some with full mortar coverage presumably due to extensive weathering - Significant cracking to straight joint between gallery and adjacent, incorporated domestic building to rear elevation - Cracks to various stone lintels and cills to rear and east elevation

Results of building fabric condition survey continued

Item	Location	Detail	Condition
Walls (interior)	Main gallery	- Plaster finish with decorative detailing	- Good - Recently refurbished
	Offices (ground and 1st floor)	- Modern gypsum plaster lining at ground level - Some plaster parging	- Poor condition at first floor - Some gaps and cracks
	Basement	- Exposed stone of walls with infill of stone and engineering brick in areas where basement lights/vents would have been. - Extensive use of inappropriate cementitious mortar pointing. - Dampproof membrane lapped up and chased into wall at low level – visible along north corridor	- Significant dampness to walls with efflorescence and significant deterioration of masonry - Small amounts of black mould growth to north in humid pockets sheltered form course of ventilation
Floors	Main gallery	- Modern concrete floor (from 1991 refurbishment) - Timber board surfacing - Ventilation grills into basement corridor	- Good condition
	Basement	- Exposed cast concrete with DPM	- Good condition - No sign of insulation, but assumed to be installed to meet regulations
Windows	Main gallery (north and west elevations)	- Repeated window style with central timber mullion and arched top light (with horizontal glazing bar to west elevation) - All originally fixed lights - Some smaller opening casements have been inserted into original single pane lights - All timber frames with clear single glazing panes - No ventilation integrated into widows - Single glazed secondary glazing installed - Internal blinds constantly drawn shut - Skylights to main gallery hall artificially lit	- Generally sound condition - Some cracking and peeling of paintwork to bottom rail of window frames and cills - Signs of previous repairs to sections of frame
	Office and service spaces (east and south elevations)	- Various window styles including casements and vertical sliding sashes - All timber frames with single glazing - No ventilation integrated into windows - Single glazed secondary glazing	- Significant deterioration of window frames, glazing bars and seal to glazing in places - Peeling paint - No draught stripping - Difficulty with operation of some secondary glazing units and windows

Results of building fabric condition survey continued

Item	Location	Detail	Condition
External doors	Main gallery space (entrance)	- Solid, raised and fielded, timber panel doors with timber side panels - Single pane arched fanlight (assumed to be single glazing) - Painted finish - Internal vestibule	- Generally in sound condition - Main front entrance continually open during visiting hours with inner vestibule doors also held open - Draught stripping of all doors undetermined
Above ground drainage	Main gallery (north and west elevations)	- Lead or cast-iron downpipes and hoppers - Hidden gutters behind stone parapet to front, rear and west elevation - Surface water gravel channel (French drain) along north elevation wall below ground floor slab level	- In good condition - Hidden gutters assumed to be in good condition -no sign of vegetation growth or overflows from blockages - Poor drainage to surface water gravel channel along north elevation
	Office and service spaces	- Half round gutters on brackets	- Small amount of vegetation growth to gutters - Irregular gradient to gutter falls

Building services

Boiler plant

Space heating is provided from two 53kW Hamworthy gas fired boilers installed around 1990. The boilers serve panel radiators. The central plant includes two independent variable temperature heating circuits serving offices and gallery. The gallery heating circuit is operational all year round while the office heating circuit is switched off in summer.

Constant speed pumps serve the heating system. The heating system is currently zoned and due to the limited size of the installation, it is unlikely to be cost-effective to provide variable speed control.

Controls

The heating system is controlled by a Landis & Gyr automatic control system installed in 1991. Temperature in the gallery is controlled by a wall mounted temperature sensor mounted at high level. The position of the sensor is unlikely to give a representative reading for controlling the space temperature in the gallery. Humidity control is currently not provided in the gallery.

The boiler control includes time control, but no facility for optimum start, automatic trend logging, alarm handling and monitoring etc. The gallery staff have limited access to adjust the control system. Thermostatic radiator valves (TRVs) are installed on radiators.

Ventilation

The gallery and office spaces are served by natural ventilation from opening the main entrance doors and through the windows in the offices. The gallery windows are fixed pane. Whilst windows in the offices are openable, the occupiers rarely open them to avoid compromising the museum security. The museum has a generous floor to ceiling height and exposed thermal mass from the heavyweight construction making natural ventilation appropriate for most spaces. 'Through the wall' extract fans are installed in some offices ; however, these are no longer operational. The extract fans remove heated air from the offices without the introduction of any make up air.

It does not appear that a ventilation system serves the archive store. Air movement in the basement corridor surrounding the archive store is provided by a fan mounted in the corridor. This would appear to draw warm air from the gallery through a floor-mounted vent on the north side and to vent it into the gallery via a similar vent on the south side. It is assumed that this is to help reduce humidity in this corridor but there is still significant dampness.

Control panel

Lydis & Gyr automatic control system maintaining space temperature in gallery and office areas. Relative humidity is not controlled.

Humidity

It is understood a local humidity control plant serves the basement archive store. The type of humidification plant should be reviewed to ensure humidity control only uses low energy plant by, for example, adopting a conservation heating approach.

Domestic water services

The building is served by mains cold water. The domestic hot water service is used to serve a kitchen and hand basins. An immersion heated hot water tank above the kitchen sink generates and stores domestic hot water. Approximately 100 litres of hot water is served. It is inefficient and carbon intensive in its current configuration. There is limited control of the domestic hot water system. Foil faced mineral wool fibre insulation is applied to domestic water pipework.

Power and lighting

The incoming power supply enters at basement level. There is evidence of ground water ingress adjacent to the entry point.

Artificial lighting serves the gallery and offices. There is a mixture of light fittings including T8 linear fluorescent fittings. Roof lights complement artificial lighting in two offices. Three large glazed lay or borrowed lights are set in the ceiling of the main gallery. These would originally have been lit by roof lights but currently electric lighting is installed above the lay lights which act as decorative diffusers for the lighting. The diffused lighting provides background illumination to the gallery. Local lighting is provided for display cabinets and exhibits. Lighting control is by manual switching. There are no automatic controls. This is appropriate to the relatively simple systems installed.

Domestic hot water cylinder

Hot water provided by electric immersion heaters.

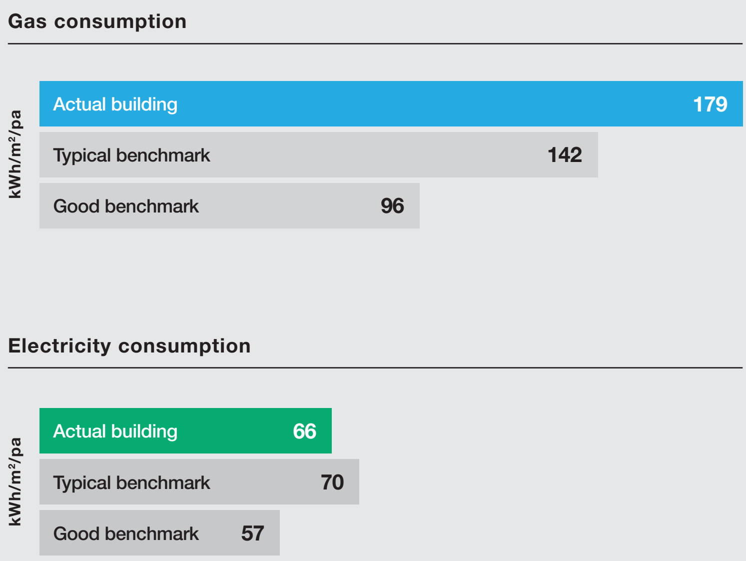
04 Bill analysis and benchmarking

The energy use at Mercer Gallery has been compared with benchmarks for gas and electrical energy consumption. Benchmarks are often defined as reflecting 'typical practice' or 'good practice'. The electricity usage is within the average range.

However, as might be expected of a heritage building, the gas usage for heating compares poorly with the benchmarks, using approximately 25% more energy than even the typical benchmark. Given the national aspirations for long-term emissions reduction, perhaps a more suitable comparator would be the 'good practice'. To reach this standard, a 46% reduction would have to be made.

46%
reduction would be needed to reach 'good practice'

Total energy use at Mercer Gallery



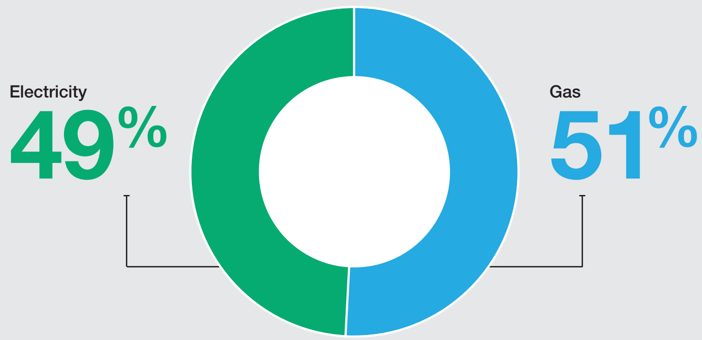
25% more
Gas used than the typical benchmark

Electricity use is within
average range

[1] CIBSE Guide F 2004 Energy Efficiency In Buildings Table 20.1

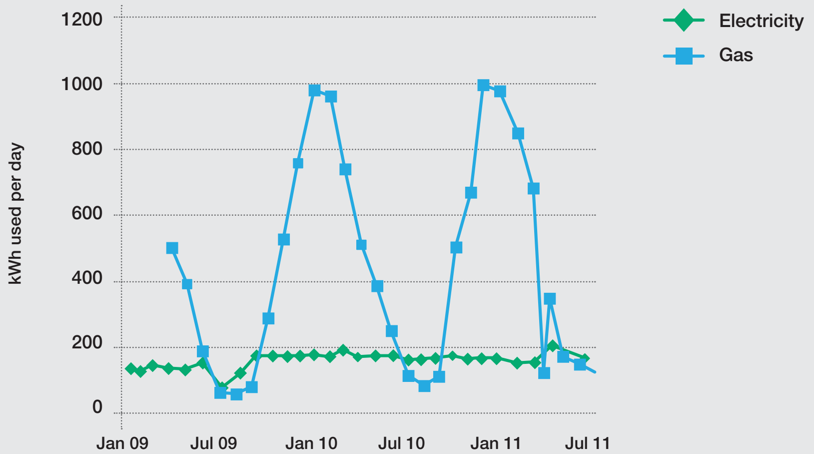
Whilst more of the energy is being used in the form of natural gas, the ratio of carbon emissions is much more even. Due to the fact that much more CO_2 is released to produce every kWh of electricity, this fuel actually contributes 49% of the emissions of the building. Therefore, it is valid to concentrate on both of the fuel types as reductions affect the overall emissions of the building.

Total building emissions - based on CO_2 output



Analysing the consumption over the seasons shows that electricity usage is very constant – perhaps leading to the conclusion that the benefit of increased daylight in the summer hours is not being fully taken advantage of because lights are left on in summer even when sufficient daylight is available. The variation in gas use is mainly as a result of the differing heating requirement throughout the year. During the summer months there is a minimal heating requirement in the gallery to maintain stable conditions. The heating circuit for the office is isolated in summer months.

Historic energy use at Mercer Gallery - Jan 2009 - July 2011



The assumptions and average energy consumption used for the cost-benefit analysis in section 6 of this study, options appraisal, are set out below with other relevant assumptions.

Energy or emissions metric	Mercer Gallery amounts
Estimate of Gross Internal Floor Area	894m^2
Annual electricity consumption	65,635 kWh
Annual gas consumption	170,658 kWh
Average electricity cost	10.22 p/kWh
Average gas cost	2.58 p/kWh
Annual electricity cost	£6,708
Annual gas cost	£4,403
Carbon emission factors - electricity	0.517 kgCO_2/kWh
Carbon emission factors - natural gas	0.198 kgCO_2/kWh

The carbon emissions factors referred to are taken from SAP 2009, the government's standard assessment for the energy rating of dwellings. Part L of the UK Building Regulations 2010 also applies these factors to non-domestic buildings.

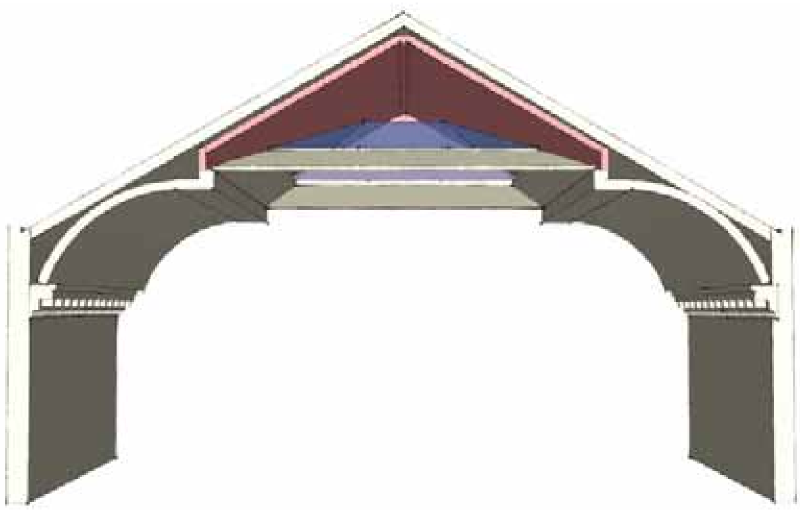
05 Interventions

Scope

Section 3 of this case study explains the building and its services installations. Much of the plant and equipment is 20 years old and either at or beyond its design life. However, a number of factors limit the scope for effective interventions that might be expected to result in major reductions in carbon emissions:

- The 1991 refurbishment was relatively thorough and some insulation, secondary glazing and other energy efficient measures were introduced
- The building services are relatively simple
- The decorative plasterwork in the main gallery is of high heritage significance and it is not practicable to introduce internal wall insulation.

There are, however, possible ways to reduce carbon emissions. The study team selected the interventions that could reasonably be expected to be worthwhile based on experience and these are shown in the table below.



Lay light

Sketch showing suggested insulation above lay light. This requires specific detailing to form a structure to install the insulation.

Feasible carbon saving interventions

No.	Intervention	Description	Heritage impact
Behaviour change			
1	Energy consumption targets/monitoring/ metering	Establish clear and accurate benchmarks of current consumption. Set realistic targets and monitor performance against targets by reading meters, including sub-meters as included below. Key carbon reduction tools.	None
2	Formal staff/building users feedback mechanisms	Establish robust and continuing procedures to use occupiers experience effectively.	None
3	Sustainability brief for staff	Set out and explain the reasons and approach to sustainability. What does it mean for the individual?	None
4	Develop building user/ manager training program	Ongoing training is important including new starters and refresher courses. Strong and clear leadership should be at the root of this.	None
5	Building users' guides, up to date, comprehensive, accessible Operation & Maintenance manuals	Occupiers and facilities managers cannot be expected to use and operate buildings without clear information appropriate to their level of involvement.	None
6	Energy efficient appliance selection	When fridges and kettles are due for replacement select AAA rated appliances. Item 16 includes a new dishwasher.	None

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
Building fabric			
7	Upgrade wall insulation	Insulate the internal face of external walls where practicable in all areas apart from the main gallery. Scarify approximately 400 m2 of existing painted walls to increase moisture permeability. In historic areas remove and set aside skirtings and architraves for reinstatement. Line walls with a layer of natural, breathable insulation (e.g. 75mm of wood fibre board or hemp batts) with suitable detailing to mitigate cold bridging. Apply a lime or clay plaster and natural paint finish.	This will mainly affect areas of medium significance in the offices, where relationships between openings and walls can be managed by careful design. Early discussion with local planning authority is recommended but the benefits of the proposals are considered to justify the internal alterations. In the north gallery, decorative details such as plaster cornices and architraves would be compromised by wall linings, and the impact on significance will be greater.
8	Upgrade roof insulation	Add a further 150mm of mineral wool insulation and resolve local shortfalls. Insulate the space above the lay lights to achieve a similar standard.	None.
9	Install draught strips	Install proprietary draught strips to all internal and external doors.	Draught strips are unlikely to affect significance, but a new draught lobby will affect spatial and architectural character of the main hall and reduce floor area of the gallery. The benefits justify this which can be mitigated by careful design. Early discussion with local planning authority essential.

No.	Intervention	Description	Heritage impact
Building services			
10	Occupancy sensors for lighting	In the office and ancillary areas only to enable automatic shutdown of lighting when spaces are unoccupied.	None
11	Energy efficient light fittings, LED lighting	Replace existing low efficiency light fittings with modern low energy equivalents such as compact fluorescent, T5 high frequency fluorescent and specialist LED display lighting.	None
12	Electrical sub-metering to all key installations	This should cover lighting, small power, machinery, plant. This facility is vital to understand how much power is being used by different services installations.	None
13	Time switches or similar on small equipment	A low cost means of guaranteeing equipment shut down when not in use.	None
14	Photovoltaics (PV) with Feed-In Tariff	Photovoltaic solar electricity panels installed on the south facing roof slope on the secondary elevation. This does not appear to be significantly overlooked but viewpoints should be reviewed with the conservation officer.	The south slope of this large roof is hidden in most views from the public realm as this side of other building overlooks a rear yard area. Viewpoints should be assessed to consider the impact and the integrity of the roof and slates should be addressed as part of the design and installation.
15	New domestic hot water system and dishwasher	Localised, on demand electric water heaters to basins and sinks. New AAA rated dishwasher with cold feed.	None
16	Modify temperature set points	19-20°C to offices and gallery. Consider background only conservation heating to gallery space for greater savings. Staff may need to wear warmer clothing during cold weather.	None
17	Ensure controls are working correctly	Initial review to maximise the benefit and efficiency of existing systems. Ensure that testing is embedded in maintenance regime.	None
18	Introduce demand controlled ventilation	Install three new replacement fans to offices with local timed controls.	None
19	Install digital control system for all major plant	Digital building management system with boiler optimum start, automatic trend logging, alarm handling, monitoring and other aids to efficient operation.	None
20	Upgrade boiler system and pumps	Two replacement, high efficiency gas condensing boilers with high efficiency pumps.	None

Low and zero carbon technologies

The case study team considered a range of possible technologies which are reviewed in the table below.

LZC Technology and Low Energy options	Approximate capital cost	Cost per 1% CO_2 reduction over base building	Operational cost	Future energy costs	Simple payback (without Feed in Tariff/RHI)
Solar Hot Water Panels	Moderate	Moderate to High	Low	Low	Moderate
Photovoltaic	Very High	Very High	Low	Low	High
Gas Fired District Heating CHP	Moderate	Moderate	Moderate	High	Moderate to High
Biofuel CHP	Moderate to High	Moderate	Moderate to High	High	Moderate to High
Biomass CHP	Very High	Moderate	Very High	Low	High
Wind Turbines	Moderate	Moderate	Low	Low	High
Off Site Wind Generation	High	Low	Low to moderate	Low	Moderate
Biomass Boilers	High	Moderate	High	Low	Low to Moderate
Ground Source Heat Pumps	High	Very High	Moderate	Moderate	High
Air Source Heat Pumps	Moderate	Moderate	Moderate	Moderate	Moderate
Open Loop water source heat pump	High	High	Moderate	Moderate	High
Exposed Thermal Mass	Low	Low	Low	Low	Low
Passivhaus	High	Moderate	Low	Low	Low
Maximisation of daylight, daylight controls, automatic lighting controls & energy efficiency lighting	Low to Moderate	Low	Low	Low	Low
Earth Tubes	Moderate	Moderate	Low	Low	Moderate

Noise impact	Planning implications	Funding/ Grants	Applicability to Mercer Gallery	Technical issues/ any other criteria
None	Roof loading and less sensitive elevation	RHI	×	Solar Hot Water limited by low hot water demand. Effective with a centralised hot water system.
None	Roof loading and less sensitive elevation	FIT	✓	Limitation on size of roof area available and possible sensitivity of views from overlooking areas.
Moderate	Flue height		×	Cost effectiveness to be balanced with carbon reduction requirements. Minimum operation hours 4000 to 5000 required to be effective.
Moderate	Flue height		×	Reliability of fuel supply, concern over sourcing of fuel product.
Moderate	Flue height, pollution levels and plantroom size.	RHI	×	Limited number of successful installations. Restricted plant room/ fuel store area, delivery access problematic, planning issues - flue height and NOx levels to address, maintenance costs.
Moderate to High	Planning application required	FIT	×	Not appropriate for city centre locations. Planning implication and output/effectiveness dependent on site specific wind speed.
High	Planning application required	FIT	×	Technology acceptable only with direct link to building as off-site turbines are located remote from buildings. Note visual impact in conservation areas etc.
Low (note noise from delivery vehicles)	Flue height, pollution levels and plantroom size	RHI	×	Plant room/fuel store area, delivery access, planning issues - flue height, NOx levels, maintenance costs.
Low	Archaeological impact to be assessed	RHI	×	Output depends on ground conditions. Limited application of low grade heat produced GSHP means the system is unsuitable for listed building with limited opportunity for fabric improvements to reduce heating demand.
Moderate	Moderate	RHI	×	Noise/plant location, efficiency in winter operation, low grade heat produced by ASHP
Low to medium	Application to Environment Agency	RHI	×	Investigation required to establish if local water body available for operation of water source heat pump
Low	None		✓	Required for natural ventilation systems. Delays peak room temperature reducing risk of overheating in occupied hours.
Low	Historic character of building		×	Low U-values required for walls & glazing not achievable on historic buildings without affecting character of building.
Low	None		✓	Energy efficient lighting and controls can be implemented.
Low	None		×	Disruptive to existing listed builings. Require space for installation and adoption of mechanical ventilation strategy

06 Options appraisal

Introduction

Section 5 proposes different interventions which will generate varying levels of savings in carbon and energy costs. It is essential to be able to compare them to decide which are the most worthwhile.

The options are appraised by cost-benefit analysis, comparing the budget cost of the intervention with the likely potential savings in the current energy costs and carbon emissions analysed in Section 4 of the case study.

The options appraisal is a high-level indicative exercise designed to give a broad brush overview of the relative benefits of different interventions. If it is decided to implement any interventions, a more detailed analysis to test assumptions will be essential.

The cost benefit analysis table on the next few pages uses a traffic light system to show, at a glance, the relative advantages and disadvantages of individual interventions.

Green - Beneficial and worth pursuing

Amber - Less beneficial but still worthwhile

Red - Less likely to acceptable on current assumptions

Cost benefit analysis

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Behaviour change									
1	Energy consumption targets/ monitoring/ metering	Easy win	100	2.0%	5.0%	326	0.3	1.58	None
2	Formal staff/ building users feedback mechanisms	Easy win	100	0.5%	0.5%	51	2.0	0.31	None
3	Sustainability brief for staff	Easy win	100	0.5%	0.5%	51	2.0	0.31	None
4	Develop building user/manager training program	Easy win	100	2.5%	5.0%	356	0.3	2.34	None
5	Building users' guides, full accessible O&M manuals	Easy win	100	0.5%	0.5%	51	2.0	0.31	None
6	Energy efficient appliance selection	Easy win	100	0.5%	0.0%	30	3.3	0.15	None
Building fabric									
7	Install wall insulation	Major	12,000	0%	15%	620	19.4	4.75	Manageable
8	Upgrade roof insulation	Cyclical	2,900	0%	7.5%	310	9.4	2.38	None
9	Install draught strips to windows and doors	Easy win	800	0%	4%	165	4.8	1.27	Manageable

Cost benefit analysis continued

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Building services									
10	Occupancy sensors for lighting	Cyclical	800	0.5%	0%	30	26.7	0.15	None
11	Energy efficient light fittings, LED lighting	Cyclical	7,500	12%	0%	720	10.4	3.64	None
12	Electrical sub-metering to all key installations	Easy win	2,800	5%	0%	300	9.3	1.52	None
13	Time switches or similar on small equipment	Easy win	200	0.5%	0%	30	6.7	0.15	None
14	Photovoltaics (PV) with Feed-In Tariff	Major	21,800	9%	0%	2,333	9.3	2.73	Manageable
15	New domestic hot water system and dishwasher	Cyclical	2,500	10%	0%	601	4.2	3.03	None
16	Modify temperature set points	Easy win	100	1%	5%	266	0.4	1.89	None
17	Ensure controls are working correctly	Easy win	1,000	1%	2%	143	7.0	0.94	None
18	Introduce demand controlled ventilation	Cyclical	800	0.5%	0.5%	51	15.8	0.31	None
19	Install digital control system for all major plant	Cyclical	10,000	2%	5%	326	30.6	2.19	None
20	Upgrade boiler system and pumps	Cyclical	13,000	0.5%	10%	443	29.3	3.32	None

07 Recommendations

Interpretation

All of the suggested interventions show worthwhile significant carbon savings but in some cases (the red items) the capital costs are relatively high and the cash payback in energy cost savings is distant. In part this arises because Harrogate Borough Council has negotiated extremely favourable energy prices and this significantly lengthens the time taken to achieve payback compared with the majority of building owners.

The calculated energy cost saving disregards inflation but it is realistic to anticipate that energy prices will continue to rise at a rate considerably greater than general inflation. It is sufficient to state here that actual payback through energy saving is likely to be much more rapid than shown in the cost-benefit analysis table.

The savings figures in the table are deliberately not totalled. Such totals would be very misleading. Each measure adopted limits the scope for further savings because the total energy use reduces each time. The order of adoption and interaction between different interventions would also have significant impacts on the overall outcome.

At a glance

Recommendations

Adopt measures to change user behaviour

Insulate office walls and double roof insulation

Low energy lighting and control

Replace existing domestic hot water system

Upgrade boilers, pumps and controls

Install photovoltaic panels

Behaviour change

It is essential to reinforce and support physical interventions with training and motivation so that the building is operated efficiently and beneficially to reduce carbon emissions and save costs. Administrators and facilities managers need to have a clear understanding of the building and its systems. This will enable appropriate leadership to arrange training and support for the staff in the building. The group of items in the first section of the table aim to provide a comprehensive range of measures to achieve this.

It is assumed that behaviour change and building management related items can be implemented by existing staff through internal strategies with normal training and personal development which needs to be sustained and continuing. Although some limited external assistance may be required, this is normal for staff training and the cost of each of these interventions is assumed to be a nominal £100. In the circumstances it is recommended that all these measures are adopted.

Glazing at rear elevation

Rear facade is less sensitive than front elevation. Secondary glazing installed to offices.

Building fabric

These interventions show a reasonable payback and should provide substantial annual carbon savings.

- Doubling the roof insulation and ensuring full coverage should pay back in about nine years, even without energy price inflation.
- Installing draught strips to internal and external doors is low cost and should show early benefits in reducing heat losses. This work should include making sure that the inner front doors to the main entrance should be kept closed but unlocked during opening hours to help minimise heat losses, together with overhaul of self-closers are required.

The following measure should be considered as part of future internal refurbishment works when they can be carried out with least disruption:

- Internal insulation of external walls in all areas other than the main gallery where heritage features prevent such treatment. In other areas careful design and detailing will be required.

Building services

Items 11-17 all show payback in around 10 years or less and energy price inflation is likely to improve this considerably.

- Energy efficient light fittings, LED lighting
- Electrical sub-metering to all key installations
- Time switches or similar on small equipment
- Photovoltaic solar electricity panels aided by the Feed-In Tariff
- New domestic hot water system and dishwasher
- Modify temperature set points
- Ensure controls are working correctly.

Recent announcements regarding the likely reductions in the Feed-In Tariff amounts suggest that the payback period of the proposed photovoltaic installation by be made significantly longer than at the currently applicable rate.

The remaining items show an indicative payback within 16-30 years.

- Items 10 and 18, occupancy sensors to turn off lighting when not in use and demand controlled ventilation are assumed to be inappropriate to the gallery. However, they could be considered as part of future refurbishment works to the offices and ancillary areas. The ventilation to the offices is not satisfactory.
- Items 19 and 20 relate to the provision of new boilers, circulating pumps and the installation of modern controls. These measures could perhaps reduce gas and electricity costs by perhaps 15% and 2.5% respectively with carbon savings of around 5 tonnes a year. However, low energy costs result in a projected payback of about 30 years. However, the existing systems are now 20 years old and at the end of their design life. It is recommended that the systems are replaced to avoid the risk of costly and inconvenient breakdown and deteriorating performance.

Other issues and opportunities

The recent refurbishment of the gallery has optimised many possible architectural interventions, resulting in a beautiful and successful space. There are few opportunities for further interventions given the high quality of finish but two may be worth pursuing as funds become available and cyclical maintenance and refurbishment is undertaken.

Reinstatement of patent glazing

Patent glazing would previously have formed part of the main roof to serve the decorative lay lights in the gallery ceiling. These are currently electrically lit and the electrical consumption of this lighting is likely to be a significant part of the total lighting cost. Reinstatement of patent glazing to the roof to naturally light the lay lights could be an option for consideration. This would allow the electric lighting to be automatically controlled by light sensors. This would reduce the requirement for artificial lighting and should reduce energy consumption.

However, this needs to be set against the risk of overheating to the gallery as a result of increased solar gain. The use of natural light can be a sensitive issue for gallery curators.

Such a visible and intrusive intervention as installing patent glazing to the roof of the gallery would require close and thorough investigation of the existing structure to assess historical significance. Close liaison would be required with architectural history and conservation specialists, including the local authority, to advise on the most appropriate solution taking into account the overall change in appearance as viewed from the public domain.

Elaborate lay light in gallery

Patent glazing' 'Reinstating natural lighting through the lay lights would reduce electricity consumption – they are currently electrically lit.

Office spaces

There is scope for improvement to the office spaces, which would generally benefit from building repairs, improvements and carbon reduction measures as proposed. The offices are rather tired and re-designing the layout offices could greatly improve the staff facilities.

Overall heritage impact

The interventions proposed to the Mercer Gallery have been designed to take account of the building's varying levels and aspects of heritage significance, and current policy including PPS5. Some areas of the building such as the offices on the south side are of less significance than the principal spaces. Here it will be possible to make substantial improvements to the working environment and reduce carbon and energy use, by adding wall linings and new windows without harming significance. The south-facing roof is hidden in most views offering an opportunity for photovoltaic panels to generate electricity, without harming the significance of the building in its setting.

In the most sensitive parts of the gallery - the entrance, main gallery and North Gallery - the quality of the architecture and decorative detail would be harmed by substantial changes such as wall linings and in these areas, the main interventions will be above ceilings and to windows where new secondary glazing could bring benefits without loss of fabric or harm to aesthetic values. Given the long payback period for a new front draught lobby, upgrading the existing door sets may be the best option and will retain a historic feature.

Case Study 02

6-8 St Peter's Street, Huddersfield

01 Summary

The Grade II Listed building at 6-8 St Peter's Street in Huddersfield town centre is owned by Kirklees Council. The building was constructed in the 1850s in sandstone with a slate roof as a woollen warehouse and comprises three storeys above ground and a basement level. The building has a high significance for its historical value as a good example of a Victorian commercial building. The building was last used as office accommodation, but is currently unoccupied and has been vacant for the last four years. Kirklees Council is keen to return the building to beneficial use.

The front elevation along St Peter's Street and side elevations along Byram Street and Wood Street have high architectural and historic value. The classical front facade also has historical value for its association with the George Hotel built in 1787 on Market Place. The rear elevation has less significance.

The building has generally fallen into disrepair since becoming vacant. The existing mechanical and electrical services are in poor condition due to lack of maintenance and a new installation will be required to serve the building. This provides an opportunity to improve the performance of the building fabric and to install energy efficient plant and efficient control strategies to reduce energy consumption from operation of the mechanical and electrical plant.

There is no information on the building's energy consumption and it was necessary to make assumptions on energy consumption based on benchmarks for similar buildings increased by 30% to reflect the relative inefficiency of the building and its systems. Electricity consumption for the building as it stands would be relatively high and this increases carbon dioxide emissions because electricity generation is more carbon intensive than heating installation which is gas fired.

There are significant opportunities to reduce carbon emissions from the building without unduly harming the historic fabric of the building. Suggested improvements would only affect the interior of the building which is generally of low significance. This case study tests the indicative costs and benefits of 23 possible interventions. All of these would provide

worthwhile savings in carbon emissions. Some, for example, installing new double glazed windows (with an appropriate style) and secondary single glazing, have distant payback but are worth implementing to provide steady savings. New boilers and related control equipment will take 20 years to pay back but replacement is essential as the existing plant is inoperable. The following are the most significant recommendations, which could result in substantial annual savings.

- A range of behaviour change related items which can be implemented at minimal cost
- Replacing the existing roof insulation which is incorrectly installed on an impermeable membrane
- Installing draught strips to doors and windows
- Internal insulation of external walls as part of general refurbishment
- Installing occupancy and daylight sensors to control lighting
- Replacing existing light fittings with low energy equivalents
- Installing photovoltaic solar electricity panels to a concealed inner pitch of the roof but payback periods may be delayed as a result of probable changes in the Feed-In Tariff
- Replacing existing boilers, pumps and control system.

02 Heritage value and statement of significance

Statement of significance

The building has high significance for its historical value as a good example of a Victorian commercial building in Huddersfield town centre built in the early 1850s as a woollen warehouse. The front (north) elevation also has historical value for its association with the George Hotel built in 1787 on Market Place.

The ashlar front façade of the hotel, dismantled and rebuilt here, has architectural significance as one of the few examples of 18th century classical architecture in the town centre. The Byram Street and St Peter's Street elevations are prominent in the grid of streets that characterise this part of Huddersfield's Victorian townscape and the whole building contributes to the character of this part of the conservation area.

The west elevation and rear are plainer architecturally. The rear has historic value as the servicing side of the warehouse. The late 19th century sash windows are an important part of the exterior architecture of the building. The interiors have been substantially altered for office use and are now mostly of low significance, with the exception of the staircase from ground to first floor, panelled window reveals to the front part of the building and the roof structure which are of high significance. The Grade II listing is appropriate for the building (listing reference number HUD 2/1172).

Rear elevation of the building.

Summary table

The table below summarises the key building features and their relative significance for ease of reference.

Building feature	Significance	Date
Interior spaces generally	Low	Late C20
Windows: N and E elevation sashes	High	Late C19
Windows S and W elevation sashes	Medium	Late C19
Windows modern - all elevations	Low	Late C20
Front doors	Low	Late C20
Rear doors	Low	Late C20
Interior: window reveals - panelled	High	Mid-late C19
Interior: window reveals, tongue and groove boarding	Medium	Mid C19
Other window details e.g.sills	Medium	C19, altered C20
Interior wall finishes	Low	Plaster either C19 lime or late C20 gypsum
Basement outer walls	Low	Mid C19
Basement windows	Low	C20
Basement floors	Medium	Mid C19, some late C20
Ceilings – tongue and groove boarding above suspended ceilings	Medium	Mid C19 (only partially seen)
Ceilings – suspended	Negative	Late C20
Roof spaces	High	Roof structure probably C19 (only partially seen)
Chimney flues/blocked fireplaces	High	C19

The building – evolution, description and setting

Building evolution

The building was erected as a woollen warehouse in the 1850s, part of the speculative development of a grid of new streets laid out by the trustees of the Ramsden Estate, prompted by the opening of the railway station in c.1850. The front elevation incorporates part of the classical front façade of the George Hotel, Market Place; this was taken down in 1850 by Sir John William Ramsden for the development of John William Street.

According to Gibson and Booth (pp30-31) the design of the George Hotel, built in 1787, could be attributed to John Carr who worked for the Ramsdens. There are three date stones at eaves level on the south elevation: 1687, 1787 and 1852; the first two are from the George Hotel. The site is shown undeveloped on the large scale town plan of 1853 (1:1056), but by 1857 a warehouse on St Peter Street was occupied by Jonas Kenyon, woollen manufacturer; Kenyons (Dogley Mills) occupied half the building up to c.1887. Edwin Walker & Co, woollen manufacturers (Field Mills) used the other half in the 1880s and 1890s.

Goad insurance plans name the two occupiers, showing the internal division and two internal hoists to the rear. There were probably two separate internal staircases, and the rooms were heated by open fireplaces. Signs of previous iron grilles to ground floor window surrounds to rear and Wood Street are evidence of former warehouse security.

The building use has been altered since the decline of textiles, adapted for office use by the local authority in the 1970s. This phase of work entailed altering internal circulation and floor plans by replacing part of the staircase, installing a lift and inserting partitions and altering internal openings.

The building's fabric and character

The 3-storey entrance front faces north and is described on the list description. The Georgian classical stone features to the front contrast with the Victorian warehouse architecture in this part of town. The building is constructed in solid carboniferous sandstone masonry, faced in ashlar to the north front and with dressed, coarser stone to other elevations.

The canted corners and ground floor plastered window surrounds to the front, Byram Street and the first 2 bays of Wood Street are part of the 1850s work. The entrance doors are all modern. Most of the Victorian sash windows are in situ, although three ground floor windows have been replaced to the rear and W elevation, and a few have modern glass or glass louvres. The distinction between plate glass sashes (ground floor front and Byram St) and 4-pane sashes is part of the building's character; the former were probably installed in the later 19th century for the display of goods, in place of small-paned windows. The 4-pane sash windows could either be 1850s or later 19th century.

Historic photographs show a corner door to the NE corner, later removed and now with a fixed modern window. The hipped roof, laid with blue slate has an inner flat and rendered chimney stacks (hidden in most views). The warehouse use is reflected in the rear taking-in doors (blocked), now with fire escape doors. The fire escape and access ramp to the south side are late C20.

Inside, the layout largely dates from 1970s alterations for council office use. The only features related to the historic plan-form are the east-west spine wall carrying the flues (in four chimneys), part of a north-south masonry cross wall, the ground to first floor staircase flight with a pine newel and turned balusters (probably late C19), and the panelled window reveal linings.

The reveal linings vary in their detail; the fielded panelling is 18th century and may have been brought from the George Hotel. The windows to the rear have plain boarded linings instead of panelled reveals, suggesting a hierarchy with higher status front rooms (showrooms) and lower status rear ware rooms. All the doors, basement and upper floor staircases and internal finishes are late 20th century.

Suspended ceilings have been installed throughout, although historic tongue and grooved linings to ceilings survive above in some areas, typical of Victorian commercial interiors. Partitions have been installed to subdivide former warehouse rooms, and some openings made in dividing masonry walls. The timber floor and roof structure appears to be Victorian. Cast-iron radiators are in situ on all floors, many damaged by freezing water.

Building setting

St Peter's Street is part of a grid of streets densely developed for commercial use from the 1850s. The area has a homogeneous character with regular rooflines, building scale and character; most of the buildings were used as woollen warehouses. The detached building fills a block, built up to the back of the pavement on all sides. Modern steel railings enclose the basement area along the entrance front. Views of the building are tightly framed along Wood Street and St Peter's Street from the west, although more open views are possible from the east across the public gardens.

03 Building condition survey

The project team undertook a high level, non-intrusive condition survey of the building on the 1st of September 2011. A summary of the findings is included below.

Fabric

The table on the next page lists the key findings from the non-intrusive survey of the building fabric.

Water ingress at basement level.

Different types of existing glazing.

Drainage pipework recessed into wall.

Gas meter.

Some windows are in poor condition.

Results of building fabric condition survey

Item	Location	Detail	Condition
Roof structure	-	- Slated, pitched and hipped with central valley over load bearing masonry spine - Traditional timber structure (rafters and purlins) - Void above second floor ceiling - Bituminous felt - Ridge vents along front elevation - Cementitious render to chimney stacks	- Mould growth within roof structure due to poor ventilation - Water staining to inner spine wall suggests leaks to roof valley
Ceiling	Throughout	- Modern grid suspended ceiling - 100mm Mineral wool sound insulation in places	- Many tiles dislodged or missing
	2nd floor	- 150mm mineral wool insulation above suspended ceiling supported in place by polythene membrane	- Dislodged tiles and insulation
Walls (exterior)	-	- 575 mm thick above ground level (including internal lining) - 700mm thick to basement - Ashlar stone with decorative detailing elevations - Pediment frontage	- Generally good condition above ground floor level - Minimal weathering - Moss growth to cornice above front windows - Chipping and deterioration of cornice in places - Cracks to stone lintel at basement level window - Water staining due to penetration through cornice joints - Moderate guano build up and staining along projected stone string course at 2nd floor level - Deterioration at lower basement level

Results of building fabric condition survey continued

Item	Location	Detail	Condition
Walls (interior)	Ground, 1st and 2nd floors	- Plasterboard lining on dabs - Parging in places - No insulation	- Some signs of leaks and water staining to inner spine wall at second floor level - Cracks along joints of lining boards
	Basement	- Plasterboard lining on dabs - Blockwork lining in areas - Wet plaster browning in areas - Paint washed masonry in areas - No insulation	- Extreme dampness - Strong smell of mould and dampness - Heavy efflorescence in places - Modern wet plaster detaching from walls
Floors	Ground, 1st and 2nd floors	- Various floor structures including timber boards and chip board on joists and concrete - Carpeted surfaces	- Uneven surfaces - Humping at load-bearing walls
	Basement	- Solid floor (concrete) - No insulation	- Damp - Rippled and water stained carpet surface
Windows	throughout	- All single glazing in timber frames - 4 pane vertical sliding sashes - Alterations including single pane sashes, casements - Replacement glazing alterations including Georgian wired and obscured - Splayed timber panel reveals and architraves in places - MDF or ply casing to reveals in places	- Some windows in poor condition - Rotten cills and frames - Inadequate repairs - Some windows draft stripped - Damage to some architraves to facilitate installation of modern suspended ceiling
External doors	Ground floor – main entrance	- Modern timber double doors with full height glazed panes - Plane single pane rectangular fan light - Arched fan light opening in filled with opaque panel	- Sound condition - Draft stripping to be checked
	Ground floor – rear entrance	- Modern glazed, two pane door with central mid height rail and timber frame - Modern glazed single pane side light	- Sound condition - Draft stripping to be checked
Above ground drainage		- Internalised down pipes exposed in places - Hidden gutter behind parapet	- Vegetation visible along parapet detail over entrance

Building services

The building is served by stand alone building services plant. The systems have deteriorated into disrepair as the building has been vacant for some time. It will be cost-effective to replace the existing installation with new plant rather than undertake extensive testing, as the system has not been maintained or operational to maintain working condition.

Boiler plant

The building was served by a modular boiler system comprising five boilers. The fifth boiler was stripped out at time of survey. The boilers are located at basement level. The boiler flue is routed in an enclosure and the flue discharge location could not be established during the survey visit. Pressure within the heating was maintained by a feed and expansion tank at roof level.

Independently pumped heating circuits serve the ground floor, first floor and third floor office areas. Each heating circuit includes a duty and standby, constant speed pumpset. The heating pipework serving radiators is distributed through the suspended floors. It was not possible to identify the pipework distribution at each floor or the positions of any commissioning valves. Pipework within the plant room is insulated. All pipework, including within suspended floors, should be insulated to avoid heat loss to un-occupied spaces and to minimise the risk of freezing.

The heating pipework system was partially drained and there is evidence of freezing of heating pipework and burst radiators. Part of the heating pipework installation has been stripped out. The remaining pipework sections were open to the room air. It is expected the pipework has suffered from internal rusting and will be at risk of accelerated corrosion if re-used. The pipework should be stripped out as its condition has deteriorated due to lack of maintenance.

Modular gas fired boiler.

Duty and standby circulation pumps serving different zones.

Domestic water services

The building is served by a mains cold water system which was turned off at the time of the survey. There is no storage plant at basement level. It was not possible to establish whether a cold water storage system is located at roof level due to lack of access. A new domestic water installation will serve the building. The building includes a fire hose reel system. It is unclear when the system was last tested.

Controls

An automatic control panel was installed in the basement boiler-room and has deteriorated into disrepair in common with other plant for environmental control. The existing basic automatic control system should be replaced with a new control system to provide energy efficient plant operation.

A combination of traditional multi-column cast iron radiators and modern panel radiators provide space heating to the building. A reflective foil is provided behind the wall and some of the panel radiators. The foil reduces the amount of heat absorbed by the wall and directs heat for space heating. Thermostatic radiator valves (TRVs) are installed on radiators and provide basic user control.

Reflective foil behind panel radiator.

Ventilation

Ventilation is currently provided by general air infiltration and by opening the sliding sash windows. 'Through the window' type ventilation fans were installed on some of the windows to provide ventilation. The haphazard installation of 'through the window' type ventilations is not recommended due to the impact on the historic character of the building and the potential for heat loss during cold weather.

The basement has poor ventilation. There is a foul smell at basement level from rising damp and/or ground water ingress. The source of moisture needs addressing as part of the building refurbishment and adequate ventilation introduced at basement level.

Control panel with partially stripped pipework.

Power and lighting

A low voltage electricity supply enters the building at basement level in the boiler room. The manually read utility meter and switchboard are also located in the boiler house. An incoming communications system cabinet is provided in basement level. A new data and telecommunications installation will be required to serve the refurbished building. In common with other building serves plant, the electrical distribution system has fallen into disrepair and needs to be stripped out.

Incoming electrical supply in the boiler room.

The building is served by a single lift which runs from basement to second floor. The lift was switched off and its age and capacity could not be established at the time of the survey.

Final circuitry wiring is routed within the ceiling voids without containment. This has led to a haphazard installation and circuit identification will be problematic. The installation needs to be rationalised to enable ease of access.

The building is currently served by mounted modular fittings laid into suspended ceilings and ceiling mounted linear fluorescent light fittings. The lighting is manual controlled, but has no facility for occupancy detection. There is no facility to automatically reduce artificial lighting when natural daylight is sufficient even though the building is well served by natural light.

Office partitions and suspended ceiling.


ST. PETER'S STREET
Fartown

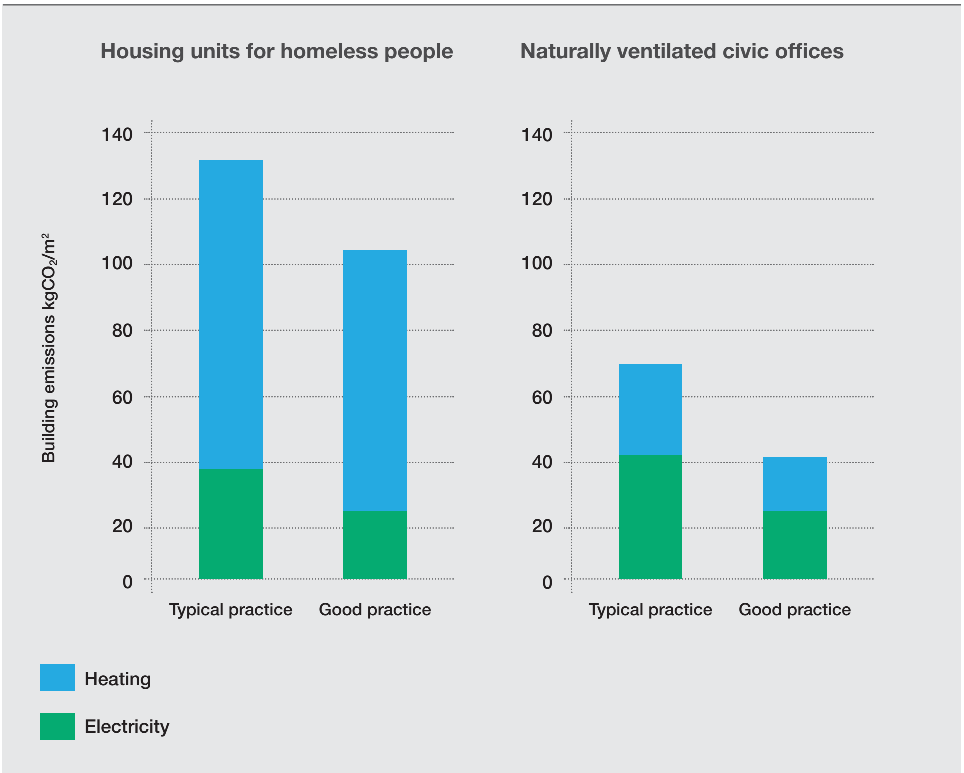
04 Bill analysis and benchmarking

Due to the fact that the building has been unoccupied for the last four years, there is no energy data available from actual energy use. However, we can use benchmarks to develop indications of significant sources of emissions.

The building was previously used as offices but there is a possibility that this use might be changed in the future to hostel style accommodation. ECG087 from the Carbon Trust gives the benchmark figures for both these types of building as indicated in the table below.

Energy consumption in kWh/m²	Housing units for homeless people		Naturally ventilated civic offices	
	Electricity	Heating	Electricity	Heating
Typical Practice	71	467	81	143
Good Practice	48	408	51	75

Making the assumption that the heating energy will be continue to be provided by the natural gas, the proportions of benchmark emissions from each of the fuels for both types of building use are shown in the graph.



The comparison of these two emissions profiles highlights the changing sources of emissions that can arise from different uses of the same building.

Clearly, if the building is to be used as a shelter for the homeless, then the reduction of emissions from the heating of the building are going to be more important than reducing electricity consumption. Efforts should therefore be concentrated on reducing heat loss and on, potentially, altering the fuel used to one with a lower carbon intensity.

If the building is to be used as an office, proportionally more attention should be paid to the electricity consumption.

However, the age of the building will obviously impact on the real energy and emissions story. This will undoubtedly mean that the heat loss is greater than that assumed for the benchmark building and opportunities for energy reductions will be more limited. That said, if the building is to be used as an office then the potential interventions to realise electricity emissions savings are those that will have minimal heritage impact such as lighting and plug loads such as IT equipment.

The table below shows average energy consumption and other assumptions used for the cost-benefit analysis in section 6.

Assumptions for options appraisal	6-8 St Peter's Street Amount
Estimate of Gross Internal Floor Area	1212 m^2
Annual electricity consumption	13,3926 kWh
Annual gas consumption	23,7916 kWh
Average electricity cost	10.22 p/kWh
Average gas cost	2.58 p/kWh
Annual electricity cost	£13,687
Annual gas cost	£6,138
Carbon emission factors - electricity	0.517 $kgCO_2$/kWh
Carbon emission factors - natural gas	0.198 $kgCO_2$/kWh

The carbon emissions factors referred to are from SAP 2009, the government's standard assessment for the energy rating of dwellings. Part L of the UK Building Regulations 2010 also applies these factors to non-domestic buildings.

05 Interventions

Scope

The most significant elements of the building are the exterior of the front and east elevations including windows, stone detailing and the roof. The 4-pane or plate-glass single-glazed sash windows are part of the architectural significance of the building and should be retained; secondary double glazing would be possible. Where sashes have been replaced with modern windows or where windows have been inserted in former doorways, there is scope for double-glazed sash windows with slim glazing bar profiles and although potentially contentious it is worth exploring. The external doors are all modern and could be replaced. On south and west elevations overlooking side streets the architecture is less sensitive and sensitive renewal of windows could be appropriate with slim profile double-glazed sashes. The partly hidden character of these areas and their lower place in the building hierarchy allows more scope for change than on principal frontages.

Internally, the finishes and fabric have relatively low heritage value and upgrading walls, floor and roof insulation is unlikely to cause to harm to significance. Panelled window reveals are worthy of retention on the front-facing windows and adjustments will be needed to the joinery allow for wall linings and secondary glazing.

The building is currently vacant and the mechanical and electrical plant has not been maintained. The building is in need of comprehensive repair, refurbishment and replacement of building services installations. This provides considerable opportunity to implement a concerted programme of interventions designed to reduce future carbon emissions. The study team has selected the interventions that could reasonably be expected to be worthwhile based on experience and these are shown in the table on the next page.

Feasible carbon saving interventions

No.	Intervention	Description	Heritage impact
Behaviour change			
1	Energy consumption targets/monitoring/ metering	Establish clear and accurate benchmarks of current consumption. Set realistic targets and monitor performance against targets by reading meters, including sub-meters as included below. Key carbon reduction tools.	None
2	Formal staff/building users feedback mechanisms	Establish robust and continuing procedures to use occupiers' experience effectively.	None
3	Sustainability brief for staff	Set out and explain the reasons and approach to sustainability. What does it mean for the individual?	None
4	Develop building user/ manager training program	Ongoing training is important including new starters and refresher courses. Strong and clear leadership should be at the root of this.	None
5	Daytime cleaning service	Cleaning during the day means lights do not have to be used at night when the building would be otherwise unoccupied.	None
6	Building users' guides, up to date, comprehensive, accessible Operation & Maintenance manuals	Occupiers and facilities managers cannot be expected to use and operate buildings without clear information appropriate to their level of involvement.	None
7	Energy efficient appliance selection	Select AAA rated appliances such as fridges, kettles, dishwashers and washing machines, as appropriate.	None
Building fabric			
8	Install wall insulation	Insulate the internal face of external walls where practicable in all areas. Scarify existing painted walls to increase moisture permeability. In historic areas remove and set aside skirtings and architraves for reinstatement. Line walls with a layer of natural, breathable insulation (e.g. 75mm of wood fibre board or hemp batts) with suitable detailing to mitigate cold bridging. Apply a lime or clay plaster and natural paint finish.	This will have a slight affect on room dimensions but as the internal layout has previously been altered and rooms are not in their historic form, this does not affect the significance of the plan-form or individual room character. The main heritage impact relates to the detailed relationship between window joinery (architraves and sills) and new wall surfaces, which can be mitigated by carefully relocating historic joinery and providing in-fill timber to match.
9	Install new loft insulation	Install insulation such as glass fibre or sheep's wool between and over joists to an overall depth of 300mm overall.	None
10	Install draught strips and a draught lobby	Install proprietary draught strips to all internal and external windows and doors. Construct a new fully glazed draught lobby with self-closing doors and draught seals to the main entrance only.	Draught strips should have no heritage impact. A new draught lobby will affect the spatial character of the lobby and the relationship between doorway and the historic staircase. A contemporary approach to design will help to differentiate between historic and inserted features.

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
11	Replacement windows and secondary glazing	Remove modern windows and substitute high performance double glazed replacements. Install high performance secondary single glazing elsewhere.	This will enhance and unify the character of the elevations by reinstating historic window patterns; the slim profile double glazing will not be readily apparent as these will be on secondary elevations. This proposal retains existing historic sash windows and maintains the external character of the building. The interiors will be slightly affected by the secondary glazing but this is acceptable given the altered character of the interiors, and the benefits of the improved window performance.
Building services			
12	Occupancy sensors for lighting	Install throughout the building in office and ancillary areas to enable automatic shutdown of lighting when spaces are unoccupied	None
13	Daylight switching/dimming of lighting according to available daylight	Provide daylight sensors to dim or even switch off lights in response to daylight levels in the room, reducing operating and energy costs.	None
14	Energy efficient light fittings, LED lighting	Replace existing low efficiency light fittings with modern low energy equivalents such as compact fluorescent, T5 high frequency fluorescent and LED lighting as appropriate.	None
15	Electrical sub-metering to all key installations	This should cover lighting, small power, machinery, plant. This facility is vital to understand how much power is being used by different services installations.	None
16	Time switches or similar on small equipment	A low cost means of guaranteeing equipment shut down when not in use.	None
17	Photovoltaics (PV) with Feed-In Tariff	Photovoltaic solar electricity panels installed on the south facing roof slope on the secondary elevation. This is not significantly overlooked.	Manageable with careful design and early discussion with local planning authority
18	Modify temperature set points	19-20°C to offices. Staff may need to wear more clothing during cold weather.	None
19	Ensure controls are working correctly	Initial review to maximise the benefit and efficiency of existing systems. Ensure that testing is embedded in maintenance regime.	None
20	Heat recovery ventilation	Heat recovery systems transfer heat between inbound and outgoing airflow streams, reducing the energy demands of the inbound air. Reduces the need to open windows during the heating season and consequential heat loss.	Manageable with careful design and early discussion with local planning authority
21	Install digital control system for all major plant	Digital building management system with boiler optimum start/stop, automatic trend logging, alarm handling, monitoring and other aids to efficient operation.	None
22	Upgrade boiler system and pumps	Two replacement, high efficiency gas condensing boilers with high efficiency pumps.	None


WOOD STREET

Low and zero carbon technologies

The case study team considered a range of possible technologies which are reviewed in the table below.

LZC Technology and Low Energy options	Approximate capital cost	Cost per 1% CO_2 reduction over base building	Operational cost	Future energy costs	Simple payback (without Feed in Tariff/RHI)
Solar Hot Water Panels	Moderate	Moderate to High	Low	Low	Moderate
Photovoltaic Panels	Very High	Very High	Low	Low	High
Gas Fired District Heating CHP	Moderate	Moderate	Moderate	High	Moderate to high
Biofuel CHP	Moderate to High	Moderate	Moderate to High	High	Moderate to high
Biomass CHP	Very High	Moderate	very High	Low	High
Wind Turbines	Moderate	Moderate	Low	Low	High
Off Site Wind Generation	High	Moderate	Low to moderate	Low	Moderate
Biomass Boilers	High	Low to Moderate	High	Low	Low to Moderate
Ground Source Heat Pumps	High	Very High	Moderate	Moderate	High
Air Source Heat Pumps	Moderate	Moderate	Moderate	Moderate	Moderate
Open Loop water source heat pump	High	High	Moderate	Moderate	High
Exposed Thermal Mass	Low	Low	Low	Low	Low
Maximisation of daylight, daylight controls, automatic lighting controls & energy efficiency lighting	Low to Moderate	Low	Low	Low	Low
Earth Tubes	Moderate	Moderate	Low	Low	Moderate

Noise impact	Planning implications	Funding/ Grants	Applicability to St Peter's Street	Technical issues/any other criteria
None	Roof loading & less sensitive elevation	RHI	?	Solar Hot Water limited by low hot water demand if used as an office building. Higher demand for alternative uses e.g. residential accommodation. Effective with a centralised hot water system.
None	Roof loading & less sensitive elevation	FIT	✓	Limitation on capital investment & size of available roof area
Moderate	Flue height		×	Cost effectiveness to be balanced with carbon reduction requirements. Minimum operation hours 4000 to 5000 required to be effective.
Moderate	Flue height		×	Reliability of fuel supply, concern over sourcing of fuel product
Moderate	Flue height, pollution levels & plantroom size	RHI	×	Limited number of successful installations. Restricted plant room / fuel store area, delivery access problematic, planning issues - flue height & NOx levels to address, maintenance costs
Moderate to high	Planning application required	FIT	×	Not appropriate in city centre location. Planning implication & output/effectiveness dependent on site specific wind speed.
High	Planning application required	FIT	×	Technology acceptable only with direct link to building as off-site turbines are located remote from buildings. Note visual impact in areas conservation areas etc.
Low (note noise from delivery vehicles)	Flue height, pollution levels & plantroom size	RHI	×	Highly variable heating requirement, Restricted plant room / fuel store area, delivery access problematic, planning issues - flue height & NOx levels to address, maintenance costs
Low	Archaeological impact to be assessed	RHI	×	City centre location with limited ground available for system. Output depends on ground conditions. Limited application of low grade heat produced GSHP unless significant thermal improvements to thermal fabric.
Moderate	Moderate	RHI	×	Noise/plant location, efficiency in winter operation, low grade heat produced by ASHP
Low to medium	Application to Environment Agency	RHI	×	Investigation required to establish if local water body available for operation of water source heat pump
Low	None		✓	Exposed thermal mass is currently present at St Peter's street.
Low	None		✓	Energy efficient lighting and controls can be implemented.
Low	None		×	Disruptive to listed buildings. Require space for installation and adoption of mechanical ventilation strategy

06 Options appraisal

Introduction

Section 5 proposes many types of interventions which will generate differing levels of savings in carbon and energy costs. It is essential to be able to compare them to decide which are the most worthwhile.

The options are appraised by means of a cost-benefit analysis comparing the budget cost of the intervention with the likely potential savings against current energy costs and carbon emissions. The current average energy consumption and related assumptions are set out at the end of section 4 (Bill analysis and benchmarking).

The options appraisal is a high-level indicative exercise designed to give a broad brush overview of the relative benefits of different interventions. In implementing any interventions a more detailed analysis will be essential to test assumptions.

Payback and energy inflation

It is clear that although a number of the interventions show worthwhile and significant carbon savings, the capital costs are relatively high and the payback in energy costs is too distant to make them commercially acceptable. Although actual energy consumption at the building is not known, Kirklees Council has negotiated extremely favourable energy prices and these have been applied to the assessed base consumption. These low energy prices significantly lengthen the time taken to achieve payback compared with prevailing energy prices for the majority of building owners.

The calculated cost saving payback disregards energy price inflation but it is realistic to anticipate that energy prices will continue to rise at a rate considerably greater than general inflation. This issue is covered in more detail in the overall guide of which this case study forms part. It is sufficient to state that actual payback through energy saving is likely to be much more rapid than shown in the cost-benefit analysis table on the next two pages.

Cost benefit analysis

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Behaviour change									
1	Energy consumption targets/ monitoring/ metering	Easy win	100	2.0%	5.0%	581	0.2	2.36	None
2	Formal staff/ building users feedback mechanisms	Easy win	100	0.5%	0.5%	99	1.0	0.58	None
3	Sustainability brief for staff	Easy win	100	0.5%	0.5%	99	1.0	0.58	None
4	Develop building user/manager training program	Easy win	100	2.5%	5.0%	649	0.2	4.09	None
5	Daytime cleaning service	Easy win	100	0.5%	0.5%	99	1.0	0.58	None
6	Building users' guides, full accessible O&M manuals	Easy win	100	0.5%	0.5%	99	1.0	0.58	None
7	Energy efficient appliance selection	Easy win	100	0.5%	0.0%	68	1.5	0.35	None
Building fabric									
8	Install wall insulation	Major	20,600	0.0%	20.0%	1,228	16.8	9.42	Manageable
9	Install new loft insulation	Cyclical	5,600	0.0%	12.0%	737	7.6	5.65	None
10	Install draught strips to doors and windows	Major	1,400	0.0%	4.0%	246	5.7	1.88	Manageable
10a	Install draught lobbies	Major	7,400	0.0%	3.0%	184	40.2	1.41	Manageable
11	Upgrade to high performance secondary glazing	Major	54,100	0.0%	20.0%	1,228	44.1	9.42	Manageable

Cost benefit analysis continued

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Building services									
12	Occupancy sensors for lighting	Cyclical	6,700	5.0%	0.0%	684	9.8	3.46	None
13	Daylight switching/ dimming of lighting	Cyclical	13,700	6.0%	0.0%	821	16.7	4.15	None
14	Energy efficient light fittings, LED lighting	Cyclical	18,200	8.0%	0.0%	1,095	16.6	5.54	None
15	Electrical sub-metering to all key installations	Easy win	3,700	5.0%	0.0%	684	5.4	3.46	None
16	Time switches or similar on small equipment	Easy win	200	0.5%	0.0%	68	2.9	0.35	None
17	Photovoltaics (PV) with Feed-In Tariff	Major	6,100	1.1%	0.0%	729	8.4	0.78	Manageable
18	Modify temperature set points	Easy win	100	0.0%	8.0%	491	0.2	3.77	None
19	Ensure controls are working correctly	Easy win	1,000	1.0%	2.0%	260	3.9	1.63	None
20	Heat recovery ventilation	Cyclical	13,600	1.0%	14.0%	996	13.7	7.29	Manageable
21	Install digital control system for all major plant	Cyclical	15,000	2.0%	7.0%	703	21.3	4.68	None
22	Upgrade boiler system and pumps	Cyclical	18,100	0.5%	15.0%	989	18.3	7.41	None

Other opportunities

Apart from the options appraised, the extensive rising and penetrating dampness in the extensive basement is a significant issue. Addressing this problem will have an impact on carbon emissions but the extent is not quantifiable without a clear understanding of the way in which the basement might be used. The space has a generous ceiling height and could provide very useful accommodation. A concrete floor has been introduced at some point, probably driving the ground borne dampness towards the partition and perimeter walls which are very damp. Specialist advice will be required and should pay careful regard to the recommendations and explanations in the excellent English Heritage document "English Heritage, 2010, Energy Efficiency and Historic Buildings -Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings".

It should also be noted that insulating the external walls will reduce the internal thermal mass available for natural modulation of interior temperatures. However, the extensive load-bearing masonry partition walls will continue to provide this function as well as a good degree of acoustic insulation.

07 Recommendations

Interpretation

All of the suggested interventions show worthwhile carbon savings but in some cases (the red items) the capital costs are relatively high and the cash payback in energy cost savings is distant. The cost-benefit analysis is based on estimated energy consumption and energy prices based on utility rates used as part of the study. The energy prices used in the assessment are extremely favourable and this significantly lengthens the time taken to achieve payback compared with the majority of building owners.

The calculated energy cost saving disregards inflation but it is realistic to anticipate that energy prices will continue to rise at a rate considerably greater than general inflation. The actual payback through energy saving is likely to be much more rapid than shown in the cost-benefit analysis table.

The savings figures in the table are deliberately not totalled. Such totals would be misleading. Each measure adopted limits the scope for further savings because the total energy use reduces each time. The order of adoption and interaction between different interventions would also have significant impacts on the overall outcome. It is not practical to suggest an overall likely energy saving but the options appraisal identifies that carbon emissions can be very greatly reduced by adopting the following complementary measures.

At a glance

Recommendations

Use building change of use as a catalyst for behaviour change

Upgrade insulation to roof

Install draft proofing

Upgrade controllability of electrical and heating systems

Photovoltaic panels aided by the Feed-In Tariff

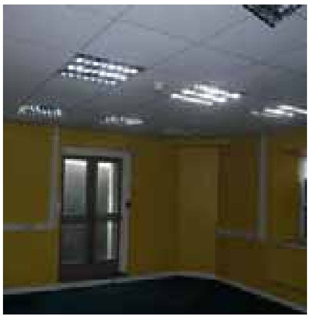
Fit internal wall insulation

Fit secondary glazing

Behaviour change

It is essential to reinforce and support physical interventions with training and motivation so that the building is operated efficiently and beneficially to reduce carbon emissions and save costs. Administrators and facilities managers need to have a clear understanding of the building and its systems. This will enable leaders to arrange training and support for the staff in the building. The group of items in the first section of the table aim to provide a comprehensive range of measures to achieve this.

It is assumed that behaviour change and building management related items can be implemented by existing staff through internal strategies with normal training and personal development which needs to be sustained and continuing. Although some limited external assistance may be required, this is normal for staff training and the cost of each of these interventions is assumed to be a nominal £100. In the circumstances it is recommended that all of these measures are adopted.



Internal wall lining to basement exterior wall.

Building fabric

The building has been vacant for some time and it will be necessary to undertake comprehensive repairs to limit water ingress through ground water, walls, basement floor and roof. The interventions explored in this section mostly show longer paybacks but all of them should provide substantial annual carbon savings.

Internal wall insulation options would need careful detailing to contain new insulant (dark pink) behind removed and replaced window reveals.

Internal insulation of external walls in all areas offers the largest running costs reduction. The payback is approximately 17 years but with typical gas running costs currently 3.6 p/kWh, the payback would be approximately 12 years.

Upgrading roof insulation will be cost effective and provide a return on capital investment within eight years.

Installing draught proofing to windows and to internal and external doors reduces energy consumption and provides a quick payback of approximately five years even with the attractive utility rates.

Payback on the installation of a draught lobby to the front entrance is currently estimated at over 30 years but it may be possible to reduce the costs to improve this through discussion with the conservation officer.

- Installing a secondary glazing system and carefully designed high performance replacements for modern windows should provide a significant reduction in energy consumption. Payback is still long at 44 years. Using typical utility rates reduces the payback to about 30 years. It is recognised that replacing any windows, however recent and unsuitable, may be contentious but it is worth exploring. Secondary single glazing would be the alternative.

Building services

It will be necessary to maximise opportunities for passive comfort control strategies to reduce energy consumption (e.g. maximising the exposed thermal mass of the building to reduce comfort cooling requirements and for heat retention).

A number of interventions show payback within 10 years and inflation is likely to improve this considerably.

- Occupancy sensors for lighting
- Electrical sub-metering to all key installations
- Time switches or similar on small equipment
- Photovoltaic solar electricity panels aided by the Feed-In Tariff
- Modify temperature set points
- Ensure controls are working correctly.

Recent announcements regarding the likely reductions in the Feed-In Tariff amounts suggest that the payback period of the proposed photovoltaic installation by be made significantly longer than at the currently applicable rate.

The remaining items show an indicative payback within 16-30 years with the very attractive rates for gas and electricity. The payback for these systems will improve significantly by adopting typical utility rates.

- Switching and dimming of light fittings according to available daylight.
- Energy efficient light fittings, LED lighting
- Heat recovery ventilation
- New digital automatic control system
- New boiler system and pumps.

These systems will show significantly shorter payback periods when typical utility costs are used. The existing systems are in need of replacement as they have not been maintained in working order and have deteriorated as the building lay vacant. This is an opportunity to install entirely new, energy efficient plant before the building is returned to use.

Heritage impact summary

As this historic building is currently in need of major refurbishment there is a good opportunity to integrate interventions for carbon reduction and energy efficiency into a holistic building project. The interior has been substantially altered and few features remain that have heritage significance. Further investigation may be needed to identity the full extent of historic finishes and fabric such as tongue and grooved boarding to warehouse ceilings, currently hidden above suspended ceilings.

The interventions have been designed to retain the building's most significant features such as sash windows, architraves and panelled window reveals. Careful detailing and finishes can ensure that wall linings are installed with a low visual impact on the significance of the interiors, and the substantial long-term benefits justify the intervention. Low cost improvements such as draught proofing existing sashes and providing roof insulation will have no impact on significance. New building services will be essential for any new use in this building and subject to careful design and installation, will have a low impact on the interior. New external vents and other fittings should be designed to minimise their impact on the elevations, using hidden roof areas and existing stacks as far as possible.

Replacing late 20th century doors and windows with more appropriate designs to enhance the exterior appearance of the building offers an opportunity for slim-profile double glazing in place of single glazing assuming it is carried out carefully and sensitively.

Case Study 03

Armley Mills, Leeds

01 Summary

Armley Mills is a Grade II* listed building complex owned and operated by Leeds City Council. The various buildings are located about four miles to the west of Leeds city centre. The buildings currently house the Leeds Industrial Museum and but the site once housed what was perhaps the world's largest woollen mill at the time. The site comprises the Main Mill of 1805-7, a linked two-storey block incorporating various uses including galleries in the former managers' houses (the East Wing) and a number of outbuildings including an electrical plant room, locomotive exhibition sheds, stores and workshops. This study focuses on some key areas and issues because of the very large scale of the site.

Armley Mills is the earliest example in the Yorkshire region of fireproof construction including the use of brick vaulted floors on cast-iron beams and columns. The Main Mill has exceptional significance for its aesthetic value as a dramatic example of a multi-storey mill built over the engineered river and adjacent to the Leeds Liverpool canal, waterways that were integral to its historic development. The robust architectural character of the exterior, including the repetitive fenestration pattern, contributes to the aesthetic and historic value of the mill. The cast-iron and brick vaulted structure is of exceptional significance for historic and technological value.

The overall condition of the buildings is fair. This is a considerable achievement bearing in mind their long period of decline prior to the opening of the museum. The building is served by a central heating system which has reached the end of its economic life. The current plant operates inefficiently and needs to be replaced by energy efficient systems. The East Wing and Main Mill are heated and the outbuildings are not heated.

The energy consumption analysis and benchmarking identify that the building uses energy inefficiently but that this impact is reduced by the limited hours of operation. There are nonetheless significant opportunities to reduce carbon emissions.

The provision of a successful and efficient low carbon retrofit will ideally require the rationalisation of space usage in the building. This will allow some buildings or areas to be retained in their current form minimising interventions to the historic fabric. On this approach the Main Mill would be served by background heating only which is appropriate to its character and the industrial nature of the majority of the exhibits. Some small areas such as archive space for sensitive materials and the cinema may need to treated differently. Other spaces such as offices, cafeteria and lecture space, which are regularly occupied by sedentary staff or visitors, will require a conventional heating system to maintain comfortable conditions with appropriate improvements in thermal efficiency.

There are significant opportunities to reduce carbon emissions from the building. This case study tests the indicative costs and benefits of 21 possible interventions solely affecting the interior of the building. These measures are unobtrusive in the Main Mill and wider ranging in the generally less significant East Wing where the measures to improve the thermal performance of the roof, walls and windows will be required. It may be appropriate to minimise these works in the residential galleries in the East Wing for authenticity.

The payback from energy cost savings arising from the interventions is more distant because of the very low energy prices negotiated by Leeds City Council. Some interventions, for example secondary single glazing, have distant payback but are worth implementing to provide steady savings into the future. On current prices new boilers and related control equipment will take up to 18 years to pay back but replacement is essential as the existing plant is inefficient and has reached the end of its economic life. The following are the most significant recommendations, which would result in substantial carbon savings.

- A range of low cost behaviour change related items
- New roof insulation to the East Wing
- Draught strips to doors and windows and seal air gaps
- Internal insulation of external walls in the East Wing
- Occupancy and daylight sensors to control lighting
- Replacing existing light fittings with low energy equivalents
- Photovoltaic solar electricity panels but payback periods may be delayed as a result of probable changes in the Feed-In Tariff
- Replacing existing boilers, pumps and control system.

Other measures including the wider benefits of rationalisation and hydro electric power generation are explored at the end of the case study.

Right - Leeds and Liverpool Canal

The building's proximity to the canal and it's former use open up the possibility of hydro-electric power.

02 Heritage value and statement of significance

Statement of significance

The main range of Armley Mill is of exceptional significance for its historical and technological value as the earliest fire-proof building surviving in Yorkshire, built with brick-vaulted floors on cast-iron beams and columns. The mill has exceptional significance for its aesthetic value as a dramatic example of a multi-storey mill built over the engineered river and adjacent to the Leeds Liverpool canal, waterways that were integral to its historic development.

The robust architectural character of the exterior, including the repetitive fenestration pattern, contributes to the aesthetic and historic value of the mill. Inside, the cast-iron and brick vaulted structure is of exceptional significance for historic and technological value.

The exposed timber roof structure is of medium significance as a typical example of a mill roof, rebuilt in 1929 (according to the List Description). The inserted staircase in the north-west corner is of lower significance than the early 19th century structure. The spatial character of the un-divided floors and internal lime wash or distemper finishes to surfaces are of exceptional significance for their historic, evidential and aesthetic value.

The completeness of the site's survival is important to the mill's significance, with a full range of industrial processes expressed by the buildings, the waterways and open spaces. The museum has high significance for its communal value. The Grade II* listing is appropriate for the building (listing reference number 1255747).

Interior

Brick build vaulted floors on cast iron beams and columns contribute to the high architectural significance of the building.

Exterior

One of the earliest fire-proof buildings surviving in Yorkshire.

Summary table

The table below lists the key findings from the non-intrusive survey of the building fabric.

Building feature	Significance	Date
Main range exterior envelope	Exceptional	1805
Main range slate roof	High	1805
Main range windows (range of single-glazed 9-pane designs)	High	C19 –C20
Ground floor interior/structure	Exceptional	1805, industrial display area
First floor interior/structure	Exceptional	1805, now archive store and school room
Second floor/structure	Exceptional	1805, now display area
Third floor/structure	Exceptional	1805, now textile spinning display
External doors, main range	High	C19
Main range roof space	High	1929 replacement for earlier roof,, late C20 inserted lining at collar level and to roof slope soffit
Heating main range	Low	Modern heating systems
Stairwell N end main range	Low	C20 insertion
Stairwell S end main range	High	C19
East Wing exterior	High	Mid C19 warehouse, altered mid C20 when upper floor removed and new roof constructed.
East wing interior	Medium	Mid C19, altered in C20

The building – evolution, description and setting

Building evolution

There is a long history of water-powered mills on this section of the river Aire, dating back to at least the 16th century. In the industrial period, a large woollen mill was developed spanning the river by Colonel Thomas Lloyd from 1788; one of the largest in the world at the time. A pair of houses for the mill managers were built next to the canal in the late 18th century. A corn mill in the lower part of the east arm of the Main Range was rebuilt in 1797.

The 1788 mill was largely destroyed by fire in 1805 and rebuilt by Benjamin Gott between 1805 and 1807. The water-powered main range dates from this construction phase and incorporated innovative fireproof construction using brick vaulted floors; the earliest example in the region. The Main Range was used for processing wool with fulling stocks on the ground floor, scribbling and carding machines on the second and third floors and a mechanics' workshops on the top floor.

A steam engine to supplement water power was first installed in c.1850. The 9-bay East Wing was built as a warehouse in the early 19th century, and substantially altered in the mid 20th century when the upper floor was removed and a new roof constructed. The decline of the Yorkshire woollen industry led to the mill closing in 1969. To halt the building's decline and in recognition of its importance, Leeds City Council bought the site and repaired the buildings; Leeds Industrial Museum opened in 1982.

Ancillary building

The completeness of the site including ancillary buildings adds to the character and importance.

Vaulted floors

The mill is one of the earliest surviving examples of this construction method.

The building's fabric and character

The 4-storey 23-bay Main Range of the mill dominates the site and is listed Grade II*. The L-plan range is built of coursed sandstone with a Welsh slate hipped roof. The low pitch of the roof is not visually prominent. The elevations are defined by a regular fenestration pattern of 9-pane windows, of slightly different detailed design.

The existing 9-pane windows are replacements for the original small-paned windows, probably dating from the late 19th century. Internally, the stone walls and brick vaulting are finished in layers of lime-wash or distemper, finishes intended to maximise internal light levels (except on the ground floor where finishes have been removed).

The vaulting is carried on cast-iron columns and beams, which provide a regular visual pattern to the large floor spaces. Most floors are undivided and lit from both sides. The first floor has been sub-divided by a modern inserted cross wall to create a school room and archive store. The stair in the NW corner appears to be a 20th Century insertion; the historic stair is to the SE of the main range. In the basement of the east arm of the Main Range is the remains of a late 18th century corn mill.

The East Wing parallel to the canal is listed Grade II and includes a 9-bay warehouse, said to be late 18th century (although also referred to as mid 19th century). This was altered in the mid 20th century when the upper floor was removed and a low-pitched corrugated asbestos roof installed, behind a parapet. Attached to the east of the warehouse is a pair of late 18th century managers' houses with sash windows.

Waterside setting

Adjacency to river and canal provides a dramatic and attractive setting.

Building setting

The 1788 and 1805-07 mills were sited to take advantage of transportation on the Leeds and Liverpool Canal, an important route for industrial raw materials, finished products and coal. The river and canal provide a dramatic and attractive setting for the mill, a semi-rural environment on the edge of Leeds. The huge main range dominates the site, with smaller mill ranges such as cloth drying, engine house, warehouse and former domestic accommodation arranged on both side of the river, mostly to the east of the main range. There are fine views of the main range from the south and north sides of the river.

03 Building condition survey

The project team undertook a high level, non-intrusive condition survey of the building in September 2011. Armley Mills is a large site and an intensive survey was not practicable.

The site comprises the Main Mill, a linked two-storey block incorporating various uses including galleries in the former managers' houses (the East Wing) and a number of outbuildings including an electrical plant room, locomotive exhibition sheds, stores and workshops.

The buildings are in fair condition overall, bearing in mind their age and the considerable period of decline before they were opened as a museum. There is some limited insulation but not to current standards. Windows are timber and single glazed; many in the East Wing have been replaced with modern equivalents.

Fabric

The table on the next page summarises the key findings from the non-intrusive survey of the building fabric.

Results of building fabric condition survey

Item	Location	Detail	Condition
Roof structure	Throughout	- Traditional pitched, slated, timber roof structure (rafters, purlins, trusses) - Flat roof over 50% of East Wing - Exposed roof structure in areas - Low parapet condition along west elevation with concealed gutter behind. - Synthetic waterproofing fabric capping parapet - No visible vents	- Generally sound condition - Flat roof not inspected - Evidence of modern timber repairs to roof structure - Some lifted sections of capping to parapet - Lichen growth and moss growth to shallower pitches
Ceiling	East wing (offices)	- Suspended gypsum plasterboard ceilings approx. 600mm beneath original timbers of structure - Modern suspended ceiling boards on proprietary frame with un-insulated service space above. - Concrete block and beam above plant – unsealed or lined	- Some dislodged or poorly fitting boards to modern suspended ceiling
	Main mill building: third floor	- Raised ceiling to roof slope - Lined with expanded polystyrene insulation backed plasterboard (approx. 25mm +12.5mm) - Some areas of flat plasterboard ceilings (lobby to stairwell)	- Large gaps where tie beams and principle rafters of trusses pass through insulated plasterboard lining
	Main mill building: second floor	- Vaulted brick ceiling supported on iron columns - Plaster parging/distemper to vaulted brick - Some bays over lintels reinforced with concrete lintels - Exposed brick vaulted ceiling without plaster finish to cinema space	- Plaster loose in places and flaking - Brick of exposed vaulted ceiling in good condition

Results of building fabric condition survey continued

Item	Location	Detail	Condition
Walls (exterior)		- Solid coursed rough stone - 500mm to 600mm thick between third and second floor level - New coursed rubble stone to modern visitor entrance - Valley condition against east elevation of main mill	- Stone in generally good condition - Light to moderate weathering – worse at high level - Spalling to south elevation beneath parapet - Generally sound pointing - Cementitious pointing in places - Full failure to some stone cills with large cracks - Cracking and chips from arched stone lintels at ground floor level - Broken sections to cornice along north elevation of main mill - Light vegetation growth along valley to east elevation and signs of slow discharge of water from roof. - Vegetation growth from walls in places
Walls (interior)	East wing (offices)	- Gypsum plasterboard lining in places, including window reveals - Some plaster to external walls - Painted exposed stone to storage and plant areas - New exposed concrete lintels over some windows - Sections of standard blockwork lining (possible reinforcement or repair of original stone) - No insulation	- Recent decoration in places - Some cracking to lining - Signs of moisture penetration to exposed masonry
	Main mill building	- Exposed stone with lath and plaster and plaster finish to third floor - Deep splayed window reveals - Window set approx 75mm from external face of wall - Splayed sloping cills formed by stone flags with plastered finish - Lift shaft added to east elevation built from red brick - Plaster stripped from stone walls and splayed stone cills in cinema space - No insulation	- Plaster coat of varying condition and depth of coverage - Some significant areas of moisture ingress and dampness visible around window reveals with patches of failed making good in modern gypsum plaster - Significant cracking and flaking to plaster of splayed window cills - Stone flags of splayed cills in generally good condition - Generally of sound condition to cinema space

Results of building fabric condition survey continued

Item	Location	Detail	Condition
Floors	East wing (offices)	- Solid with exposed stone flags in areas - Carpet finish to offices	- Sound condition
	Main mill building	- Stone flag floors with concrete screed above - Generally finished with a sealant - Indentations for machinery fixings visible to second floor	- Sound condition
Windows	East wing (offices)	- All single glazed with timber frames - Some recently replaced windows (6 over 6 pane casement and vertical sliding sashes) with security railing to interior - Larger 4 pane windows to north elevation to match main mill windows with rough stone mullions (in plant room)	- Generally in good condition - Adequately sealed where plasterboard lining has been applied
	Main mill building	- All single glazed with thick (approx. 40mm wide) timber frames - General 9 pane design, often with central, side-hung opening casement, although in some cases all panes were fixed - Several variations of the general 9 pane window design from different times - Internal fabric blinds applied and used to third floor interactive gallery to prevent glare and over heating - Clear Perspex screwed to window frames in lieu of a guarding at lower level - Various types of single glazing replacement, including frosted, Georgian wired and modern float glass where room use or damage has dictated	- Difficult operation of opening casements due to warping of frames and over painting - Signs of leaks to windows of archive with water marks - Some panes cracked and some fully broken - Generous paint coverage to windows to west elevation in generally sound condition - Rotten cill and frames requiring repair or replacement - Degrading mortar seals to some window perimeters
External doors	East wing (offices)	- Solid timber boarded doors - Stone and concrete at thresholds	- Sound condition - No draft stripping and significant gaps around perimeter of door leaf - Cold bridging through continuation of concrete and stone at thresholds
Above ground drainage		- Simple surface water drainage via run-off into adjacent bodies of water - Hoppers and downpipes to west elevation of main mill discharge directly into mill pond - Some lined timber gutters - Concealed gutters behind parapet condition to west and south elevation - Box steel gutter to east elevation of main mill	- Some area of standing water likely due to uneven surfacing - Rusting to gutter along eastern roof pitch of main building - Holes in gutter due to severe corrosion in small areas - Some overflowing gutters causing efflorescence to masonry - Detached downpipe to east of main mill building with no below ground drainage connection - Vegetation to gutters in places

Building services

Armley Mills is served by stand alone mechanical and electrical systems. The survey covered the status of the mechanical and electrical plant but not the industrial exhibits or services in the outbuildings.

Space usage

Rationalising space use in Armley Mills would allow the provision of energy efficient mechanical and electrical systems. Spaces that require different environmental conditions are currently controlled together leading to a compromise environmental control solution. Re-configuring the spaces would allow the appropriate conditions to be maintained depending on space usage requirements. The following approach should be considered.

- Group the spaces housing industrial exhibits to be served by background space heating. Background heating will provide fabric protection and background heating for staff. Provide local heating in areas permanently occupied by staff. Staff supervising exhibits should be provided with clothing to suit low level heating of spaces. This approach could be applied to the Main Mill.
- Provide heating to conventional temperature in permanently occupied spaces (e.g. offices, reception, cafe etc.) Upgrade the performance of the fabric of external building envelope for spaces with conventional heating. This could be applied to the East Wing.
- Reconfigure the archive storage and provide suitable conditions for long term storage of artefacts. Store sensitive material (e.g. printed materials and photographs) separately from less sensitive materials such as machinery.

The buildings currently suffer high levels of uncontrolled infiltration from outside air. Draught proofing should be applied to all windows and doors (internal and external doors) to reduce uncontrolled infiltration.

Utility services

The museum at Armley Mills is served by:

- An incoming electrical supply including switchgear, meter, and a Petbow standby generator. The electrical plant is located in an outbuilding.
- A gas supply serving two gas fired boilers.
- A mains cold water system. There was no cold water storage identified during the survey. At roof level there is likely to be a feed and expansion tank for the heating system.
- Sprinkler protection as part of the fire engineering system. The sprinkler break tank and sprinkler pumps were not inspected as they are not relevant to the survey.

The services to each building are not sub-metered. The services to each building should be sub-metered and their performance compared to energy benchmarks.

Metering

A single meter for each fuel supplies the whole complex, reducing the possibility of isolating energy consumption.

Boiler plant

Space heating is provided from two gas fired boilers at ground floor of the Accommodation building. The heating plant serves the Main Mill and the West Wing. The ground floor of Main Mill and the outbuildings are not heated.

The heating plant, including boilers, flue, pumps, pipework and control valves, has reached the end of its economic life. Two constant speed, belt-driven pumps serve the heating system. There is evidence of water leaks from failed pump seals. Insulation to the boiler was stripped out and at the time of the survey no insulation was provided to pipework in the plant room. The heating system is not zoned which is inefficient. The heating plant should be replaced with modern energy efficient plant.

Boiler plant

The heating plant has reached the end of its economic life, creating an opportunity for replacement with a lower-carbon system.

A combination of panel radiators and natural convectors provide space heating to the East Wing. The radiators include thermostatic radiator valves (TRVs), however there is no facility for user adjustment to the convectors.

Myson fan convectors provide heating to the Main Mill. LOW/MEDIUM/HIGH/OFF settings provide manual adjustment to control the fan convectors. No time control is provided to the fan convectors. Like most of the heating system, the units have reached the end of their economic life and are in need of replacement.

Heating pipework runs at high level in the conditioned spaces of the Main Mill building. The pipework is not insulated to enable it to assist with space heating. This approach is not effective in the tall spaces as the warm heated air is trapped at high level and does not in fact contribute to heating the space.

Controls

The heating system is controlled by a Satchwell automatic control system. The system was switched off during the visit. It is doubtful whether the system is currently operational. This legacy control system should be stripped out and replaced with a modern digital automatic control system. The new digital automatic control system should include user interface via touchpad display panels, additional sensors, sub-meters on the Accommodation and Main Mill heating systems. The control system should incorporate sequential boiler control, zoned time control and weather compensation, optimum start/stop, alarm reporting/monitoring and trend logging.

Exhibits that require more stable environmental conditions to be displayed in display cabinets that incorporate environmental control. Explore alternative methods of providing environmental control for other exhibits such as conservation heating[1] as employed by the National Trust. The robust industrial exhibits will be displayed in spaces with background heating. It is not unreasonable to expect visitors to wear more clothing on cold days in an industrial museum.

Ventilation and Infiltration

Most spaces in Main Mill and the East Wing are provided with natural ventilation from opening windows. Hardware for the opening lights needs to be repaired to enable the controlled provision of natural ventilation.

The windows and doors are poorly sealed. As a result, the building suffers from high levels of uncontrolled infiltration which makes a significant contribution to energy loss from the building.

Armley Mills includes generous floor to ceiling heights and exposed heavyweight wall and ceiling construction. The building is suited to a passive environmental control approach to maintain comfortable conditions in summer.

There is no humidity control at Armley Mills museum. Future retrofit should avoid active humidification control by adopting energy efficient measures such as conservation heating.

Excellent passive design

Generous floor to ceiling heights, exposed heavyweight construction and ample ventilation provides the basis for a good low-energy design.

Domestic water services

The building is served by mains cold water and the building is protected by a sprinkler system. The location of any sprinkler tanks or domestic cold water storage tanks could not be identified during the survey.

[1] National Trust Conservation Directorate, Guidance Note No. 6/2, July 2020

Power and Lighting

Power supply to equipment and lighting systems is only provided with manual switching and is not sub-metered.

In common with historic mill buildings, The Main Mill and other buildings at Armley Mills are provided with generous natural daylight from the window design.

The Main Mill includes a mixture of lighting schemes including compact fluorescent fittings as direct replacements of incandescent light fittings. The historic lamp shades have been retained and re-used. The lighting level over some of machinery was low. A dated track lighting scheme is used in some of the exhibition spaces. The system should be replaced and a more efficient system installed.

Manual switching is used to control lighting within the building. There is no lighting control to switch off lighting when a space is empty or when there is adequate levels of natural daylight. The windows do not include UV filtration as Armley Mills mainly houses industrial exhibits generally in the centre of the rooms. It is expected that this strategy can be maintained in the Main Mill. All lighting and power sub-circuits should be sub-metered to enable assessment of energy consumption in different spaces.

External lighting was still switched on at the time of the visit indicating lack of time control or photocell control. External lighting should only be switch on when daylight levels are low and between pre-set times.

Inefficient lighting

Dated tracked lighting scheme could be replaced with something significantly more efficient.

Lack of adequate controls

External lighting on during the day highlights the need for more advanced control systems or behaviour change.

04 Bill analysis and benchmarking

The energy consumption at Armley Mills has been compared with benchmarks for gas and electricity consumption, and the results can be seen in the graph below, measured in the energy used over a year for each square metre of the building.

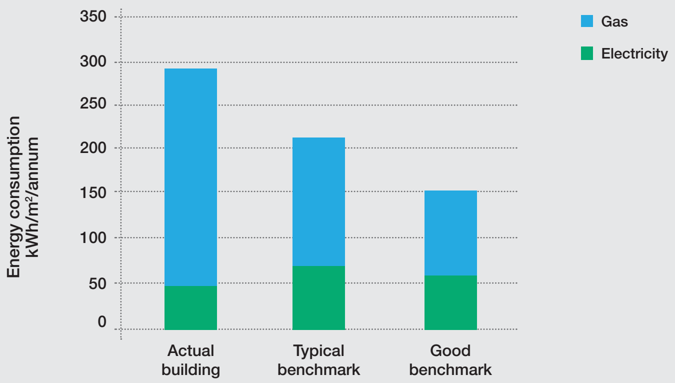
The electricity consumption is at quite a low level when compared to the benchmarks. The reason for this could be that the most appropriate benchmark is one that covers both museums and art galleries. The benchmark figures will therefore include buildings that have a high degree of display lighting. Display lighting can be particularly energy intensive due to the high brightness but there is little display lighting at Armley Mills – most lighting is to the general spaces.

With regard to the gas consumption, the building is using around 75% more than even the typical benchmark. This is not unexpected in a heritage building with its inherently less efficient fabric. However, the energy consumption figures and areas used in this comparison include some areas where only low-level background heating is provided. This means that the performance would be worse if these areas were heated to traditional comfort levels as is assumed in the benchmark figures.

It is clear from these results that there is opportunity to reduce the energy consumption used to heat the building.

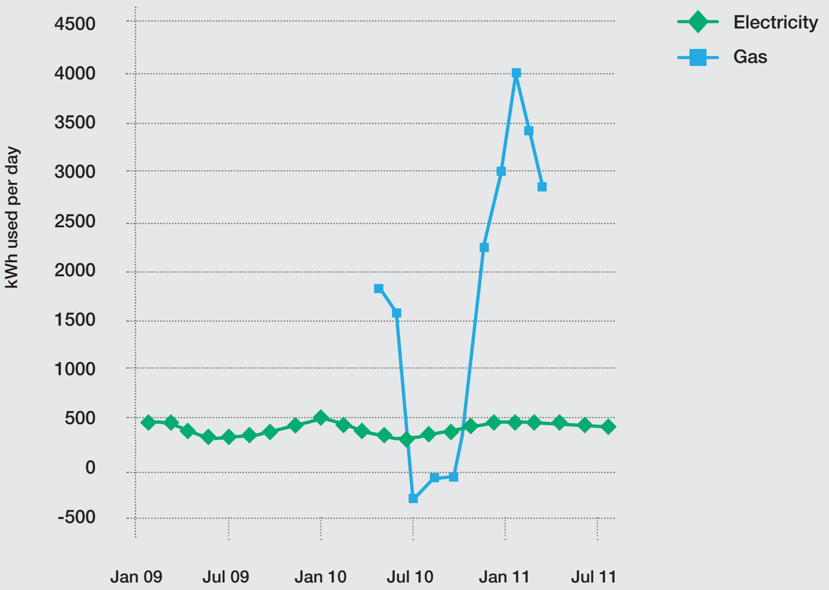
The profile of the gas consumption, whilst confused slightly by the negative figures created by the correction of estimated bills, is highly seasonal suggesting that the emissions are largely due to heating loads as opposed to domestic hot water.

Energy consumption at Armley Mills, Leeds



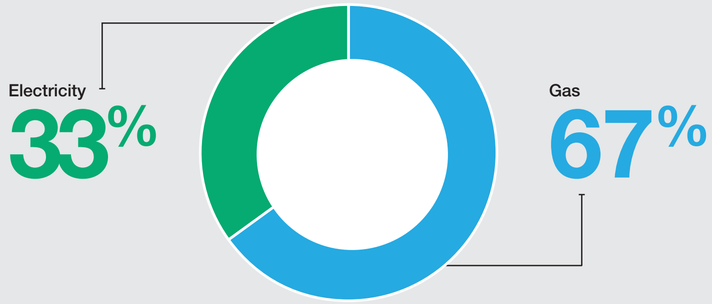
The seasonal variations seen in the electricity consumption are also interesting. The winter maximum is often double the summer minimum. Assuming that there are no areas of the building that are electrically heated, this profile could indicate that the benefit of increased daylight hours in the summer months is being usefully exploited to reduce energy consumption at that time.

Historic energy use at Armley Mills, Leeds



Finally, even when the higher carbon intensity of electricity is taken into account, it can be seen that fossil fuels account for two-thirds of the emissions from the building.

Proportion of carbon emissions from each fuel type



The table below shows average energy consumption and other assumptions used for the cost-benefit analysis in section 6.

Gas and electricity costs are based on the rates from Harrogate Borough Council for consistency with other case studies. The carbon emissions factors referred are from SAP 2009, the government's standard assessment for the energy rating of dwellings. Part L of the UK Building Regulations 2010 also applies these factors to non-domestic buildings.

Assumptions for options appraisal	Armley Mills, Leeds Amount
Estimate of Gross Internal Floor Area	2737 m^2
Annual electricity consumption	12,7432 kWh
Annual gas consumption	675,099 kWh
Average electricity cost	10.22 p/kWh
Average gas cost	2.58 p/kWh
Annual electricity cost	£13,024
Annual gas cost	£17,418
Carbon emission factors - electricity	0.517 $kgCO_2/kWh$
Carbon emission factors - natural gas	0.198 $kgCO_2/kWh$

05 Interventions

Scope

The most significant elements of the mill are the envelope and historic fire-proof floor structure: the masonry, arrangement of openings, plain windows, boarded doors, slate roof, vaulted floors which should all be maintained and visible. There is scope to secondary-glaze windows without affecting the external character of the mill, where this is essential, although this will detract from the robust quality of the interior. To insulate walls will affect character of walls where brickwork 'grins' through the layers of limewash and distemper. Above floor insulation is potentially feasible at first floor, to insulate this floor from the ground floor, without harming the significance of the vaulted floor structure.

Maintaining the breathability of walls and improving passive ventilation is important to preserve the building fabric.

There is scope of renewable energy generation at this site; both water power and roof-mounted solar panels are advocated by Leeds City Council in the recent Conservation Study of the mill (2010).

The study team has selected the interventions that could reasonably be expected to be worthwhile based on experience and these are shown in the table on the next two pages.

Feasible carbon saving interventions

No.	Intervention	Description	Heritage impact
Behaviour change			
1	Energy consumption targets/monitoring/ metering	Establish clear and accurate benchmarks of current consumption. Set realistic targets and monitor performance against targets by reading meters, including sub-meters as included below. Key carbon reduction tools.	None
2	Formal staff/building users feedback mechanisms	Establish robust and continuing procedures to use occupiers' experience effectively.	None
3	Sustainability brief for staff	Set out and explain the reasons and approach to sustainability. What does it mean for the individual?	None
4	Develop building user/ manager training program	Ongoing training is important including new starters and refresher courses. Strong and clear leadership should be at the root of this.	None
5	Daytime cleaning service	Cleaning during the day means lights do not have to be used at night when the building would be otherwise unoccupied.	None
6	Building users' guides, up to date, comprehensive, accessible Operation & Maintenance manuals	Occupiers and facilities managers cannot be expected to use and operate buildings without clear information appropriate to their level of involvement.	None
Building fabric			
7	Install wall insulation	Insulate the internal face of external walls where practicable in the East Wing. This may not be appropriate in the domestic gallery areas. Scarify paintwork to improve moisture penetration. Line walls with a layer of natural, breathable insulation (e.g. 75mm of wood fibre board or hemp batts) with suitable detailing to mitigate cold bridging. Apply a lime or clay plaster and natural paint finish.	This will affect areas of medium significance in the East Wing but this intervention should still be possible where relationships between openings and walls can be managed by careful design. Early discussion with local planning authority is recommended but the benefits of the proposals are considered to justify the internal alterations. If the domestic galleries are maintained, wall insulation would not be appropriate as interiors should be kept as original as possible.

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
8	Install roof insulation	Install natural insulation to underside of flat roof to the East Wing and between rafters in the adjacent pitched roof area over the shop and cafe area (e.g. 100mm of wood fibre or hemp batts) In the former mill managers' houses used as gallery space increase existing insulation to roof space to 270mm (e.g. sheep's wool or glass fibre)	This will not affect areas of significance in the East Wing as the roof is a modern flat roof or a roof space void.
9	Install draught strips	Install draught strips to all windows and internal and external doors. Seal as many as possible other air leakage routes, in particular around the insulated lining to the roof over the Main Mill.	This will have a minimal impact as the insulated roof lining is already in place.
10	Install high performance secondary glazing	Install high performance secondary single glazing to the non-display areas of the East Wing.	This will affect areas of medium significance in the East Wing but is easily reversible and should be relatively discreet. Early discussion with local planning authority is recommended but the benefits of the proposals are considered to justify the internal alterations.

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
Building services			
11	Occupancy sensors for lighting	Install throughout the building to enable automatic shutdown of lighting when spaces are unoccupied	None
12	Daylight switching and dimming of lighting according to available daylight	Provide daylight sensors to dim or even switch off lights in response to daylight levels, reducing operating and energy costs.	None
13	Energy efficient light fittings, LED lighting	Replace existing low efficiency light fittings with modern low energy equivalents such as compact fluorescent, T5 high frequency fluorescent and LED lighting as appropriate.	None
14	Electrical sub-metering to all key installations	This should cover lighting, small power, machinery, plant. This facility is vital to understand how much power is being used by different services installations.	None
15	Time switches or similar on small equipment	A low cost means of guaranteeing equipment shut down when not in use.	None
16	Photovoltaics (PV) with Feed-In Tariff	Photovoltaic solar electricity panels installed on the modern, south facing flat roof above the East Wing.	No material impact on significance as the flat roof area is a modern addition. The site overlooked but the installation would not materially worsen the current appearance.
17	Modify temperature set points	Reduce temperature settings to maintain 15-16°C to galleries and 19-20°C to other areas. Staff may need to wear more clothing during cold weather, particularly in the galleries.	None
18	Ensure controls are working correctly	Initial review to maximise the benefit and efficiency of existing systems. Ensure that testing is embedded in maintenance regime. Train gallery staff to make minor adjustments to control system. Higher level access restricted to specialists.	None
19	Install digital control system for all major plant	Digital building management system with boiler optimum start/stop, automatic trend logging, alarm handling, monitoring and other aids to efficient operation.	None
20	Upgrade boiler system and pumps	Two replacement, high efficiency gas condensing boilers with high efficiency pumps.	None

Low and zero carbon technologies

The case study team considered a range of possible technologies which are reviewed in the table below.

LZC Technology and Low Energy options	Approximate capital cost	Cost per 1% CO_2 reduction over base building	Operational cost	Future energy costs	Simple payback (without Feed in Tariff/RHI)
Solar Hot Water Panels	Moderate	Moderate to High	Low	Low	Moderate
Photovoltaic	Very High	Very High	Low	Low	High
Gas Fired District Heating CHP	Moderate	Moderate	Moderate	High	Moderate to high
Biofuel CHP	Moderate to High	Moderate	Moderate to High	High	Moderate to high
Biomass CHP	Very High	Moderate	very High	Low	High
Wind Turbines	Moderate	Moderate	Low	Low	High
Off Site Wind Generation	High	Moderate	Low to moderate	Low	Moderate
Biomass Boilers	High	Low to Moderate	High	Low	Low to Moderate
Ground Source Heat Pumps	High	Very High	Moderate	Moderate	High
Air Source Heat Pumps	Moderate	Moderate	Moderate	Moderate	Moderate
Open Loop water source heat pump	High	High	Moderate	Moderate	High
Exposed Thermal Mass	Low	Low	Low	Low	Low
Passivhaus	High	Moderate	Low	Low	Low
Maximisation of daylight, daylight controls, automatic lighting controls & energy efficiency lighting	Low to Moderate	Low	Low	Low	Low
Earth Tubes	Moderate	Moderate	Low	Low	Moderate
Water wheel to generate electricity	High	Moderate	Moderate	Low	High

Noise impact	Planning implications	Funding/ Grants	Applicability to St Peter's Street	Technical issues/any other criteria
None	Roof loading & less sensitive elevation	RHI	×	Solar Hot Water limited by low hot water demand in building. System is effective with a centralised hot water system absent at Armley Mills.
None	Roof loading & less sensitive elevation	FIT	✓	Limitation on size of roof area available. Consider installing on flat roof to East Range.
Moderate	Flue height		×	Cost effectiveness to be balanced with carbon reduction requirements. Minimum operation hours 4000 to 5000 required to be effective.
Moderate	Flue height		×	Reliability of fuel supply, concern over sourcing of fuel product
Moderate	Flue height, pollution levels & plantroom size	RHI	×	Limited number of successful installations. Restricted plant room/fuel store area, delivery access problematic, planning issues - flue height and NOx levels to address, maintenance costs.
Moderate to high	Planning application required	FIT	×	Not appropriate in location close to build-up area and due to local topography. Planning implication and output/effectiveness dependent on site specific wind speed.
High	Planning application required	FIT	×	Technology acceptable only with direct link to building.
Low (note noise from delivery vehicles)	Flue height, pollution levels & plantroom size	RHI	✓	Plant room/ fuel store area, delivery access, planning issues - flue height, NOx levels, maintenance costs. Some of the outbuildings could be modified to accommodate biomass plantroom.
Low	Archaeological impact to be assessed	RHI	×	Output depends on ground conditions. Limited application of low grade heat produced GSHP means the system is unsuitable for listed building with limited opportunity for fabric improvements to reduce heating demand.
Moderate	Moderate	RHI	×	Noise/plant location, efficiency in winter operation, low grade heat produced by ASHP.
Low to medium	Application to Environment Agency	RHI	×	Local water body for operation of water source heat pump is available from adjacent water course. Limited use of low grade heat in building unless thermal performance upgraded to new building standards.
Low	None		✓	Exposed thermal mass is currently provided at Armley Mills particularly in the Main Mill.
Low	Historic character of building		×	Low U-values required for walls and glazing not achievable on listed building without affecting character of building.
Low	None		✓	Use energy efficient lighting and control systems throughout the buildings.
Low	None		×	Disruptive to existing listed builings. Require space for installation and adoption of mechanical ventilation strategy. Concern about water levels at site which are likely to be high.
moderate	Moderate		✓	This technology re-uses water wheels used to power the mills but this time to generate electricity. Limited capacity and some heritage concerns.

06 Options appraisal

Introduction

Section 5 proposes different interventions which will generate varying levels of savings in carbon and energy costs. It is essential to be able to compare them to decide which are the most worthwhile.

The options are appraised by cost-benefit analysis, comparing the budget cost of the intervention with the likely potential savings in the current energy costs and carbon emissions analysed in Section 4 of the case study.

The options appraisal is a high-level indicative exercise designed to give a broad brush overview of the relative benefits of different interventions. If it is decided to implement any interventions, a more detailed analysis to test assumptions will be essential.

The cost benefit analysis table on the next two pages uses a traffic light system to show, at a glance, the relative advantages and disadvantages of individual interventions.

Green - Beneficial and worth pursuing

Amber - Less beneficial but still worthwhile

Red - Less likely to acceptable on current assumptions

Cost benefit analysis table

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Behaviour change									
1	Energy consumption targets/ monitoring/ metering	Easy win	100	2.0%	5.0%	1,131	0.1	6.68	None
2	Formal staff/ building users feedback mechanisms	Easy win	100	0.5%	0.5%	152	0.7	1.00	None
3	Sustainability brief for staff	Easy win	100	0.5%	0.5%	152	0.7	1.00	None
4	Develop building user/manager training program	Easy win	100	2.5%	5.0%	1,196	0.1	8.33	None
5	Daytime cleaning service	Easy win	100	0.5%	0.5%	152	0.7	1.00	None
6	Building users' guides, full accessible O&M manuals	Easy win	100	0.5%	0.5%	152	0.7	1.00	None
Building fabric									
7	Install wall insulation	Major	46,900	0.0%	13.5%	2,351	19.9	18.05	Manageable
8	Install roof insulation	Cyclical	3,800	0.0%	3.9%	679	5.6	5.21	None
9	Install draught strips	Easy win	6,000	0.0%	7.0%	1,219	4.9	9.36	Manageable
10	Install high performance secondary glazing	Major	20,300	0.0%	4.5%	784	25.9	6.02	Manageable

Cost benefit analysis table continued

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Building services									
11	Occupancy sensors for lighting	Cyclical	2,400	1.0%	0.0%	130	18.4	0.66	None
12	Switching/ dimming according to available daylight	Cyclical	10,300	7.0%	0.0%	912	11.3	4.61	None
13	Energy efficient light fittings, LED lighting	Cyclical	41,100	12.0%	0.0%	1,563	26.3	7.91	None
14	Electrical sub-metering to all key installations	Easy win	7,500	5.0%	0.0%	651	11.5	3.29	None
15	Time switches or similar on small equipment	Easy win	300	0.5%	0.0%	65	4.6	0.33	None
16	Photovoltaics (PV) with Feed-In Tariff	Major	11,200	2.2%	0.0%	1,206	9.3	1.45	Manageable
17	Modify temperature set points	Easy win	100	1.0%	5.0%	1,001	0.1	7.34	None
18	Ensure controls are working correctly	Easy win	1,000	1.0%	2.0%	479	2.1	3.33	None
19	Install digital control system for all major plant	Cyclical	20,000	2.0%	5.0%	1,131	17.7	8.00	None
20	Upgrade boiler system and pumps	Cyclical	28,300	0.5%	10.0%	1,807	15.7	13.70	None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07 Recommendations

Interpretation

All of the suggested interventions show worthwhile significant carbon savings but in some cases (the red items) the capital costs are relatively high and the cash payback in energy cost savings is distant. In part this arises because Leeds City Council is understood to have negotiated extremely favourable energy prices and this significantly lengthens the time taken to achieve payback compared with the majority of building owners.

The calculated energy cost saving disregards inflation but it is realistic to anticipate that energy prices will continue to rise at a rate considerably greater than general inflation. It is sufficient to state here that actual payback through energy saving is likely to be much more rapid than shown in the cost-benefit analysis table.

The savings figures in the table are deliberately not totalled. Such totals would be very misleading. Each measure adopted limits the scope for further savings because the total energy use reduces each time. The order of adoption and interaction between different interventions would also have significant impacts on the overall outcome. It is not practical to suggest a likely overall saving.

At a glance
Recommendations

Training and behaviour change initiatives

Rationalise space use to reduce energy consumption

Reduce temperature of gallery spaces

Install draught strips and seal gaps

Insulate walls and roof of East Wing

Daylight sensors for lighting

Install more efficient lighting

Upgrade boilers, pumps and controls

Install photovoltaic panels

Fit secondary glazing to East Wing

Behaviour change

It is essential to reinforce and support physical interventions with training and motivation so that the building is operated efficiently and beneficially to reduce carbon emissions and save costs. Administrators and facilities managers need to have a clear understanding of the building and its systems. This will enable appropriate leadership to arrange training and support for the staff in the building. The group of items in the first section of the table aim to provide a comprehensive range of measures to achieve this.

It is assumed that behaviour change and building management related items can be implemented by existing staff through internal strategies with normal training and personal development which needs to be sustained and continuing. Although some limited external assistance may be required, this is normal for staff training and the cost of each of these interventions is assumed to be a nominal £100. In the circumstances it is recommended that all these measures are adopted.

Building fabric

Some of the interventions explored in this section show somewhat distant payback but all of them should provide substantial and continuing annual carbon savings.

- Improved roof insulation in the East Wing should pay back in about 6 years
- Installing draught strips to internal and external doors and gap sealing is low cost and should show early benefits in reducing heat losses. The indicative payback is 5 years.

The following measures should be considered as part of future internal refurbishment works when they can be carried out with least disruption:

- Installing internal insulation of external walls in the East Wing which should pay back in about 20 years.
- Installing high performance secondary single glazing does not pay back for over 25 years. This is largely because the windows are a small proportion of the wall area.

Building services

Items 12 and 14-18 all show payback within 12 years notwithstanding very low energy prices.

- Daylight switching and dimming
- Electrical sub-metering to all key installations
- Time switches or similar on small equipment
- Photovoltaic solar electricity panels aided by the Feed-In Tariff
- Modify temperature set points
- Ensure controls are working correctly.

Lighting systems

Daylight switching and dimming could show a reasonable payback period compared to the life of the system.

Recent announcements regarding the likely reductions in the Feed-In Tariff amounts suggest that the payback period of the proposed photovoltaic installation by be made significantly longer than at the currently applicable rate.

The remaining items show an indicative payback between 16 and 26 years and energy price increases will reduce this considerably.

- Installing more efficient light fittings (item 13) is calculated to save 8 tonnes of carbon a year but the relatively significant costs only pay back in energy cost savings in 26 years. This may well be improved on more detailed investigation.
- Items 20 and 21relate to the provision of new boilers, circulating pumps and the installation of modern controls. These measures could perhaps reduce gas and electricity costs by perhaps 15% and 2.5% respectively with carbon savings of around 22 tonnes a year. However, low energy costs result in a projected payback of up to 18 years. However, the existing systems are obsolete and becoming unreliable. It is recommended that the systems are replaced to achieve a major reduction in energy consumption and to avoid the risk of costly and inconvenient breakdown and deteriorating performance.

Other issues and opportunities

Rationalisation and re-planning

There is scope for the museum's requirements and the mills accommodation to be more successfully reconciled through re-planning the building's layout and zoning. A rationalisation of this type would enable the retrofit strategy suggested in this case study and maximise long-term opportunities for carbon reduction and running costs.

This would be achieved in part by careful grouping of spaces with complimentary internal environments and uses. It would not necessitate the reduction of space currently occupied by the museum, but diversification and designation of space for other complementary uses could be considered to broaden and increase visitor numbers. These may include uses such as a small craft workshop and retail spaces, although thorough feasibility analysis would be required to appraise such proposals.

Space usage

Re-planning the internal layout and zoning would open up possibilities for significant carbon savings.

Improvement to the condition, access and experiential qualities of external spaces adjacent to the mill would similarly extend the range of activities available and connectivity between exhibitions or other uses.

Expanding the entrance point into the interactive gallery would provide opportunities for better presentation of visitor information, introduction to interpretation devices and provide an immediate experience within the original mill building with a glimpse of the galleries beyond. It would also encourage a positive sense of direction to the beginning of the route through the museum.

Advantages

Improving the relationship between spaces and the natural progression through exhibition areas and other museum facilities would be integral to the re-planning and would result in a better visitor experience, continuing appeal as an attraction and more sustained building use.

Careful re-zoning of the spaces will enable more efficient service distribution and programming, which would reduce heat and power losses to low usage spaces and decrease energy consumption and carbon emissions (if there were to be some reliance on mains power).

Implications

Significant changes such as those outlined here would require careful liaison between all stakeholders and a cross-disciplinary approach combining tourism, education, environment, heritage, engineering and architectural disciplines. This would help build committed, consolidated and fact-based support for a credible, fundable and deliverable project.

Upheaval to the galleries and exhibits would present logistical challenges and would need to be carefully planned and controlled. Risk assessments would be essential when considering relocation of exhibits.

During on site operations the museum would also experience a period of closure when no revenue could be taken.

Appraisal

This intervention should intensify usage of the spaces within the mill buildings. Increased energy efficiency, lower carbon emissions and an improved quality of tourism attraction would need to be assessed against upheaval and downtime to the museum and capital cost.

It is very important for the building to continue to be capable of adaption to maintain its viability and ongoing use. Rejuvenation of the mill may also complement wider regeneration initiatives in Armley.

Hydro electricity generation

The 2010 heritage study considers hydro energy generation by means of a reverse Archimedes screw in the River Aire.

One of the original water wheels remains at Armley Mills and there is an opportunity to restore this to working order to power a mini-hydro electric scheme to generate electricity.

Both opportunities would generate electricity for use on site. Out of hours surplus electricity could be fed into the grid. Although there is currently insufficient information to establish costs and revenues, it should be possible to obtain the benefits of the Feed In Tariff under current government support mechanisms for micro hydro projects. In addition the heritage value of the water wheel coupled with the sustainable energy proposal might increase the project's chances of securing grant funding.

Water wheels

Restoration of the water wheels would provide significant opportunities for low carbon electricity generation along with increased heritage value.

Overall heritage impact

The interventions proposed to Armley Mills have been designed to take account of the building's varying levels of heritage significance and opportunities to improve energy efficiency as part of future refurbishment. No changes are proposed to the Grade II* listed Main Range which is of exceptional significance. In this range it is proposed that heating levels and energy requirements remain low, provided some more demanding uses such as archive storage or education can be reviewed. Other areas such as the Grade II listed East Wing are of less significance and present more scope for intervention without affecting significance. The external walls and roof of this range could be insulated internally and windows refurbished with draught-proofing without harming significance. A high standard of design and installation will be essential.

Upgrading building services will not affect the significance of the building, if carefully detailed and installed.

The long history of power generation on this site provides a precedent for exploring options to generate energy today. Installing water turbines or reinstating water wheels could capture the public's imagination as well as generate electricity and should not affect significance if carefully designed and installed. The low-pitched (almost flat) roof over the former warehouse in the East Wing is a 20th century structure of no significance and photovoltaic panels could be sited here, hidden behind the parapet, without affecting the significance of the site or its setting.

Case Study 04

Almondbury Dwelling, Huddersfield

01 Summary

13 St Helen's Gate Almondbury is a Grade II listed traditional early 19th Century two-storey stone handloom weaver's cottage with a stone slate roof. It is in an attractive semi-rural village on the outskirts Huddersfield and has been in the ownership of Kirklees Council for many years. It is understood that following use as storage, it was re-converted to a two-bedroom dwelling about thirty years ago.

The building is significant for its historical and architectural value as a stone-built weaver's cottage in West Yorkshire, part of an attractive group on this street. Although altered in detail, its overall form and appearance are intact, giving the building high significance. The first floor is lit by characteristic horizontal mullioned windows to provide light into the loomshop.

The building is generally in good repair and has a new high efficiency gas condensing combination boiler. Windows are single glazed and generally provide good natural light. Most rooms have generous ceiling heights. There is no wall insulation but the loft insulation was recently topped up to meet current standards. There are some limited and relatively normal issues with dampness but generally the cottage is warm and dry with characteristically substantial stone walls. There is a small garden to the rear.

The analysis of the energy bills available for this property showed some unexpected results. The electricity use is much higher than would be expected and it is highly seasonally variable. This is due to the fact that the systems that are in the building at the moment were only installed this year. For the period covered by the data, the only gas-fired heating was a fire in the lounge. All other heating and the provision of hot water was carried out using electricity. In making assessments of potential future energy savings and carbon reduction, realistic assumptions have been adopted based on relevant benchmarks. It is generally the case that small terraced cottages of this type with substantial stone walls are relatively thermally efficient.

This case study concludes that there are limited opportunities to reduce carbon emissions from the building. These are not greatly limited by the historic fabric of the building. Suggested improvements would only affect the interior of the building which is generally of low significance. The study tests the indicative costs and benefits of 12 possible interventions. All of these would provide worthwhile savings in carbon emissions. Some, for example, installing secondary single glazing have distant payback but are worth implementing to provide steady savings. The following are the most significant recommendations, which could result in substantial annual savings.

- A range of behaviour change related items which can be implemented at minimal cost
- Installing draught strips to doors and windows
- Internal insulation of external walls as part of future refurbishment works but this would lead to some loss of space, particularly in the kitchen
- Replacing tungsten filament light bulbs with low energy equivalents
- Installing photovoltaic solar electricity panels to the rear roof slope which is not significantly overlooked but it is recognised that this could be controversial. However, payback periods may be delayed as a result of probable changes in the Feed-In Tariff.

02 Heritage value and statement of significance

Statement of significance

The building is significant for its historical and architectural value as a stone-built weaver's cottage in West Yorkshire, part of an attractive group on this street. Although altered in detail, its overall form and appearance are intact and so it has high significance. The first floor is lit by characteristic horizontal mullioned windows for the loomshop but there is a sash for the front parlour; all the joinery is modern.

The rear west elevation has been more altered, is not visible from the front and has slightly lower significance. The small-scale interiors have been refurbished on several occasions, and retain no historic features of note, apart from the plan-form, some late 19th century joinery items and the staircase. The roof structure was not seen. The interiors have overall low significance. The Grade II listing is appropriate for the building (listing reference number 1231784).

Rear elevation

Alterations have reduced the heritage significance of the rear of the property.

Summary table

The table below lists the key findings from the non-intrusive survey of the building fabric.

Building feature	Significance	Date
Exterior walls, front and rear	High	Early C19
Exterior walls, S gable	Medium	Early C19
Brick chimney stacks	High	Probably C20
Windows: E front GF sash	Medium	Late C20 replacement for historic sash
Windows: E front FF weavers window	Medium	Late C20 replacement for historic joinery/glass in early C19 surround/ mullions
Windows: W, rear elevation	Low	Late C20 joinery in early C19 first floor stone mullions
Front door	Low	Late C20
Rear door	Low	Late C20
Interior: front GF room	Medium	Refurbished late C20
Interior: kitchen/pantry	Low	Refurbished late C20
Stairs to first floor	Medium	C18 – C19
Interior: FF front bedroom	Medium	Refurbished late C20
Interior: FF bathroom and second bedroom	Low	Refurbished late C20
Roof-space/structure	Not seen	Date unknown
Stone slate roof covering	High	Probably re-laid C20

The building – evolution, description and setting

Building evolution

The cottage was probably built around the early 1800s, and is a typical example of a weaver's cottage with one large well-lit loom shop at first floor. This building type was constructed from c.1770 to 1850 in woollen cloth producing valleys in this area.

The building's use for weaving probably ceased in the second half of the C19, when the upper floor was sub-divided into bedrooms and some internal refurbishment carried out. It will have been in more or less continuous domestic use since, although the occupier remembers the house being temporarily used as council store before it was refurbished in 1983. Most of the external joinery was replaced, with the possible exception of some first floor fixed windows, and the interior 'modernised' as part of this refurbishment by the Council.

Interior

Compact interior retains almost no historic fabric other than defining the plan-form.

The building's fabric and character

The small terraced cottage is typical of the hundreds of stone cottages built across the Yorkshire Pennines before c.1840. The 2-storey front facing east has some formal architectural character, with one vertically-sliding sash to the ground floor and a 4-light mullioned window, originally designed to light the first floor loomshop. All the door and window joinery is modern to front and rear but original openings have been maintained and some of the first floor fixed glazing may be 19th century. Straight joints to the right of the first floor front window suggest an earlier opening here, perhaps a taking-in door which was later blocked.

At the rear the first floor former 5-light mullioned window to the loomshop has been altered by blocking the middle light, probably when the interior space was sub-divided. The building is built of local carboniferous sandstone with riven stone slates to the asymmetrical roof; the front pitch is longer. The two stacks are red brick.

The compact interior has been refurbished and retains almost no historic fabric other than the walls that define the plan-form, and the projecting chimney breasts. The only other features are the narrow tongue & groove ground floor ceilings, the timber window linings to the mullioned window, one 4-panelled bedroom door and the landing balustrade, all probably late C19 pine.

The rest of the joinery, the front draught lobby, fittings and wall finishes date from 1983 or later. Fireplaces have been removed and openings blocked. Blocked doorways in the party wall with No.11 on both floors suggest that the cottages may have been connected in the past.

Building setting

The cottage is the left hand of a pair with No.11, part of a varied terrace of stone-built cottages of similar date. Only the front is visible from the public realm. At the back is a small enclosed garden.


ALASDAIR INGRAM
Architect
Gate 9
Graphic Design
Tel: 01484 422233
Mob: 07967592111
GATE 9 DESIGN LIMITED

03 Building condition survey

13 St Helen's Gate Almondbury is a traditional early 19th century two-storey stone handloom weaver's cottage with a stone slate roof. It is in an attractive semi-rural village on the outskirts Huddersfield and has been in the ownership of Kirklees Council for many years. It is understood that following use as storage, it was re-converted to a two bedroom dwelling about thirty years ago. Although the accommodation is modest, ceiling heights are unusually generous and the principal, front bedroom is a good size with excellent natural light from the characteristic, long window that would have lit the original weaver's loomshop. There is a small garden to the rear. Recent modernisation included the installation of a new gas boiler and loft insulation to current standards. The current condition of the property is as follows.

Fabric

The table on the next page lists the key findings from the non-intrusive survey of the building fabric.

Setting

The cottage is an excellent example of a stone handloom weaver's cottage.

Interior

The interior of the building has undergone significant refurbishment, reducing its heritage significance.

Results of building fabric condition survey

Item	Location	Detail	Condition
Roof structure		- Traditional timber structure – rafters, purlins - A-symmetrical pitch - Stone slates with un-capped, angled stone ridge tiles (2 no. vented) - 2 no. separate brick chimney stack - Application of roof felt unknown - Areas of abutment with adjacent property walls - Boiler flues and vents terminating through roof	- Suitable upstand of flashing at abutments - Irregularities to lead flashing which could allow water penetration from driving wind - Missing weatherproofing around flue/vent terminals
Ceiling	Ground floor	- Timber boarded with gloss paint finish to immediate underside of floor joists and around beams	- Generally good condition - Small gaps between boards due to movement
	1st floor	- Textured paper on lath and plaster ceiling - Ceilings raised above eaves to form rafter-line sections to front and rear of property - Insulation at ceiling level of 270mm mineral wool, applied March 2011 - No insulation to areas of ceiling in line with rafters	- Generally good condition - Water staining to ceiling in front bedroom on first floor indicating previous leak - Peeling paper and staining to bathroom ceiling due to condensation and high moisture levels - Hatch to roof space with some draft stripping
Walls (exterior)		- 575mm thick stone - Coursed stone (variable sizes) - Raised and cut pointing - Injected dpc evident to exposed partition wall at front	- Some stone spalling at low level to front of house - Cementitious mortar pointing - Cementitious mortar filling to significantly deteriorated stones at rear of house - Gaps to pointing up around drainage outlets - Some brick specials missing from rear stack

Results of building fabric condition survey continued

Item	Location	Detail	Condition
Walls (interior)	Ground front	- Textured paper lining applied to plaster - No insulation	- Damp along front of house, up to 1m above floor level, particularly where the external ground floor level is higher than the internal level, allowing moisture to penetrate from the outside - Signs of damp to interior corners of ground floor (in lounge) where paper is detaching and bubbling away from walls
	Ground rear	- Textured paper lining, applied to plaster - No insulation - Kitchen walls largely obscured by units	- Some efflorescence to painted walls in pantry to rear of house, along external wall and solid partition wall with kitchen
Floors	Ground floor	- Solid ground floor with carpet finish - Stone treads to staircase – construction not known - No insulation	- Level and sound condition
	1st floor	- Timber floor boards with carpet surface	- Sound condition
Windows		- Single glazing in painted timber frames - 3 no. new fixed lights with horizontal glazing bar and 1no. vertical sliding sash to first floor front - 1 no. new 6 over 6 vertical sliding sash to ground floor front - 1 fixed light and 1 side hung casement to each of the 3 window sets to rear, all with horizontal glazing bars - Single, partially in-filled fixed light with vent to pantry - All windows set into stone surrounds with stone mullions internally encased with ply or timber boarding– insulation undetermined - Windows set close to external face with deep, splayed internal reveals. - No trickle vents	- Good condition of frames, glazing and seals - Significant cracking to softwood window boards
External doors		- Solid timber door with clear, single pane fanlight to front door - Internal draft lobby to front door	- Generally good condition - Stone threshold forms cold bridge from interior to exterior - No draft stripping to doors
Above ground drainage		- Painted cast iron downpipes - Painted and lined timber gutters - Drainage gaps in external surfaces allows surface water to soak away to rear garden	- Good condition

Building services

The building services installations are typically limited in extent but are generally in good order. The building was recently renovated and a new heating system was installed.

Heating plant

Manually read electricity and gas meters are provided. The gas supply serves a gas-fired boiler and a gas fire in the living room.

Space heating is provided by a Valliant EcotecPro combination boiler. A combination boiler provides both space heating and domestic hot water service. Combination boilers are energy efficient in combustion and heat recovery and they avoid hot water storage. The central heating system serves panel radiators and temperature control is provided by thermostatic radiator valves (TRVs). A vertical flue discharges boiler emissions through the roof.

A traditional gas fire heater, located in the fireplace, provides supplementary heating to the living room. The flue is routed via the chimney to roof level. The gas fire was not recently replaced and its control is stiff to operate and needs to be rectified. In gas fires of this type a large proportion of heat is exhausted to outside and its operation should be limited as it will significantly increase energy costs and carbon emissions.

Ventilation

Natural ventilation is provided by opening windows. The building has high floor to ceiling height which provides relatively generous internal air volumes apart from in the low-ceilinged kitchen and pantry to the rear where the floor level is significantly higher. The building is kept cool in summer by the thermal mass of the stone wall construction and solid floor. This structure also continues to store heat after the radiators shut down and generally provides natural modulation to internal environmental conditions.

Traditionally internal finishes to walls and ceilings will absorb moist air to a significant degree and this will be purged later by evaporation. However, as in most modern interiors, it appeared that impermeable plastic-based emulsion paint has been used and the benefits of this natural ventilation system will be limited. This is likely to be most significant in the kitchen and bathroom where additional need to open windows will increase heat losses during colder weather.

Power and lighting

Lighting is provided by a combination of compact fluorescent lamps and filament lamps. A number of decorative lights use tungsten filament lamps. Manual switching is installed, as is usual in domestic properties.

External walls

External walls are 575mm thick and of variable condition.

Heating system

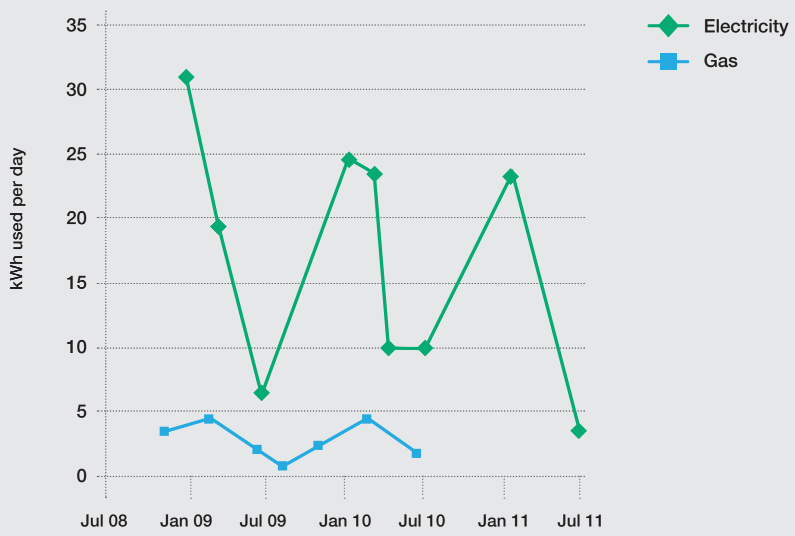
The heating and hot water is provided by an efficient modern system.

04 Bill analysis and benchmarking

The analysis of the energy bills available for this property showed some unexpected results. The electricity use is much higher than would be expected and it is highly seasonally variable.

This is due to the fact that the systems that are in the building at the moment were only installed this year. For the period covered by the data, the only gas-fired heating was a fire in the lounge. All other heating and the provision of hot water was carried out using electricity.

Historic energy use at Almondbury Dwelling, Huddersfield

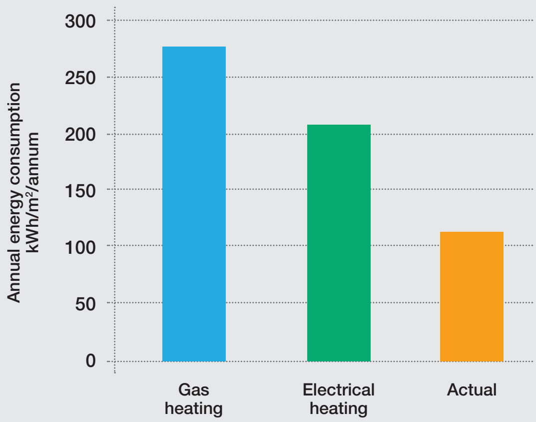


It is therefore no longer appropriate to examine the proportion of emissions from each of the energy types as it will be out of date.

However, irrespective of how the property is heated, it seems to be using significantly less than expected. The Energy Saving Trust carried out calculations for average mid terrace properties, examining both gas-fired and electrical heating. Both of these figures exceed the actual usage by quite some margin.

This highlights the need for bearing in mind the real situation when carrying out this sort of exercise. The low energy consumption is undoubtedly a result of the fact that the building is occupied by one elderly person whereas the benchmarks are probably assuming the terrace is a family home. In addition, well-maintained, traditional terraced cottages with deep stone walls are often more efficient than later, brick built industrial terraced housing which predominates in statistical analyses.

The effect of heating fuel on annual energy consumption benchmarks



The table below shows average energy consumption and other assumptions used for the cost-benefit analysis in section 6.

Assumptions for options appraisal	Almondbury Dwelling, Huddersfield Amount
Estimate of Gross Internal Floor Area	66 m^2
Annual electricity consumption	4,928 kWh
Annual gas consumption	18,360 kWh
Average electricity cost	10.22 p/kWh
Average gas cost	3.026 p/kWh
Annual electricity cost	£504
Annual gas cost	£556
Carbon emission factors - electricity	0.517 $kgCO_2$/kWh
Carbon emission factors - natural gas	0.198 $kgCO_2$/kWh

The carbon emissions factors referred to are from SAP 2009, the government's standard assessment for the energy rating of dwellings. Part L of the UK Building Regulations 2010 also applies these factors to non-domestic buildings.

05 Interventions

Scope

The most significant elements of the historic building are within the envelope: the masonry, arrangement of openings and roof covering should be maintained as existing. As all the external joinery and glass is recent (1983 or later), there is scope to renew or upgrade the windows and doors, whilst maintaining the appearance of traditional windows with narrow glazing bar windows, particularly to the front.

Internally, upgrading walls, floor and roof insulation is unlikely to cause harm to significance, although the small size of the rooms constrains options to line walls. The tongue and groove boarded ceiling linings are part of the building's character and should be retained. There are signs of rising damp in the solid walls and maintaining breathability/ ventilation will be important. Replacing external cement mortar/render in lime-based materials would help with this.

The efficient gas boiler and well insulated loft have already improved the overall thermal performance of the building. These boost the inherent benefits of thick stone walls, terraced construction and restricted areas of glazing. As a result opportunities for improvement are more limited than in many historic buildings. Nonetheless the study team has selected possible interventions that could reasonably be expected to be worthwhile based on experience and these are shown in the table on the next two pages.

Recommendations

Feasible carbon saving interventions

No.	Intervention	Description	Heritage impact
Behaviour change			
1	Energy consumption targets/monitoring/ metering	Establish clear and accurate benchmarks of current consumption. Set realistic targets and monitor performance against targets by reading meters. Key carbon reduction tools.	None
2	Develop building user training programme	Provide clear guidance to building occupants on systems installed in the building and operating them energy efficiently.	None
3	Energy efficient appliance selection	Select AAA rated appliances such as fridge, kettle, dishwasher, freezer and washing machine, as appropriate.	None
Building fabric			
4	Install wall insulation	Insulate the internal face of the external front and rear walls where practicable. Careful detailing and removal/reinstatement of skirtings and architraves will be essential. Line walls with a layer of natural, breathable insulation (e.g. 75mm of wood fibre board or hemp batts) with suitable detailing to mitigate cold bridging. Apply a plaster and natural paint finish.	Due to the plain interiors and existing openings, adjusting window reveals should not affect significance, subject to careful design and early discussion with local planning authority
5	Install draught strips, seal gaps	Fit proprietary draught strips to all windows and internal and external doors and loft hatch. Seal as many as possible other small gaps, cracks and openings.	None
6	Install secondary glazing	Install high performance secondary single glazing carefully designed to be as unobtrusive as possible.	It will be possible to install secondary glazing, subject to careful design and early discussion with local planning authority, with low impact on internal and external significance

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
Building services			
7	Energy efficient lamps	Replace existing low efficiency tungsten filament bulbs with with modern low energy equivalents.	None
8	Photovoltaics (PV) with Feed-In Tariff	Photovoltaic solar electricity panels installed on the rear, west facing roof slope. This is not significantly overlooked.	As the rear roof slope is not significantly overlooked and hidden from the public realm, this location will not affect views of the building or its significance, subject to careful design and early discussion with local planning authority

Low and zero carbon technologies

The case study team considered a range of possible technologies which are reviewed in the table below.

LZC Technology and Low Energy options	Approximate capital cost	Cost per 1% CO_2 reduction over base building	Operational cost	Future energy costs	Simple payback (without Feed in Tariff/RHI)
Solar Hot Water Panels	Moderate	Moderate to High	Low	Low	Moderate
Photovoltaic	Very High	Very High	Low	Low	High
Gas Fired District Heating CHP	Moderate	Moderate	Moderate	High	Moderate to high
Biofuel CHP	Moderate to High	Moderate	Moderate to High	High	Moderate to high
Biomass CHP	Very High	Moderate	very High	Low	High
Wind Turbines	Moderate	Moderate	Low	Low	High
Off Site Wind Generation	High	Moderate	Low to moderate	Low	Moderate
Biomass Boilers & Woodburning stoves	High	Low to Moderate	High	Low	Low to Moderate
Ground Source Heat Pumps	High	Very High	Moderate	Moderate	High
Air Source Heat Pumps	Moderate	Moderate	Moderate	Moderate	Moderate
Open Loop water source heat pump	High	High	Moderate	Moderate	High
Exposed Thermal Mass	Low	Low	Low	Low	Low
Passivhaus	High	Moderate	Low	Low	Low
Maximisation of daylight, daylight controls, automatic lighting controls & energy efficiency lighting	Low to Moderate	Low	Low	Low	Low

Noise impact	Planning implications	Funding/ Grants	Applicability to St Peter's Street	Technical issues/any other criteria
None	Roof loading & less sensitive elevation	RHI	×	Solar Hot Water limited by low hot water demand in dwelling. Solar thermal is effective with a centralised hot water system but hot water currently provided by a combination boiler.
None	Roof loading & less sensitive elevation	FIT	✓	Limitation on size of roof area available and although not heavily overlooked, potentially controversial.
Moderate	Flue height		×	Cost effectiveness to be balanced with carbon reduction requirements. Minimum operation hours 4000 to 5000 required to be effective.
Moderate	Flue height		×	Reliability of fuel supply, concern over sourcing of fuel product. Not appropriate for single dwelling.
Moderate	Flue height, pollution levels & plantroom size	RHI	×	Limited number of successful installations. Not appropriate for single dwelling. Consider as part of district heating scheme.
Moderate to high	Planning application required	FIT	×	Planning implication and output/effectiveness dependent on site specific wind speed.
High	Planning application required	FIT	×	Off site wind turbines not appropriate for dwellings as off site wind turbines exporting to grid.
Low (note noise from delivery vehicles)	Flue height, pollution levels & plantroom size	RHI	✓	Plant space/fuel store area, delivery access, planning issues - flue height, NOx levels, maintenance costs. Option of wood burning stove with back boiler to be considered prior to the next upgrade of the heating system or to replace existing gas fire.
Low	Archaeological impact to be assessed	RHI	×	Output depends on ground conditions. Limited application of low grade heat produced GSHP means the system is unsuitable for listed building with limited opportunity for fabric improvements to reduce heating demand.
Moderate	Moderate	RHI	×	Noise/plant location, efficiency in winter operation, low grade heat produced by ASHP. Limited application of low grade heat in historic building unless fabric improvements made.
Low to medium	Application to Environment Agency	RHI	×	No local water body for operation of water source heat pump.
Low	None		✓	Exposed thermal mass is currently a feature of the dwelling.
Low	Historic character of building		×	Low U-values required for walls and glazing not achievable on historic buildings without affecting character of building.
Low	None		✓	Use energy efficient light fittings.

06 Options appraisal

Introduction

Section 5 proposes a number of types of interventions which will generate differing levels of savings in carbon and energy costs. It is essential to be able to compare them to decide which are the most worthwhile.

The options are appraised by means of a cost-benefit analysis comparing the budget cost of the intervention with the likely potential savings against current energy costs and carbon emissions. The current average energy consumption and related assumptions are set out at the end of section 4 (Bill analysis and benchmarking).

The options appraisal is a high-level indicative exercise designed to give a broad brush overview of the relative benefits of different interventions. In implementing any interventions a more detailed analysis will be essential to test assumptions.

Payback and energy inflation

It is clear that although a number of the interventions show worthwhile and significant carbon savings, the capital costs are relatively high and the payback in energy costs is too distant to make them particularly attractive. However, they will provide continuing savings long into the future.

The calculated cost saving payback disregards energy price inflation but it is realistic to anticipate that energy prices will continue to rise at a rate considerably greater than general inflation. This issue is covered in more detail in the overall guide of which this case study forms part. It is sufficient to state that actual payback through energy saving is likely to be much more rapid than shown in the cost-benefit analysis table on the next two pages.

Cost benefit analysis table

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Behaviour change									
1	Energy consumption targets/ monitoring/ metering	Easy win	100	2.0%	5.0%	38	2.6	0.18	None
2	Easy to understand user guide/manual & user training	Easy win	100	2.5%	4.0%	35	2.9	0.21	None
3	Energy efficient appliance selection	Easy win	100	2.0%	0.0%	10	9.9	0.05	None
Building fabric									
4	Upgrade wall insulation	Major	2,900	0.0%	35.0%	194	14.9	1.27	Manageable
5	Install draught strips	Easy win	400	0.0%	6.0%	33	12.0	0.22	Manageable
6	Upgrade to high performance secondary glazing	Major	2,700	0.0%	20.0%	111	24.3	0.73	Manageable
Building services									
7	Energy efficient light fittings, LED lighting	Cyclical	300	8.0%	0.0%	40	7.4	0.20	None
8	Photovoltaics (PV) with Feed-In Tariff	Major	1,700	8.4%	0.0%	198	8.6	0.21	Manageable

Other opportunities

Although there may be some impact on space in the lounge, it may be worth considering extending the existing draught lobby by perhaps 300mm to make it easier to close the front door before opening the inner door. This would best be dealt with in conjunction with future decorations or during the installation of secondary glazing.

Installing a conservation grade flush roof light or sun-pipe into the rear pitch of the roof to offer natural light to the first floor landing and stairwell would provide a modest but effective improvement to this weaver's cottage. This space currently relies entirely on artificial light or borrowed light from adjacent bedrooms, which the client has to leave open.

Advantages

The primary advantage of this intervention would be the reduced dependency on artificial light during daylight hours, and thereby reduced carbon emissions. Other advantages include an improved sense of well being due to increased natural light and opportunity for background ventilation of the house via natural stack effect. It would also ease use of the stairwell and landing without reliance on borrowed light from adjacent spaces.

Implications

A roof light or sun-pipe installation would necessitate the formation of an opening to the rear roof slope and framed light shaft internally from the aperture to first floor ceiling level. The latter would require insulation and decoration and some making good to the existing disturbed ceiling.

Appraisal

This intervention would need to be considered against the reduced insulation values of the roof-light when compared to continuous insulation of the roof space at ceiling level and continued dependence on artificial and borrowed light. To minimize a relative cold spot occurring, the roof light would be triple or quadruple glazed with a whole window value of 0.6 or 0.8W/m2K and fitted with a blind. The perimeter of the light shaft would be continuously insulated to a high standard along its full length.

07 Recommendations

Interpretation

All of the suggested interventions show worthwhile carbon savings but in some cases (the red items) the capital costs are relatively high and the cash payback in energy cost savings is distant. However, the building owner should bear in mind the observations on energy price inflation in section 6.2.

The savings figures in the table are deliberately not totalled. Such totals would be misleading. Each measure adopted limits the scope for further savings because the total energy use reduces each time. The order of adoption and interaction between different interventions would also have significant impacts on the overall outcome. It is not practical to suggest an overall likely energy saving but the options appraisal identifies that carbon emissions can be very greatly reduced by adopting the following complementary measures.

Behaviour change

It is essential to reinforce and support physical interventions with training and motivation so that the building is operated efficiently and beneficially to reduce carbon emissions and save costs. The building is let as social housing. Occupiers and housing managers need to have a clear understanding of houses and their systems. This will enable managers to arrange training and support for occupiers. The group of items in the first section of the table aim to provide a range of measures to achieve this.

It is assumed that housing managers will have a high level of awareness of the simple systems installed and the importance of beneficial behaviour to reduce energy usage. Suggested items would be implemented by existing staff through internal strategies with normal training and personal development which needs to be sustained and continuing. The cost of each of these interventions is assumed to be a nominal £100. In the circumstances it is recommended that all of these measures are adopted. It is believed that in the case of the 11 St Helen's Gate, Almondbury the training and information has been provided but the items are included for completeness.

At a glance
Recommendations

Draught proofing around all windows and doors

Internal insulation of the external walls

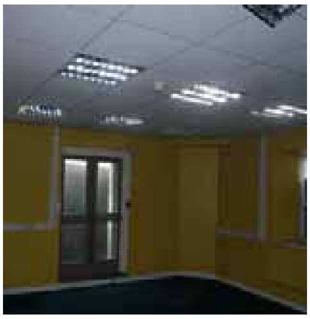
Install low energy light-bulbs

Install a wood-burning stove

Building fabric

The interventions explored in this section mostly show longer paybacks but all of them should provide substantial annual carbon savings. The recommended measures will reduce air infiltration and it will be important to ensure that windows are opened as required to maintain appropriate levels of ventilation.

- Internal insulation of external walls offers the largest running costs reduction. The payback is approximately 15 years
- Installing draught proofing to windows and to internal and external doors reduces energy consumption and provides a quick payback of approximately 12 years.
- Installing a secondary glazing system provides a significant reduction in energy consumption. Payback is distant at 24 years but this is a very long-term benefit that is a worthwhile hedge against energy price inflation and fuel poverty.



Lighting

Lighting system provides some opportunity for improvement.

Building services

Two interventions show payback within 10 years and inflation is likely to improve this considerably.

- Replacing inefficient tungsten filament bulbs with low energy equivalents
- Photovoltaic solar electricity panels aided by the Feed-In Tariff.

Recent announcements regarding the likely reductions in the Feed-In Tariff amounts suggest that the payback period of the proposed photovoltaic installation by be made significantly longer than at the currently applicable rate.

One of the interventions relating to the building services that can yield significant savings is the reduction of temperature set points (i.e. turning the thermostat down). This may well have yielded savings in this case study building but it is not included in the options discussed due to the fact that the occupant is elderly and the effects of such an action on her comfort and health cannot be determined.

Heritage impact summary

The relatively small interventions proposed for this cottage can be designed and installed without harming the significance of the building. Existing windows and doors are not proposed for replacement and the exterior appearance of the building will largely remain unchanged from the front. Installing secondary glazing and external wall linings is feasible in the cottage without affecting significant historic finishes or details; the ground floor front windows have plain reveals, all plaster finishes are modern and the first floor tongue and groove window reveals linings can be retained in situ. Fitting photovoltaic roof panels will affect the rear roof pitch and it will be essential to maintain the integrity of the roof. But, as this is hidden from public view, the panels would be reversible and bring identifiable benefits, this is considered to be justified.

Case Study 05

Lord Deramore's School, York

01 Summary

Lord Deramore's primary school is in adjacent to York University in Heslington, on the outskirts of the city. It is owned and maintained by the City of York Council. The original building was constructed in 1856 with two storeys and a slate roof. It has been extended several times at single storey level over different periods. Most of these extensions are of poor quality and at odds with the attractive Victorian school building. The building has extensive grounds which provide scope for future extension.

The Grade II listed building is significant for its historical and architectural value as a brick-built village primary school, incorporating a former headmaster's house to the south end, and as part of an attractive group on the village street. The small-paned windows to the original school are particularly important to the character of the front elevation, even though some are steel replacements for the original cast-iron windows.

The building fabric has suffered water damage from driving rain, roof leaks, leaking pipework and condensation problems. There is little thermal insulation, generally single glazing, extensive air leakage and the buildings suffer from poor comfort conditions. The dated main central heating plant is oil-fired. Taken together these circumstances result in very high energy bills unusually heavily weighted towards heating fuel consumption which accounts for 86% of carbon emissions. This represents a considerable opportunity for improvement.

The findings of the survey coupled with the history of costly problems resulting from leaks demonstrate the essential importance of regular, preventive repairs and maintenance. This is particularly important for historic buildings with solid walls and breathable construction.

There are opportunities to reduce carbon emissions from the building but these are limited by the historic significance of the elaborate interior of the main gallery space which will not allow internal wall insulation. This case study tests the indicative costs and benefits of 22 possible interventions. All of these would provide worthwhile savings in carbon emissions but for some, for example replacing lighting related investment, payback is too distant, even taking into account the more rapid payback that is likely to result from predicted energy price inflation. Current electricity consumption seems surprisingly low and further investigation may reveal a different picture. The following are the most significant recommendations, which could result in substantial annual savings.

- A range of behaviour change related items which can be implemented at minimal cost
- Roof insulation
- Internal insulation of external walls as part of general refurbishment
- Installing secondary glazing/replacement of existing low significance windows with new high performance double glazed windows.
- Installing photovoltaic solar electricity panels to the south facing roof but payback periods may be delayed as a result of probable changes in the Feed-In Tariff
- Replacement of the existing boilers, pumps and control system.

All of the measures identified are important to preserve and promote a sustainable future for the historic buildings. However, there is a common heating system and the interventions also cover the jumble of modern additions to the building. The cost and benefit of investment in these more recent buildings should be carefully assessed against the potential benefits of a more comprehensive redevelopment.

02 Heritage value and statement of significance

Statement of significance

The building is significant for its historical and architectural value as a brick-built village primary school, incorporating a former headmaster's house to the south end, and for its contribution to an attractive group on the village street.

The school's character is also derived from the expansion in 1907 and 1957, with the design of the additions following the pattern for steeply pitched gabled roofs, tall windows and brick exteriors established by the first building. The c.1968 rear additions do not contribute to the significance of the heritage asset, although they may be subject to Listed Building Consent as they are attached to the listed school.

The small-paned windows to the original school are particularly important to the character of the front elevation, even though some are steel replacements for the original cast-iron windows.

Boarded timber doors on this range are also significant, but inserted fire escape doors or windows in former doorways are not. Some of the 1850s interiors have high significance, particularly the open-roofed hall at the north end of the front range, internal Victorian doors and exposed roof timbers. The Grade II listing is appropriate for the building (listing reference number 1316285).

Front facade

Main façade of building provides a contribution to an attractive village.

Summary table

The table below summarises the key building features and their relative significance for ease of reference.

Building feature	Significance	Date
Exterior walls and pitched slate roofs, front range	High	1856
Exterior walls and pitched slate roofs , rear addition	High	1907
Brick chimney stacks	High	C19
Exterior walls and pitched roof, 1950s addition	Medium	1957
Windows: front range, cast-iron fixed or opening lights	High	1856
Windows: front range and 1950s addition, steel casements	Medium	Mid C20 replacements for cast-iron
External doors, front range (historic doors)	High	C19
External doors, front range (modern)	Low	Late C20 replacements for historic doors or inserted escape doors
Late C20 blocks, external envelope (doors, windows, walls, floors and roof)	None	Late C20 or early C21 fenestration, screens and doors, roof coverings etc
Interior: Front range: ground floor classrooms and hall	High	1856, modern suspended ceilings
Front range entrance lobbies and stair hall	High	1856
Interior: FF front range	Medium	1856
Interior: rear addition	Medium	1907, altered C20
Roof space/structure	Not visible in all areas	C19
1957 addition	Medium	1957

High value glazing

Many windows in the building contribute significantly to the heritage significance.

Building evolution

The school was built in 1856, by George and Alicia Lloyd as a memorial to Yarburgh Yarburgh who had provided the funding. To the rear a single-storey, one room addition was built in the 1907, funded by Yarburgh's legacy, possibly designed by W Brierley. In 1957 an addition was built to the NW, connected to the original school by a flat-roofed link and new boiler room. The rear single-storey additions were built in 1968, so the school could take 280 children. Some of the fenestration/glazed screens were replaced in aluminium double glazing in 2010. In the grounds to the south is a free-standing temporary unit was added in 2009. Recent internal refurbishment includes suspended ceilings to the front classrooms in the original building.

The building's fabric and character

The school is a good example of a village school built before the 1870 Education Act. The front facing SW has a picturesque character with Elizabethan revival style mullioned windows and arched doorways, described on the listing. The building is built of hand made red brick with Welsh slate steeply pitched roofs, octagonal brick stacks and a tall flèche over a bell frame and former roof ventilator to the north hall.

The interior contains some little altered spaces, such as front entrance lobbies, the former school house and particularly the north hall in the original school with an open timber roof and high windows. Suspended ceilings obscure the roof in other class rooms. Fireplaces have all been blocked, some without ventilation being provided. Plaster finishes appear original in most areas.

03 Building condition survey

Lord Deramore's primary school is in adjacent to York University in Heslington on the outskirts of the city and is maintained by the City of York Council. The original building was constructed in 1856 in brick with two storeys and a slate roof. It has been extended several times at single storey level over different periods. Most of these extensions are of poor quality and at odds with the attractive Victorian school building. The building has extensive grounds which provide scope for future extension.

The building fabric has suffered water damage from driving rain, roof leaks, leaking pipework and condensation problems. There is little thermal insulation, generally single glazing, extensive air leakage and the buildings suffer from poor comfort conditions. The dated main central heating plant is oil-fired. These circumstances result in very high energy bills and carbon emissions.

Fabric

The commentary in this table relates to the fabric of the original Victorian heritage building, in view of the historic buildings focus of this study. The Edwardian extension is constructed in similar materials but is single storey.

The 1950s building and later extensions are of cavity wall construction. The two classrooms in the former share a pitched, slated roof and the latter have flat felted roofs that have a long history of leaks and, if retained should be re-covered. The 1950s building has approximately 100 mm of loft insulation. It appears that the remaining buildings have no roof insulation.

The findings of the survey coupled with the history of costly problems resulting from leaks demonstrate the essential importance of regular, preventive repairs and maintenance. This is particularly important for historic buildings with solid walls and breathable construction.

Mixed history

Extensions have been added a number of times, often detracting from the attractive original building.

Roof landscape

The roofs of the extensions all have insufficient insulation and some are in poor condition.

Results of building fabric condition survey

Item	Location	Detail	Condition
Roof structure	1850s original building	- Traditional slated timber structure – rafters, purlins, trusses - Uncapped, clay ridge tiles - Lead clad bell tower to Year 6 classroom closed up - Apex, louvred vents to ridge ends of Year 5 classroom - No roof insulation - Traditional torching to underside of slates - No roof felt	- Leaks to roof slope and gable parapet abutments - Slipped/cracked slates with some with piecemeal repairs - Failing flashing or inadequate flashing detailing to valleys and abutments - Lead flashing missing in places - Ridge tiles in sound condition
Ceiling	1850s original building	- C20th gypsum ceilings in areas – occasionally suspended below original lath and plaster ceilings (staff room) - Areas of original lath and plaster ceiling exposed in places - Flat ceilings raised above eaves level to form rafter-line sections of ceiling in places - Ceiling fully at rafter level to Year 6 class room with exposed purlins	- Active/recent water penetration through ceilings at rafter level
Walls (exterior)	1850s original building	- 375mm thick solid red brick with stone detailing - Varying types and ages of brick infill - Original lime mortar evident with cementitious re-pointing carried out in places	- Significant deterioration to pointing in places due to rainwater goods failing - Spalling and efflorescence is evident in places- significantly around front and rear entrance doors - Signs of decomposed vegetation behind cementitious re-pointing
Walls (interior)	1850s original building	- Plaster finish with exposed stone mullion/ surrounds to windows - Areas of new gypsum plaster finish repairs have occurred - Fresh decoration with paint finish	- Active/recent water penetration - Water staining beginning to show through fresh decoration to entrance lobby - Signs salt efflorescence in places – largely obscured by redecoration
Floors	1850s original building	- Suspended timber floors - Chipboard surface with carpet finish to ICT suite - Floor boards to 1st floors - Mixture of vinyl, carpet, timber surfaces - No insulation	- Generally good condition - Recent repair work following failure of floor structure due to prolonged plumbing leak

Results of building fabric condition survey continued

Item	Location	Detail	Condition
Windows	1850s original building	- Single glazing - Variety of frame materials, including timber, wrought iron and possibly cast iron - Leaded glass lights, opening and fixed in various arrangements including 9 over 12 over 15 to year 5 classroom, separated by stone transoms - Selection of opening operations to window types including, side hung, top hung, horizontal centre pivot - New timber framed, single pane modern windows to modern building extensions	- Some in sound condition, many in poor condition and unfit for use - Many opening windows painted shut - Cracks to glass panes and some with shot holes from vandalism - Loose panes to leaded glass - Distortion to frames restricting operation and holding casement in partially open position - No draft stripping - Poor painting compromising operation - Paint peeling off in places - All metal windows allowing drafts - Rotten timber to some timber frames - Significant condensation to stone surrounds - Some windows inadequate to meet basic levels of security and intruder prevention - No controlled ventilation to any windows
External doors	1850s original building	- Solid timber battened door leaf in solid timber frame set into stone door surround to main entrance - New glazed timber rear door with single glazed side light	- Doors in generally good condition - No draft stripping to main front door and visible gaps between perimeter of door leaf and frame/floor - Nylon draught strip to new rear door
Above ground drainage	1850s original building	- Black painted cast iron rainwater goods on spikes and facia brackets	- Signs of corrosion to cast iron - Signs of overflowing gutters and downpipes due to inadequacy or blockages - Detached downpipe from gutter - Poor connection to base of some downpipes - General surface water drainage is poor, with areas of standing water

Building services

Utilities

Oil is supplied from a storage tank to serve boilers in the mechanical plant room. The boilers provide space heating and domestic hot water for the school. A new natural gas supply serves the kitchen. The school is served by a mains cold water system. The utility meters are read manually.

Heating and domestic hot water

Space heating and domestic hot water are provided by two Clyde Combustion oil fired, cast iron sectional boilers installed in 1996. The heating system is generally inefficient and generates high levels of carbon emissions compared when benchmarked against equivalent buildings.

Heating oil has higher carbon emission compared to natural gas or wood fuels. (e.g. carbon emission for heating oil is 0.274 $kgCO_2$/kWh compared to 0.198 $kgCO_2$/kWh for natural gas). This means a gas fired heating installation emits lower carbon compared to a gas fired installation. Oil fired boilers have an economic life of approximately 25 years according to CIBSE[3]. Changing from oil to either natural gas or wood fuel systems would reduce carbon emissions from the heating system. The oil tank room could be configured as wood fuel store so there is adequate storage space to enable this change. The existing capacity of the natural gas supply is assumed to be adequate for the purpose.

It would normally be most cost effective to replace the oil boiler installation at the end of its economic life (approximately 9 years), but this would delay the onset of energy and carbon saving.Both oil boilers are served by constant speed oil burners which are less efficient than modulating burners which closely match heating output with demand and saving energy. Modulating burners should be installed on the boilers and must be installed on all new boiler installations.

The heating system operates as constant speed system. The system does not include a boiler shunt pump system. Water serving the heating system (LTHW[4]) is circulated though both boilers even during periods of low heating demand. This arrangement is not energy efficient as the system incurs resistance from a boiler even when the boiler is not operational and the heating pumps use additional electrical energy.

Domestic hot water is generated from the heating system and stored in a horizontal hot water cylinder. The central storage system incurs distribution losses

Heating pipework within the plant room was recently insulated but not protected by a cladding system. A trench is used to distribute pipework from the plant room. It was not feasible to access the trench during the survey to investigate the condition of pipework between the plant room and main buildings.

Inefficient heating system

The inefficient oil-fired boilers are a carbon-intensive way of providing heat and hot water.

Boiler controls

The boiler control systems does not include features that would result in lower carbon emissions.

[2] Chartered Institution of Building Services Engineering, CIBSE Guide M, 2008

[3] Low Temperature Hot Water

Heating is provided by panel radiators and fan convectors. The fan convectors installed within the school are noisy. The staff regularly switched them off to avoid noise nuisance and consequently comfort conditions are not achieved.

Under floor heating is the ideal heating system to serving tall spaces such as the former hall and mezzanine floor in the original Victorian school building. However, an under floor heating installation is more expensive to install compared to conventional radiator heating system and requires high thermal performance of the external envelope to limit the heat loss. Radiators and fan convectors are other options. Low noise fan convectors will be required and they have the advantage of encouraging air movement. Heat will gather at high level and a means of distributing this more effectively is examined in the section on ventilation which follows.

Fan convector units

Noisy heating units are often switched off to void nuisance, leading to cold conditions.

Ventilation

The school is primarily naturally ventilated. A new supply and extract mechanical ventilation system, which serves the kitchen, was recently installed as part of the kitchen upgrade.

Openable windows provide natural ventilation. The window hardware in a number of classrooms malfunctions making it impossible to provide controlled natural ventilation. Other teaching spaces do not have operable windows and have signs of inadequate ventilation such as condensation and stains on the building fabric are evident. The school has resorted to regular painting but this does not address the source of the problem. In addition, oil and plastic based paints are not permeable and do not allow the plaster and brickwork of the walls and ceiling to absorb air borne moisture. This issue should be tackled as part of the ventilation strategy coupled with repairs to damaged window hardware to provide controllable natural ventilation.

High ceilinged old school hall

Temperature gradients in high ceilinged spaces can lead to cool conditions at ground level. A destratification fan can be used to mix air and spread warmth.

The old school hall includes a bell tower which previously provided natural ventilation but has been blocked up. Windows in the hall are not currently operable. Both should be reinstated to provide ventilation to the school hall. Wind assisted natural ventilation through the turret should be better controlled by adding adjustable electrically operated dampers for temperature control. De-stratification fans should be installed at high level in the hall to move heat trapped at high level to low level.

Automatic control systems

The central boiler plant is served by a Drayton automatic control system. The control system include a time override facility for both heating and domestic hot water system, time control, holiday and term time mode, compensation etc. The legacy control system does not include modern features for effective energy management nor a facility for internet connection to enable access to an display of energy consumption data.

Power and lighting

Power is supplied from a low voltage power supply. It was not possible to access the meter room during the survey. External containment has been used to for electrical services distribution for recent buildings. This is unsightly with potential for vandalism.

Lighting is provided by a combination of ceiling mounted linear fluorescent fittings and recessed modular light fittings. The lighting is controlled manually and there is no presence detection or daylight control even though the building is served by a good proportion of natural daylight.

Good daylight levels are provided to most spaces through windows. A number of internal spaces include rooflights providing natural daylight.

Rooflights

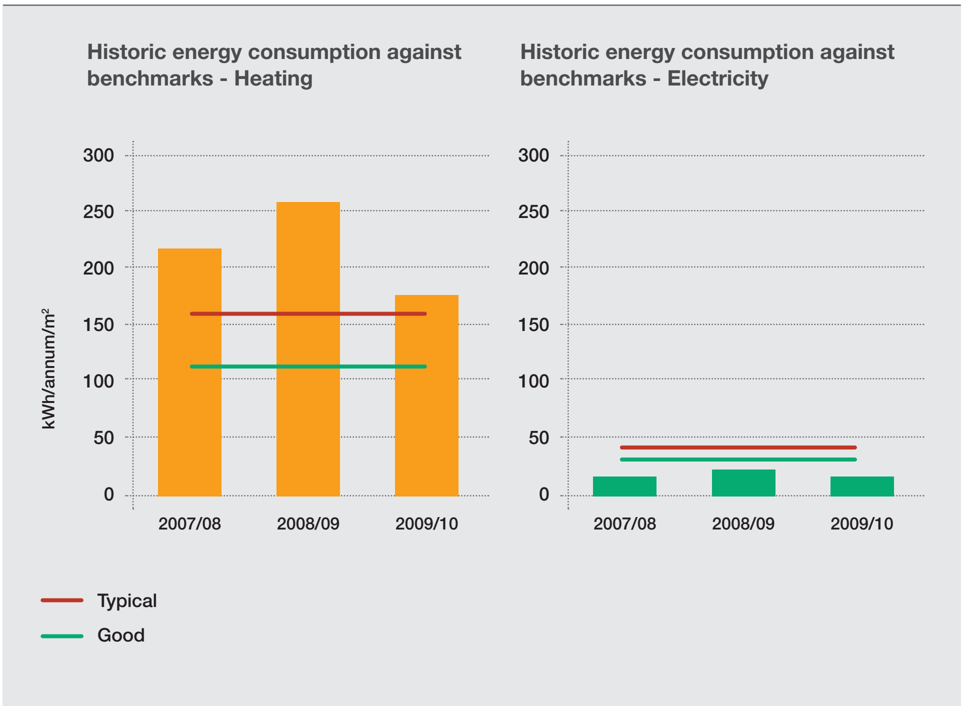
Rooflights are provided in many spaces, significantly improving daylight levels.

04 Bill analysis and benchmarking

The electricity and heating fuel energy use for Lord Deramore's Primary School have been compared with benchmarks published by the Chartered Institute for Building Services Engineers (CIBSE) in their Guide F publication.

As with other buildings in this study, there is a disconnect between the performance of the building in terms of these two fuel types. When the electricity consumption is divided by the floor area to allow comparison with benchmark buildings of various sizes, it is lower than the 'Good Practice' guideline figures.

Conversely, the energy used to heat the school exceeds the 'Typical Practice' benchmark. In the case of Lord Deramore's, this includes the energy of the natural gas and the heating oil.



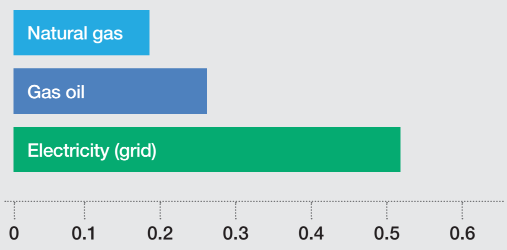
In addition, there is a large variability seen in the heating energy consumed, with over 40% more energy being used in 2008/09 than in the following year. An investigation of the cause of this change year-on-year should be carried out as it is probably too large to have been caused simply by changing external temperatures.

When examining the emissions of the building as opposed to the energy consumption, heating is still the major source of carbon dioxide released over the course of a year. This is in spite of the fact that electricity is more carbon intensive. However, this effect is reduced slightly as gas oil releases a third more CO2 than the more efficient natural gas fuel.

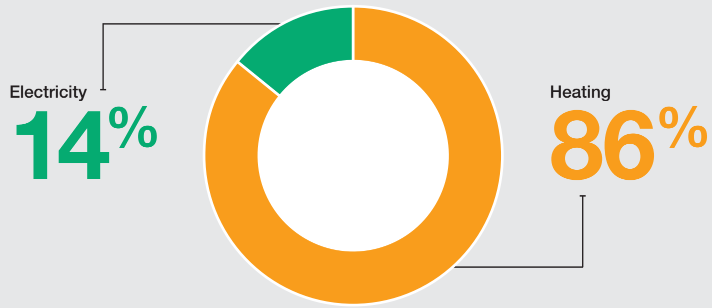
When all these factors have been taken into account, heating the school accounts for 86% of the emissions over the three years for which data is available.

It is therefore clear that efforts should be concentrated in this area in order to maximise savings.

kg of CO_2 generated in producing each kWh of energy



Proportion of carbon emissions from each fuel type



The assumptions and average energy consumption used for the cost-benefit analysis in section 6 of this study, options appraisal, are set out below with other relevant assumptions. The consumption data did not include prices. We have assumed the same local authority energy purchase rates secured by York Council.

Assumptions for Options Appraisal	Lord Deramore's Primary School, York Amount
Estimate of Gross Internal Floor Area	1220 m^2
Annual electricity consumption	25,536 kWh
Annual heating oil consumption	319,757 kWh
Average electricity cost	10.22 p/kWh
Average heating oil cost	6.06 p/kWh
Annual electricity cost	£2,610
Annual heating oil cost	£19,377
Carbon emission factors – electricity	0.517 $kgCO_2$/kWh
Carbon emission factors – heating oil	0.274 $kgCO_2$/kWh

The carbon emissions factors referred to are taken from SAP 2009, the government's standard assessment for the energy rating of dwellings. Part L of the UK Building Regulations 2010 also applies these factors to non-domestic buildings.

05 Interventions

Scope

Section 3 of this case study explains the building and its services installations. Improvement to thermal insulation values, draught stripping, secondary or replacement glazing and replacement of the oil-fired heating system with a wood fuel or gas-fired boiler could greatly reduce energy bills and carbon emissions, as well as improving internal environmental conditions. However, these measures must be coupled with a careful and complementary ventilation strategy using natural means as far as possible.

The study team selected the interventions that could reasonably be expected to be worthwhile based on experience and these are shown in the table on the next three pages.

Natural ventilation strategy

Former roof ventilator could be reinstated to complement a natural ventilation strategy.

Feasible carbon saving interventions

No.	Intervention	Description	Heritage impact
Behaviour change			
1	Energy consumption targets, monitoring, metering	Establish clear and accurate benchmarks of current consumption. Set realistic targets and monitor performance against targets by reading meters, including sub-meters as included below. Key carbon reduction tools.	None
2	Formal staff feedback mechanisms	Establish robust and continuing procedures to use occupiers' experience effectively.	None
3	Sustainability brief for staff	Set out and explain the reasons and approach to sustainability. What does it mean for the individual?	None
4	Develop staff training/ teaching programme	Ongoing training is important including new starters and refresher courses. Strong and clear leadership should be at the root of this including explaining to pupils the consequences of their actions and the reasons for energy conservation. This is an important learning opportunity.	None
5	Daytime cleaning service	Reduces overall operating hours for lighting and heating.	None
6	Building users' guides, up to date, comprehensive, accessible Operation and Maintenance manuals	Staff and facilities managers cannot be expected to use and operate buildings without clear information appropriate to their level of involvement.	None
7	Energy efficient appliance selection	When fridges, kettles, dishwashers, freezers and washing machines are due for replacement select AAA rated appliances.	None

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
Building fabric			
8	Upgrade wall insulation	Insulate the internal face of all external walls where practicable. Scarify existing painted walls to increase moisture permeability. In historic areas remove and set aside skirtings and architraves for reinstatement. Line walls with a layer of natural, breathable insulation (e.g. 75mm of wood fibre board or hemp batts) with suitable detailing to mitigate cold bridging. Apply a lime or clay plaster and natural paint finish. For a lower cost, less disruptive but less effective option cavity install cavity wall insulation in the 1950s and later extensions only.	This will affect interiors of high significance in the front range but since architectural wall decoration is minimal (there are no architraves, for example) impact on significance will be low , subject to careful design. Early discussion with local planning authority is recommended but the benefits of the proposals are considered to justify the internal alterations.
9	Upgrade roof insulation	Install insulation such as glass fibre or sheep's wool between and over joists in all pitched roof areas with ceilings at top floor level to an overall depth of 300mm. In the old school hall and first floor staff room, scarify paintwork to ceiling plaster to improve air permeability and install natural insulation between roof beams (e.g. 75mm of wood fibre board or hemp batts). Apply a plaster and natural paint finish. In the flat-roofed extension buildings line the ceilings similarly. This treatment is preferable to modern impermeable insulation systems because of its ability to absorb greater amounts of moist air in classrooms resulting from dense occupancy, respiration and respiration.	This will affect areas of high significance in the front range but through careful design it will be possible to retain the exposed roof structure and minimise impact on significance. Early discussion with local planning authority is recommended but the benefits of the proposals are considered to justify the internal alterations. In post-war areas, heritage significance is lower and will not be affected.
10	Install draught strips	Install proprietary draught strips to all internal and external doors	Draught strips are unlikely to affect significance, if discreet and appropriate. Refurbishing windows to open and close will enhance significance.
11	Upgrade to high performance secondary glazing	Install high performance secondary glazing to the areas of high significance. Elsewhere this has been assumed as a general solution but the costs and benefits should be compared with replacement high performance double glazing.	For high significance areas, new secondary glazing will have a low affect on external views and significance is protected by retaining historic metal windows. Less significant, non-historic windows could be replaced without harming significance, subject to careful design and early discussion with local planning authority.

Feasible carbon saving interventions continued

No.	Intervention	Description	Heritage impact
Building services			
12	Occupancy sensors for lighting	To enable automatic shutdown of lighting when spaces are unoccupied	None
13	Switching/dimming according to daylight	To provide automatic measures to see that lights are not left switched on when daylight is sufficient.	None
14	Energy efficient light fittings, LED lighting	Replace existing low efficiency light fittings with modern low energy equivalents such as compact fluorescent, T5 high frequency fluorescent and LED fittings.	None
15	Electrical sub-metering to all key installations	This should cover lighting, small power, machinery, plant. This facility is vital to understand how much power is being used by different services installations.	None
16	Time switches or similar on small equipment	A low cost means of guaranteeing equipment shut down when not in use.	None
17	Photovoltaics (PV) with Feed-In Tariff	Photovoltaic solar electricity panels installed on a south facing roof slope on the modern extensions to the rear.. This should not be controversial.	This proposal will have a low impact on significance and the setting of the listed school, subject to careful design and installation, and early discussion with local planning authority
18	Modify temperature set points	19-20°C to classrooms. Coupled with insulation and draught stripping the buildings should maintain temperature much more effectively than at present.	None
19	Ensure controls are working correctly	Initial review to maximise the benefit and efficiency of existing systems. Ensure that testing is embedded in maintenance regime.	None
20	Introduce demand controlled ventilation	Install new replacement fans to toilets with local timed controls.	None
21	Install digital control system for all major plant	Digital building management system with boiler optimum start, automatic trend logging, alarm handling, monitoring and other aids to efficient operation.	None
22	Upgrade boiler system and pumps	Two replacement, high efficiency gas condensing boilers with high efficiency pumps.	None

Low and zero carbon technologies

The case study team considered a range of possible technologies which are reviewed in the table below.

LZC Technology and Low Energy options	Approximate capital cost	Cost per 1% CO_2 reduction over base building	Operational cost	Future energy costs	Simple payback (without Feed in Tariff/RHI)
Solar Hot Water Panels	Moderate	Moderate to High	Low	Low	Moderate
Photovoltaic	Very High	Very High	Low	Low	High
Gas Fired District Heating CHP	Moderate	Moderate	Moderate	High	Moderate to high
Biofuel CHP	Moderate to High	Moderate	Moderate to High	High	Moderate to high
Biomass CHP	Very High	Moderate	very High	Low	High
Wind Turbines	Moderate	Moderate	Low	Low	High
Off Site Wind Generation	High	Moderate	Low to moderate	Low	Moderate
Biomass Boilers	High	Low to Moderate	High	Low	Low to Moderate
Ground Source Heat Pumps	High	Very High	Moderate	Moderate	High
Air Source Heat Pumps	Moderate	Moderate	Moderate	Moderate	Moderate
Open Loop water source heat pump	High	High	Moderate	Moderate	High
Exposed Thermal Mass	Low	Low	Low	Low	Low
Maximisation of daylight, daylight controls, automatic lighting controls & energy efficiency lighting	Low to Moderate	Low	Low	Low	Low

Noise impact	Planning implications	Funding/ Grants	Applicability to Mercer Gallery	Technical issues/ any other criteria
None	Roof loading & less sensitive elevation	RHI	?	Highest output from solar thermal available when school is closed. Low to moderate hot water demand in primary (no showers). A centralised hot water system already in use which could be modified to serve a solar thermal system.
None	Roof loading & less sensitive elevation	FIT	✓	Limitation on capital investment available and size of roof/façade area.
Moderate	Flue height		×	Cost effectiveness to be balanced with carbon reduction requirements. Minimum operation hours 4000 to 5000 required to be effective.
Moderate	Flue height		×	Reliability of fuel supply, concern over sourcing of fuel product.
Moderate	Flue height, pollution levels & plantroom size	RHI	×	Limited number of successful installations. School currently served by oil boilers. Plant room and fuel store area, delivery access, planning issues (flue height, NOx levels) similar to oil boilers. Higher maintenance costs.
Moderate to high	Planning application required	FIT	×	Not appropriate in location close to build-up area. Planning implication and output/effectiveness dependent on site specific wind speed.
High	Planning application required	FIT	?	Technology acceptable only with direct link to school.
Low (note noise from delivery vehicles)	Flue height, pollution levels & plantroom size	RHI	✓	School currently served by oil boilers. Plant room and fuel store area, delivery access, planning issues (flue height, NOx levels) similar to oil boilers. Higher maintenance costs.
Low	Archaeological impact to be assessed	RHI	×	Output depends on ground conditions. Limited application of low grade heat produced GSHP means the system is unsuitable for listed building with limited opportunity for fabric improvements to reduce heating demand. GSHP could be considered to modern buildings when thermal performance is upgraded.
Moderate	Moderate	RHI	×	Noise/plant location, efficiency in winter operation, low grade heat produced by ASHP. ASHP could be considered to modern buildings when thermal performance is upgraded. Noise and potentially higher running costs to be reviewed.
Low to medium	Application to Environment Agency	RHI	×	No local water body for operation of water source heat pump is available.
Low	None		✓	Required for natural ventilation systems. Delays peak room temperature reducing risk of overheating in occupied hours.
Low	None		✓	Energy efficient lighting and controls to be implemented.

06 Options appraisal

Introduction

Section 5 proposes different interventions which will generate varying levels of savings in carbon and energy costs. It is essential to be able to compare them to decide which are the most worthwhile.

The options are appraised by cost-benefit analysis, comparing the budget cost of the intervention with the likely potential savings in the current energy costs and carbon emissions analysed in Section 4 of the case study.

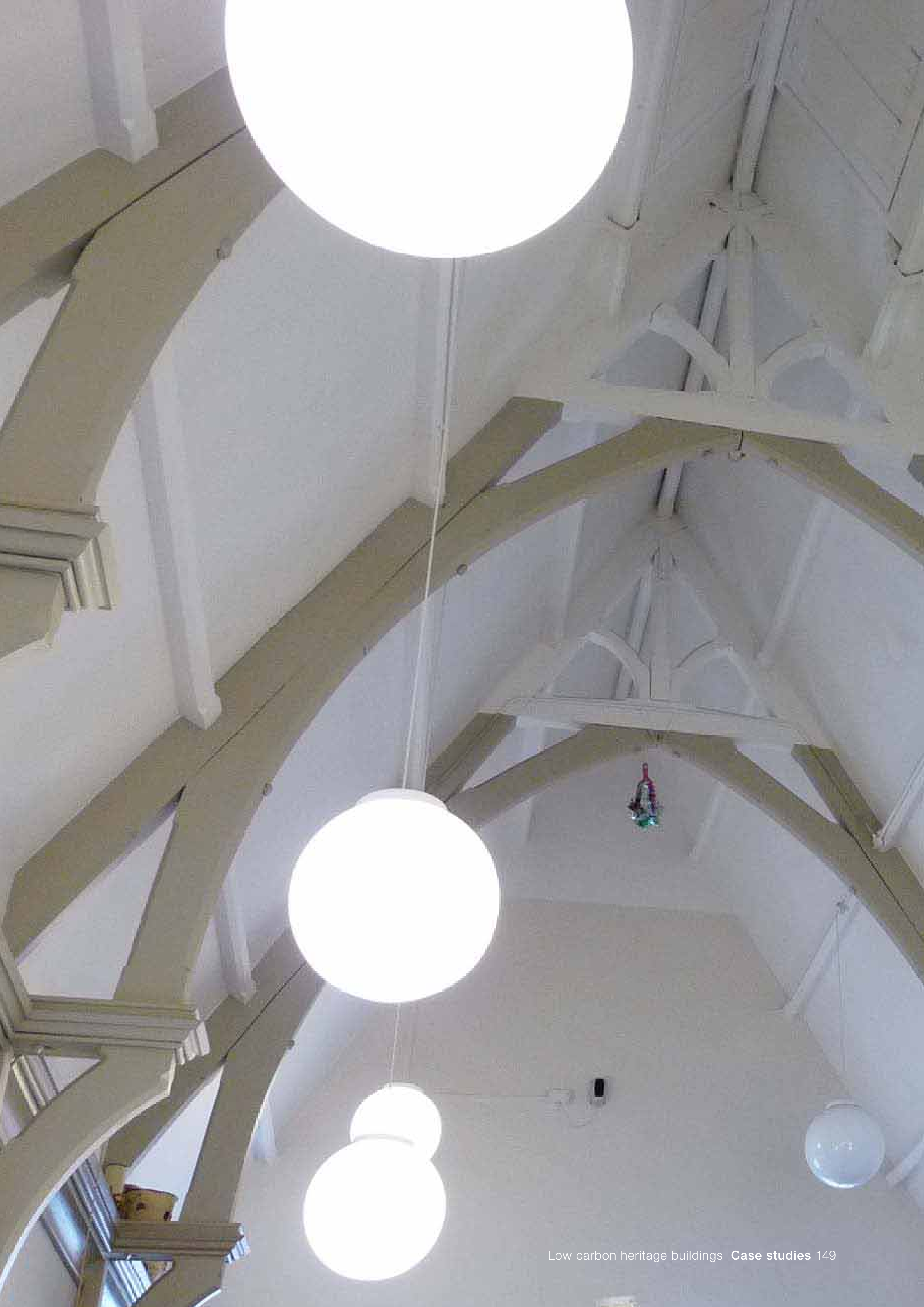
The options appraisal is a high-level indicative exercise designed to give a broad brush overview of the relative benefits of different interventions. If it is decided to implement any interventions, a more detailed analysis to test assumptions will be essential.

The cost-benefit analysis table on pages 150-151 uses a traffic light system to show, at a glance, the relative advantages and disadvantages of individual interventions

Green - Beneficial and worth pursuing

Amber - Less beneficial but still worthwhile

Red - Less likely to acceptable on current assumptions



Cost benefit analysis

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Behaviour change									
1	Energy consumption targets/ monitoring/ metering	Easy win	100	2.0%	5.0%	1,021	0.1	4.38	None
2	Formal staff/ building users feedback mechanisms	Easy win	100	0.5%	0.5%	110	0.9	0.50	None
3	Sustainability brief for staff	Easy win	100	0.5%	0.5%	110	0.9	0.50	None
4	Develop building user/manager training program	Easy win	100	2.5%	5.0%	1,034	0.1	4.71	None
5	Daytime cleaning service	Easy win	100	0.5%	0.5%	110	0.9	0.50	None
6	Building users' guides, full accessible O&M manuals	Easy win	100	0.5%	0.5%	110	0.9	0.50	None
7	Energy efficient appliance selection	Easy win	100	0.5%	0.0%	13	7.7	0.07	None
Building fabric									
8	Upgrade wall insulation	Major	37,800	0.0%	20.0%	3,875	9.8	17.52	Manageable
9	Upgrade roof insulation	Cyclical	15,000	0.0%	30.0%	5,813	2.6	26.28	None
10	Install draught strips	Major	900	0.0%	4.0%	775	1.2	3.50	Manageable
11	Upgrade to high performance secondary glazing	Major	30,500	0.0%	10.0%	1,938	15.7	8.76	Manageable

Cost benefit analysis continued

Ref.	Intervention	Level	Capital cost £	Electricity saving %	Gas saving %	Gas & electricity savings £ pa	Simple payback Years	Carbon saved tCO_2	Heritage impact
Building services									
12	Occupancy sensors for lighting	Cyclical	2,100	3.0%	0.0%	78	26.8	0.40	None
13	Switching/ dimming according to available daylight	Cyclical	7,100	4.0%	0.0%	104	68.0	0.53	None
14	Energy efficient light fittings, LED lighting	Cyclical	18,300	8.0%	0.0%	209	87.7	1.06	None
15	Electrical sub-metering to all key installations	Easy win	3,700	5.0%	0.0%	130	28.4	0.66	None
16	Time switches or similar on small equipment	Easy win	400	0.5%	0.0%	13	30.7	0.07	None
17	Photovoltaics (PV) with Feed-In Tariff	Major	36,600	35.9%	0.0%	3,949	9.3	4.73	Manageable
18	Modify temperature set points	Easy win	100	1.0%	5.0%	995	0.1	4.51	None
19	Ensure controls are working correctly	Easy win	1,000	1.0%	2.0%	414	2.4	1.88	None
20	Introduce demand controlled ventilation	Cyclical	1,700	0.5%	0.5%	110	15.5	0.50	None
21	Install digital control system for all major plant	Cyclical	15,000	2.0%	5.0%	1,021	14.7	4.64	None
22	Upgrade boiler system and pumps	Cyclical	24,900	0.5%	10.0%	1,951	12.8	8.83	None

Other opportunities

Rationalisation and redevelopment

The school has steadily been battling deteriorating building conditions throughout the complex of conjoined structures. The organic development of the accommodation via several extensions has resulted in a haphazard arrangement of spaces which are increasingly unfit for purpose. Circulation routes are convoluted, relying on access through classrooms and creating obscured corners and alcoves. The range of teaching spaces differs significantly resulting in inconsistent and potentially disconcerting environmental changes between the year group bases. Perhaps more importantly the school buildings are falling far short of providing acceptable environmental conditions including health and well-being, security, intruder prevention, accessibility and general comfort.

Given the low historical significance of the more modern extensions, their poor conditions and performance present a clear opportunity for replacement of all modern structures.

The historical significance of the original 19th Century school building, although also requiring repair and improvement, validates its preservation. It is a valued asset to the Heslington community and village form. As a result it could provide opportunities for exemplary architectural design combining old and new school construction. The original building could provide facilities for use by the village community while teaching bases would be accommodated within modern, purpose built, sensitively conjoined accommodation to the rear or side.

Modern extensions

Some later additions do little to add to the character and value of the original 19th century building.

Advantages

The building currently demands ongoing repair. It presents poor return on investment, albeit piecemeal, which is taken up with repairs and renewal of failing repairs. Extensive new build facilities would provide better quality spaces, which could support modern teaching methods and provide healthy, stimulating, inspirational environments. In turn this would benefit pupil behaviour, development and the ongoing success of the school. This would present better value and longevity to the school.

New construction would also necessitate a high degree of performance specification to achieve low energy consumption, low carbon emissions, ease of maintenance and accessibility to all.

Implications

Such large scale overhaul of the school would present logistical challenges and may require a design response suitable for phased delivery to allow the school to continue during development elsewhere on the site. Alternatively temporary relocation or closure may be necessary.

The proposed improvements to the original school building would have to be incorporated into the scope of work as essential interventions to sustain the long-term viability of the historic structure.

Appraisal

The clear benefits to pupils, teaching staff and the performance of the school as a whole, both educationally and environmentally, presents a powerful and undisputable argument for such a comprehensive intervention to the current state of the building. This and the long term success of the school and sustainability of the valued C19th school building would need to be balanced with capital cost, local and national policy and logistical challenges.

07 Recommendations

Interpretation

All of the suggested interventions show worthwhile significant carbon savings but in some cases (the red items) the capital costs are relatively high and the cash payback in energy cost savings is distant. In part this arises because The York City Council is understood to have negotiated extremely favourable energy prices and this significantly lengthens the time taken to achieve payback compared with the majority of building owners.

The calculated energy cost saving disregards inflation but it is realistic to anticipate that energy prices will continue to rise at a rate considerably greater than general inflation. It is sufficient to state here that actual payback through energy saving is likely to be much more rapid than shown in the cost-benefit analysis table.

The savings figures in the table are deliberately not totalled. Such totals would be very misleading. Each measure adopted limits the scope for further savings because the total energy use reduces each time. The order of adoption and interaction between different interventions would also have significant impacts on the overall outcome. It is not practical to suggest a likely overall saving.

At a glance

Recommendations

Raise importance of energy saving through behaviour change

Draught stripping should bay back within a year

Install roof insulation

Internal wall insulation

Review building control systems

Behaviour change

It is essential to reinforce and support physical interventions with training and motivation so that the building is operated efficiently and beneficially to reduce carbon emissions and save costs. Administrators and facilities managers need to have a clear understanding of the building and its systems. This will enable appropriate leadership to arrange training and support for the staff in the building. The group of items in the first section of the table aim to provide a comprehensive range of measures to achieve this. There is also a strong educational opportunity in teaching children about energy, buildings and the environment.

It is assumed that behaviour change and building management related items can be implemented by existing staff through internal strategies with normal training and personal development which needs to be sustained and continuing. Although some limited external assistance may be required, this is normal for staff training and the cost of each of these interventions is assumed to be a nominal £100. In the circumstances it is recommended that all these measures are adopted.

Secondary glazing

The incorporation of secondary single glazing could significantly improve the thermal properties of heritage windows.

Building fabric

The interventions explored in this section should provide substantial annual carbon savings.

- Roof insulation should pay back within five years, even without energy price inflation
- Installing draught strips to internal and external doors is low cost, should pay back in a little over a year and should show early benefits in reducing heat losses
- Installing new secondary single glazing should pay back in about 15 years and will provide long term, continuing savings. In the low significance areas it should be assessed against the cost of replacement high performance double glazing

Mullioned window

Mullioned windows along with arched doorways add to a picturesque character.

The following measures should be considered as part of future internal refurbishment works when they can be carried out with least disruption:

- Internal insulation of external walls will pay back within ten years. The extensions could have cavity wall insulation as an alternative but is not likely to provide as great a carbon reduction.

Building services

Items 17-19 all show payback within 10 years and inflation is likely to improve this considerably.

- Photovoltaic solar electricity panels aided by the Feed-In Tariff
- Modify temperature set points
- Ensure controls are working correctly.

Recent announcements regarding the likely reductions in the Feed-In Tariff amounts suggest that the payback period of the proposed photovoltaic installation by be made significantly longer than at the currently applicable rate.

The remaining items show an indicative payback within 13-90 years. However, this is skewed by the surprisingly low electrical consumption and the low price at which the energy is procured. In carbon terms the returns are very worthwhile.

Items 21 and 22 relate to the provision of new boilers, circulating pumps and the installation of modern controls. These measures could perhaps reduce gas and electricity costs by perhaps 15% and 2.5% respectively with carbon savings of around 14 tonnes a year. However, low energy costs result in a projected payback of 13-15 years. It is recommended that the systems are replaced because of their impact in reducing carbon emissions and running costs.

Overall heritage impact

The interventions proposed to Lord Deramore's School have been designed to take account of the building's varying levels of heritage significance and the current poor quality school environment. Some areas of the building such as the late 20th century additions to the east are of no significance and a case could be made for their replacement with more efficient new buildings to enhance the setting of the school, subject to design and to funding. In the historic 1850s and 1907 buildings it will be possible to make substantial improvements to the school environment and reduce carbon and energy use by adding wall linings, roof insulation and secondary window glazing without harming significance. A high standard of design and installation will be essential.

Refurbishing existing historic windows to improve ventilation and draught-proofing will ensure the survival of the distinctive cast-iron or steel windows and help users control the school environment. Re-furbishing the historic hall roof vent and using de-stratification fans would also improve heat distribution and ventilation in this large room without affecting heritage significance.

The south-facing roofs on the late 20th century extensions are not prominent in views of the school and if these buildings are retained and refurbished, photovoltaic panels on the roofs could generate electricity without harming the significance of the historic building or its setting.

Upgrading building services will not affect the significance of the building, if carefully detailed and installed.

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Arup
Project Manager and Engineer

Andy Sheppard
t +44 (0)114 283 3709
e andy.sheppard@arup.com

Native
Architect

Sally Kirk-Walker
t +44 (0)1904 656133
e sally@nativearchitects.com

Architectural History Practice
Heritage building specialists

Marion Barter
t +44 (0)01457 861374
e marion.barter@architecturalhistory.co.uk