Museum Sector Display Energy Certificate Analysis and Case Studies

Operational Rating and CO_2 Emissions

There are a large number of museum buildings in the UK. Many are listed and often struggle with funding. With energy costs rising and a drive to reduce our carbon footprint, it can often be difficult to know where to spend time and money. All museums are different; opening hours, visitor numbers, exhibition format and needs. However, we all have a responsibility to contribute to carbon reduction.

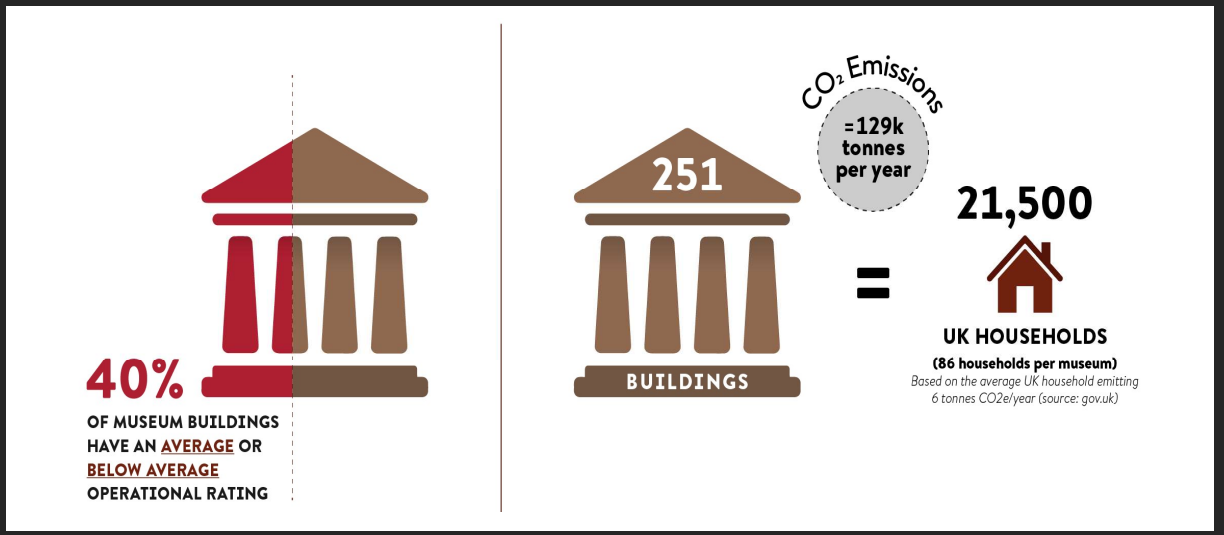
To help gain a better understanding of the of the energy usage and carbon impact of the museum sector, a number of case studies were carried out. Buro Happold's Environmental & Sustainability Engineers visited site and utilising the approach outlined in the Arts Green Book reviewed the building envelope, its major mechanical and electrical plant and environmental systems along with the energy usage figures and profiles. This enabled a better understand of where and when energy is being used and highlighted a number of areas where that would help to reduce energy use and carbon footprint.

The information in the following pages summarises a research exercise from the publicly available data from DEC certificates. Display Energy Certificates (DECs) are designed to show the energy performance of publicly occupied buildings. They use a scale that runs from 'A' to 'G' - 'A' being the most efficient and 'G' being the least.

The aim of this research was to gather information about the current state of the UK museum buildings', in terms of energy usage and related carbon emissions (*), to set the scene on key sector metrics and potential savings for the group.

The data extracted from the DEC database has been filtered by benchmark (cultural activities) and then segregated to ensure the sample was representative of the museums sector only. The final list of venues analysed was 251, 70 of which are members of the NMDC.

(*) The carbon emissions associated to this research are the ones used by the DEC engine instead of the more current values used in the rest of the study.



The infographics on this page represent data involving operational rating and related CO2 emissions.

40% of buildings analysed were scored D to G, which means that their performance was average or below average compared to the benchmark.

In terms of CO2 emissions, the totality of the 251 venues analysed emit a total of 129k tonnes of CO2 per year. This equates to the emissions generated by 21,500 UK households every year.

It should be noted that operational rating does not account for thermal comfort in buildings, and it's mainly based on energy usage (a building using less heating / electricity will score higher even if that affects the final user comfort).

For More Information on the Arts Green Book:

Buro Happold celebrates the launch of the Arts Green Book - Buro Happold

Home - Arts Green Book

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Case Study Feasibility Cost Review

All costs based on high level review of scopes included with Buro Happold "Display Energy Certificates analysis and Case Studies".

Accuracy of costs therefore -10% to plus 30% and should be validated as designs progress.

Costs are based on rates and prices current in March 2024

Costs include for all relevant subcontractor and main contractor on-costs plus an allowance for professional fees @ 10%

Exclusions

Risk allowances (design, construction and development (or Optimism Bias)

Inflation from March 2024

Client internal costs including fundraising, advocacy, project management and capacity building

Finance costs

Impact of discovery of asbestos or other deleterious materials

Impact of discovery of archaeology

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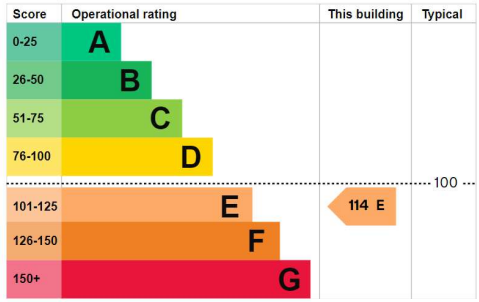
	Quick Wins	Maintenance Projects	Capital Projects
Fitzwilliam Museum	£365,200	£3,266,700	£742,900
The Bowes Museum	£329,000	£1,999,100	£9,250,400
The Yorkshire Museum	£1,047,800	£533,800	£2,221,200
Leeds City Museum	£141,700	£468,500	£2,791,900
Museum of the Home	£73,000	£1,103,200	£3,515,700
Royal Pavilion, Brighton	£270,100	£1,745,200	£1,084,300

Fitzwilliam Museum, Cambridge

Profile / Fitzwilliam Museum, Cambridge

- The Fitzwilliam is the largest and oldest museum of the University of Cambridge estate, housing over half a million objects and works of art, spanning over 10,000 years. It is a leading cultural provider in the region, welcoming 350,000-400,000 visitors a year.
- The original Founder's Building was built in the 1830s. Since then, there have been multiple extensions and refurbishments including flat roof insulation upgrades.
- The site includes permanent gallery spaces, exhibition spaces, a café, gift shop, libraries, archive rooms, conservation studios, offices and meetings rooms.
- Spaces are regularly used for public events and corporate hires.
- The Fitzwilliam Museum is in an important phase of transformation. The Museum's ten-year Masterplan will be a key mechanism through which it plans to develop and reinvigorate its spaces, connect with audiences onsite and digitally as never before, and revolutionise the ways its collections and research are experienced. A significant aspect of the Masterplan is a commitment to improve sustainability and protecting the environment, aligning with the University's target to achieve absolute zero carbon emissions by 2048.

Operational Rating



The key constraints to development on this site include;

- The listed status of the building, original fabric and glazing.
- Very tight space constraints, particularly with back of house spaces.
- Specific environmental requirements for installations & artwork.
- Consistent foot traffic, would make building works difficult to carry out.

Annual Energy & Carbon Performance

Gross Internal Area:
11,415 m²

Total Annual Gas usage:
1,287 MWh/yr

Total Annual Electricity Usage:
1,367 MWh/yr

Total Carbon emissions per annum:
~535 t.CO_{2e}

Total Carbon emissions per m²:
~46.9 kg.CO_{2e}/m²

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Recommendations / Fitzwilliam Museum, Cambridge

This section outlines the key opportunity areas to reduce the operational carbon footprint and move towards net zero carbon. A combination of the Home Survey Tool and a site survey were used.

Quick Wins

1. Apply AHU switch-off times to minimise unnecessary conditioning.
2. Timers on kitchen hot water to prevent constant heating.
3. Maintenance regime: Clean filters, especially to the humidification plant.
4. Give "Visitor Experience" hosts a warmer uniform for winter and leave heating setpoints at 19degC.

Maintenance Projects

1. Run-around coils for AHU heat recovery where thermal wheels do not exist or cannot fit. As well as upgrade to ASHP AHU as part of the planned AHU upgrade.
2. Lighting switch from Halogen to LED.
3. Daylight and presence detection on lighting control to back-of-house spaces.
4. Heating circuit control valves to allow better control of heating. Consider during planned boiler upgrade.
5. Electrical Sub-meter to show where the big consumers are.

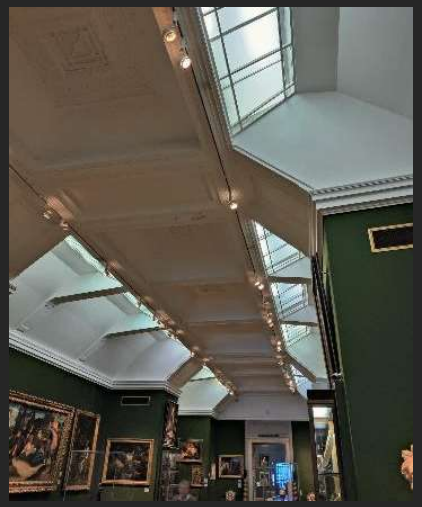
Capital Projects

1. Roofing works: passively minimise heat gain to the Italian gallery, thereby reducing the humidification demand: install external south-light shading; and install a ventilation system to purge the summer heat and use night-time cooling.
2. Photovoltaic Panels: A possible solution to reduce the solar gain in the Italian gallery is to install PV panels over the skylight spaces, thus also producing green electricity on site.
3. Continue to work with the University Estates team to embed the Masterplan into strategic university planning.

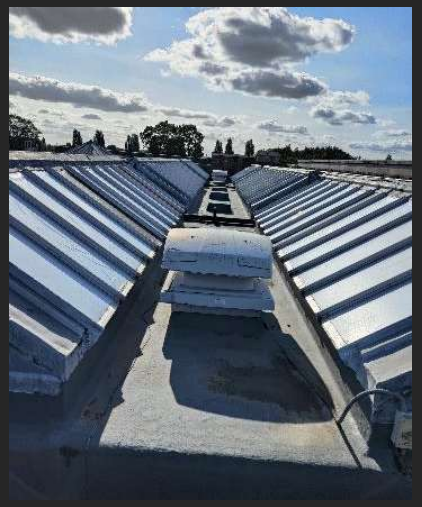
Existing Halogen lighting

Thermal image of uninsulated pipework

Limited heating control in galleries



No daylight sensing



Opportunity for PV panels

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Costs and Carbon Savings / Fitzwilliam Museum, Cambridge

These figures are indicative and estimated based on a high-level appraisal using our experience.

Recommendation	Estimated Carbon Saving*
Hot water timers	1.6 $t.CO_{2e}$ (0.3%)
Filter maintenance	1.1 $t.CO_{2e}$ (0.2%)
AHU heat recovery	2.1 $t.CO_{2e}$ (0.4%)
Halogen lights to LED	2.1 $t.CO_{2e}$ (0.4%)
Daylight & Presence detection for lighting	15.0 $t.CO_{2e}$ (2.8%)
Heating circuit control valves	10.2 $t.CO_{2e}$ (1.9%)
Electrical sub-metering	4.3 $t.CO_{2e}$ (0.8%)
PV array over Italian gallery skylights	1.1 $t.CO_{2e}$ (0.2%)
TOTAL	**37.5 $t.CO_{2e}$** (7%)

**tonnes CO2 saved and % improvement over existing emissions*

Feasibility Cost Review	Quick Wins	Maintenance Projects	Capital Projects
Fitzwilliam Museum	£365,200	£3,266,700	£742,900

**costs provided by* FLINT + PARTNERS

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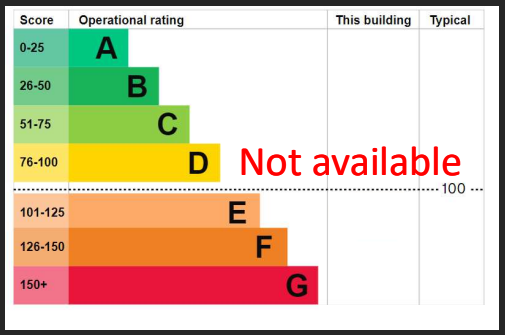
Bowes Museum, Barnard Castle

Profile / Bowes Museum, Barnard Castle

- The Bowes Museum is a charity managing a Grade 1 listed, Accredited Museum and parkland in Barnard Castle. Founded by Joséphine & John Bowes 150+ years ago, this purpose-built art gallery and Museum brings together an extraordinary, designated collection of European fine art as a cultural resource for the people of Northern England, where today artists, designers and makers are celebrated. Located on the east edge of Barnard Castle, the 8-hectare site slopes down from the North to the entrance.
- The main building includes offices within the mansard roof and a high-end café at ground floor.
- The museum is now run by a charity.
- The main building is grade 1 listed and there are a number of listed buildings and features within the grounds.

Operational Rating



- The building fabric is largely original with much of the thermal envelope having been maintained but not significantly upgraded since the building was built.
- The building was upgraded with central heating soon after it was built and is now largely heated by gas boilers feeding the original cast iron radiators via single pipe loop distribution.
- The museum is looking to improve control of temperature and humidity in all areas of collection.
- The museum is keen to reduce its environmental impact including reducing energy consumption and moving towards renewables over time.
- Electrical distribution has been recently updated.

Annual Energy & Carbon Performance

Gross Internal Area:
8000 m^2

Total Annual Gas usage:
1,200 MWh/yr

Total Annual Electricity Usage:
360 MWh/yr

Total Carbon emissions per annum:
438 $t.CO_{2e}$

Total Carbon emissions per m^2:
55 $kg.CO_{2e}/m^2$

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Recommendations / Bowes Museum, Barnard Castle

This section outlines the key opportunity areas to reduce the operational carbon footprint and move towards net zero carbon. A combination of the Home Survey Tool and a site survey were used.

Quick Wins

1. Improved recording of electrical submetering to identify and control high usage areas.
2. Review all time schedules to confirm no plant operating outside of required operating periods.
3. Review central boiler controls. Maximise weather compensation if included for improved efficiency and stable room control. Manually compensate if necessary.
4. 3rd floor boiler replacement with all electric solution (current boilers inoperable).

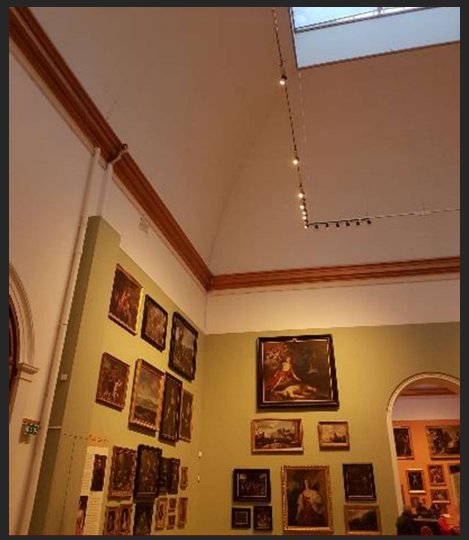
Maintenance Projects

1. Lighting switch to LED.
2. Improve lighting controls for daylight and/or occupancy.
3. Add thermostatic radiator valves to radiators.

Capital Projects

1. Flat roof and mansard roof insulation. Internal insulation.
2. Window improvements including gallery lanterns. Window repairs. Secondary glazing.
3. Replacement of heating distribution as 2 pipe system with updated control and additional emitters as necessary to operate at lower temperature. Include for office floor off central boilers.
4. New BMS for enhanced monitoring and control of systems & conditions.
5. Main galleries replacement of boilers with electric HP alternative. Investigation of GSHP.
6. Café kitchen change to all electric with new recirculating kitchen ventilation.
7. Identify any opportunity for inclusion of PV. Consider ground mounted.

Electrical power readings



Potential to switch lighting to LED

Existing radiators do not have thermostatic valves

Window openings

Existing flat roof with limited insulation

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Costs and Carbon Savings / Bowes Museum, Barnard Castle

These figures are indicative and estimated based on a high-level appraisal using our experience.

Recommendation	Estimated Carbon Saving*
Improved recording of electrical submetering to identify and control high usage areas	1.62 tCO_2 (0.4%)
Review all time schedules to confirm no plant operating outside of required operating periods	0.71 tCO_2 (0.2%)
Review central boiler controls. Maximise weather compensation if included for improved efficiency and stable room control	0.94 tCO_2 (0.2%)
3rd floor boiler replacement with all electric solution	12.0 tCO_2 (2.7%)
Lighting switch to LED	11.3 tCO_2 (2.6%)
Improve lighting controls for daylight and/or occupancy	0.81 tCO_2 (0.2%)
Add thermostatic radiator valves to radiators	1.88 tCO_2 (0.4%)
Flat roof and mansard roof insulation. Internal insulation	20.30 tCO_2 (4.6%)
Window improvements including gallery lanterns. Window repairs. Secondary glazing	11.8 tCO_2 (2.7%)
Replacement of heating distribution as 2 pipe system with updated control and additional emitters as necessary to operate at lower temperature. Include for office floor off central boilers	11.56 tCO_2 (2.6%)
New BMS for enhanced monitoring and control of systems	7.08 tCO_2 (1.6%)
Main galleries replacement of boilers with electric HP alternative	113.28 tCO_2 (25.9%)
Café kitchen change to all electric with new recirculating kitchen ventilation	2.36 tCO_2 (0.5%)
PV	4.04 tCO_2 (0.9%)
TOTAL	**199.70 tCO_2** (45.6%)

**tonnes CO2 saved and % improvement over existing emissions*

Feasibility Cost Review	Quick Wins	Maintenance Projects	Capital Projects
The Bowes Museum	£329,000	£1,999,100	£9,250,400

**costs provided by* FLINT + PARTNERS

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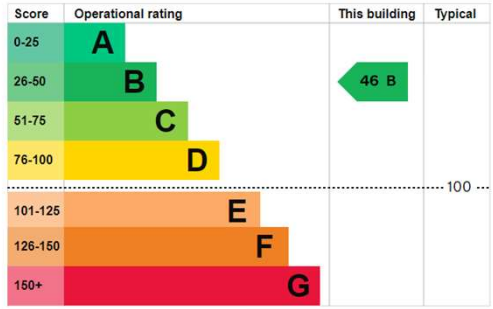
The Yorkshire Museum, York

Profile / The Yorkshire Museum, York

- The Yorkshire Museum is a purpose build museum housing a range of significant collections. The building was opened in 1830 and is in the Greek revival style. Located in the centre of York, the 4 hectare site slopes down to the river Ouse. The grounds contain many archaeological constraints.
- A flat roof extension, the Tempest Anderson Hall, was added to the building in the early 1900s. Whilst matching the original building in visual appearance it is of reinforced concrete construction.
- The Museum is operated by a trust which also operates the York Castle Museum and the York Art Gallery.
- Both the original building and extension are grade 1 listed.

Operational Rating



- The building fabric is largely original. Funding is being sought for replacing the roof and roof lights with additional insulation "where possible".
- The building has historic central heating distribution fed via gas boilers. There are a mix of historic and modern radiators with some fan convectors. Boilers were replaced within the last 5 years.
- Windows are almost entirely single glazed, some steel framed.
- York city is proposing a heat network and has identified Yorkshire Museum as one possible anchor building.

Annual Energy & Carbon Performance

Gross Internal Area:
3088 m^2

Total Annual Gas usage:
336 MWh/yr

Total Annual Electricity Usage:
82 MWh/yr

Total Carbon emissions per annum:
110 $t.CO_{2e}$

Total Carbon emissions per m^2:
36 $kg.CO_{2e}/m^2$

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Recommendations / The Yorkshire Museum, York

This section outlines the key opportunity areas to reduce the operational carbon footprint and move towards net zero carbon. A combination of the Home Survey Tool and a site survey were used.

Quick Wins

1. Review roof works proposed and identify any areas where insulation is limited. Investigate alternative insulation options that can be included within the roof works package.
2. Review all time schedules to confirm no hot water or heating plant operating outside of required operating periods.
3. Review central boiler controls. Maximise weather compensation, if included, for improved efficiency and stable room control. Manually compensate if necessary.
4. Review temperature/humidity records for all areas to identify and subsequently investigate areas outside target range.
5. Continue/complete replacement of existing lighting with LED lighting.

Maintenance Projects

1. Improve lighting controls for daylight and/or occupancy.
2. Improve draught-proofing to doors. Include air curtain/draught lobby at entrance.
3. Add thermostatic radiator valves to radiators.
4. Improved electrical submetering and record to identify and control high usage areas.
5. Investigate inclusion of PV on the flat roof.

Capital Projects

1. Window repairs. Secondary glazing.
2. Replacement of heating distribution system with updated control and additional emitters as necessary to operate at lower temperature.
3. New BMS for enhanced monitoring and control of systems and conditions.
4. Investigate and plan for future connection to district heat network.

Existing lighting, no occupancy controls

Flat roof with opportunities for PV

Existing building fabric

Gas boilers, opportunity to reduce heating water temperature

No valves on existing radiators

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Costs and Carbon Savings / The Yorkshire Museum, York

These figures are indicative and estimated based on a high-level appraisal using our experience.

Recommendation	Estimated Carbon Saving*
Review roof works proposed and identify any areas where insulation is limited	1.48 tCO2 (1.3%)
Review all time schedules to confirm no plant operating outside of required operating periods	0.18 tCO_2 (0.2%)
Review central boiler controls. Maximize weather compensation, if included, for improved efficiency and stable room control	0.12 tCO_2 (0.1%)
Window repairs. Secondary glazing	2.95 tCO_2 (2.7%)
New BMS for enhanced monitoring and control of systems and conditions	3.36 tCO_2 (3.0%)
Investigate inclusion of PV on the flat roof	1.0 tCO_2 (0.9%)
Improve draught-proofing to doors. Include air curtain/draught lobby at entrance	0.22 tCO_2 (0.2%)
Investigate and plan for future connection to district heat network	47.2 tCO_2 (42.5%)
TOTAL	**56.5 tCO2** (50.9%)

**tonnes CO2 saved and % improvement over existing emissions*

Feasibility Cost Review	Quick Wins	Maintenance Projects	Capital Projects
The Yorkshire Museum	£1,047,800	£533,800	£2,221,200

**costs provided by* FLINT + PARTNERS

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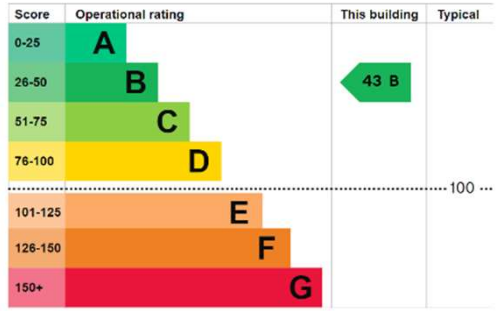
Leeds City Museum, Leeds

Profile / Leeds City Museum, Leeds

- Leeds City Museum building was built in the 1860s as a Mechanics Institute. It subsequently operated as a theatre. The Leeds City Museum took up residence in the building in 2008 after an extensive conversion and refurbishment. Buro Happold were structural and services engineers for the refurbishment.
- Leeds City Museum is on a tight city centre site.
- The main building is grade II* listed.
- Lighting in public areas was recently upgraded to LED with support from the Public Sector Decarbonisation Scheme.

Operational Rating



- The building was initially heated via gas boilers after the refurbishment but has subsequently been connected to the city district heating system.
- Overheating and underheating are both reported by the museum.
- Humidity is only controlled directly in the special exhibitions space. Other spaces use temperature control to control humidity.

* Gas usage will reduce to zero in future years as the site is now connected to the city district heating scheme.

Annual Energy & Carbon Performance

Gross Internal Area:
5100 m²

Total Annual Gas usage:
596 MWh/yr*

Total Annual Electricity Usage:
88 MWh/yr

Total Carbon emissions per annum:
164 t.CO_{2e}

Total Carbon emissions per m²:
32kg.CO_{2e}/m²

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Recommendations / Leeds City Museum, Leeds

This section outlines the key opportunity areas to reduce the operational carbon footprint and move towards net zero carbon. A combination of the Home Survey Tool and a site survey were used.

Quick Wins

1. Review of electrical submetering to identify and control high usage areas.
2. Review all time schedules to confirm no plant operating outside of required operating periods.
3. Review temperature/humidity records for all areas to identify and subsequently investigate areas outside target range.
4. Ensure all water outlets (excluding café kitchen) are fitted with flow restrictors.

Maintenance Projects

1. Improve lighting controls for daylight and/or occupancy.
2. Review Electrical appliances for efficiency rating and replace as appropriate.
3. Review historic ventilation operation, CO2, humidity and temperature records to identify potential savings by increasing recirculation or decreasing flow rates.
4. Add DX heater battery to reception ventilation direct electric heater battery.
5. Blank off plant louvres not required to be open to atmosphere.

Capital Projects

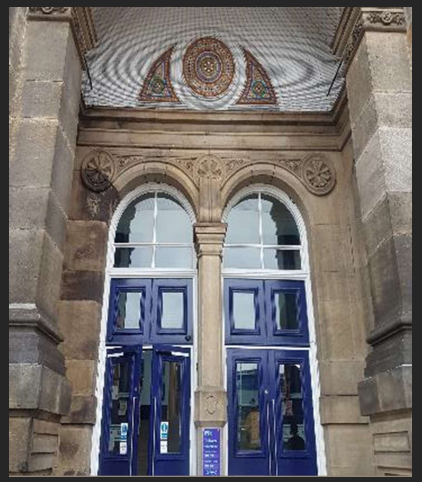
1. Window repairs. Secondary glazing to single glazed windows. Investigate potential for internal insulation at Brodrick Hall high level windows.
2. Café kitchen change to recirculating ventilation.
3. Identify any opportunity for inclusion of PV.
4. Review roof insulation and upgrade/improve where possible.
5. Investigate addition of draught lobby.

Café kitchen

Daylight entering gallery space

Existing building fabric

Consider opportunities for improved insulation performance



Entrance with no draught lobby

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Costs and Carbon Savings / Leeds City Museum, Leeds

These figures are indicative and estimated based on a high-level appraisal using our experience.

Recommendation	Estimated Carbon Saving*
Review of electrical submetering to identify and control high usage areas	0.38 tCO2 (0.2%)
Review all time schedules to confirm no plant operating outside of required operating periods	0.35 tCO2 (0.2%)
Review temperature/humidity records for all areas to identify and subsequently investigate areas outside target range	1.16 tCO2 (0.7%)
Ensure all water outlets (excluding kitchen) are fitted with flow restrictors	0.58 tCO_2 (0.4%)
Improve lighting controls for daylight and/or occupancy	0.19 tCO2 (0.1%)
Review Electrical appliances for efficiency rating and replace as appropriate	0.43 tCO_2 (0.3%)
Review historic ventilation operation, CO2, humidity and temperature records to identify potential savings by increasing recirculation or decreasing flow rates	2.78 tCO_2 (1.7%)
Window repairs. Secondary glazing	5.8 tCO_2 (3.5%)
Café kitchen change to recirculating ventilation	1.16 tCO_2 (0.7%)
PV	10.96tCO_2 (0.6%)
TOTAL	**13.8 tCO2** (8.4%)

**tonnes CO2 saved and % improvement over existing emissions*

Feasibility Cost Review	Quick Wins	Maintenance Projects	Capital Projects
Leeds City Museum	£141,700	£468,500	£2,791,900

**costs provided by* FLINT + PARTNERS

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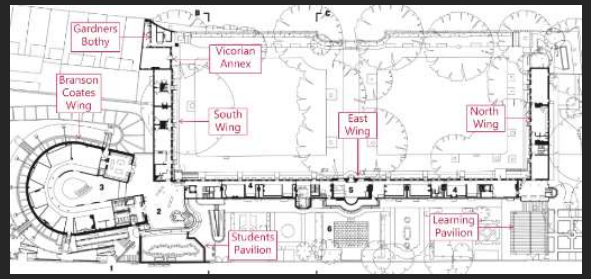
The Museum of the Home, London

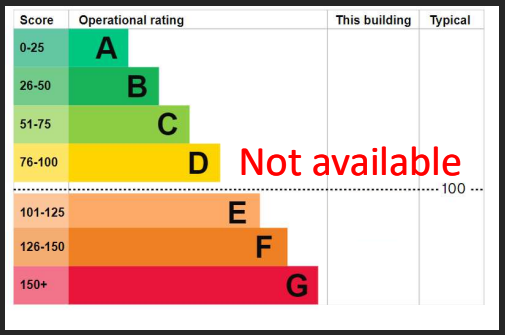
Profile / The Museum of the Home, London

- Located adjacent to Hoxton Station in London UK, The Museum of The Home is dedicated to collection of furniture and interiors. The museum explores home and home life from 1600 to the present day with a series of room displays.
- The museum consists primary of 14 Grade 1 listed Alms houses built in 1712, a 1998 extension by architects Branson Coates, and a 2021 development of two modern Pavilion rooms.
- As part of the 2021 development the East wing was refurbished, and a new gas heating system installed.

- Grade 1 listing makes façade and window upgrades unviable. Main decarbonisation options centre on using systems efficiency and decarbonising the primary energy supply.



Operational Rating



Annual Energy & Carbon Performance

Gross Internal Area:
~5500 m²

Total Annual Gas usage:
399 MWh/yr

Total Annual Electricity Usage:
239 kWh/yr

Water Use: **1844 m3**

Total Carbon emissions per annum:
~116 t.CO_{2e}

Total Carbon emissions per m²:
~21 kg.CO_{2e}/m²

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Recommendations / The Museum of the Home, London

This section outlines the key opportunity areas to reduce the operational carbon footprint and move towards net zero carbon. A combination of the Home Survey Tool and a site survey were used.

Quick Wins

1. Controls optimisation of heating system has already saved ~10%.
2. Decrease night-time set back temperatures.
3. Set back night-time gallery AHU vent rates.
4. Review adding weather compensation to Constant temperature heating loop.
5. Carry out general draught-proofing to doors.

Maintenance Projects

1. Add heat recovery to all supply and extract systems as part of end-of-life plant upgrades.
2. Full LED lighting upgrade with control system.
3. Add loft insulation to North and South Wings.
4. Intelligent TRV upgrade in North and South Wings.

Capital Projects

1. Combine the 3 site heating systems.
2. Replace Gas Boilers with either an Air Source Heat pump or Ground Source Heat Pump.
3. Opportunity to make heating system part of the exhibition E.g. history of how are our homes are heated.

Potential for TRV upgrades to radiators

Current ventilation strategy

Gas boiler, consider replacement with heat pumps

Potential for ground source heat pumps could be explored

Home Survey Tool >

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Costs and Carbon Savings / The Museum of the Home, London

These figures are indicative and estimated based on a high-level appraisal using our experience.

Recommendation	Estimated Carbon Saving*
Carry out general draught-proofing to doors	2.3 tCO2 (2.0%)
Full LED lighting upgrade with control system	5.8 tCO2 (5.0%)
Add loft insulation to North and South Wings	5.8 tCO2 (5.0%)
Add heat recovery to all supply and extract systems as part of end-of-life plant upgrades	3.5 tCO2 (3.0%)
ASHP Upgrade	65 tCO2 (56.0%)
TOTAL	**82.4 tCO2** (71%)

**tonnes CO2 saved and % improvement over existing emissions*

Feasibility Cost Review	Quick Wins	Maintenance Projects	Capital Projects
Museum of the Home	£73,000	£1,103,200	£3,515,700

**costs provided by* FLINT + PARTNERS

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Royal Pavilion, Brighton

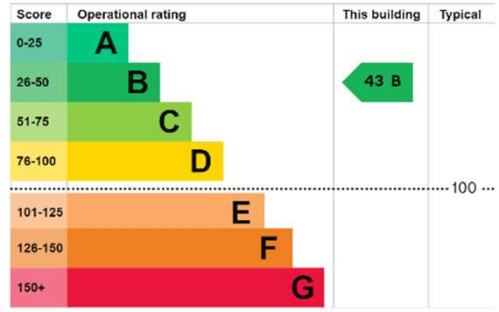
Profile / Royal Pavilion, Brighton

- The Royal Pavilion is a Grade I listed building. Whilst some areas of the building date back to the original construction in the 1780s, the majority of the building form and layout is a result of the major expansion works by architect John Nash which were completed in 1823. The original function of the building was as a royal residence; however, the building has been used for many purposes including an assembly hall, wedding venue and military hospital. The last major refurbishment is understood to have been in the 1980s.

The key constraints to development on this site include;

- the listed status of the building.
- long term challenges in maintaining temperature and humidity.
- limited funding available for major capital projects.

Operational Rating



- Note – DEC from 2018, as the Royal Pavilion is now part of the Royal Pavilion and Museums Trust.
- Some of the gas supply is provided from adjacent Dome building which is not sub-metered, therefore DEC utility data is based on area weighted average only.

Annual Energy & Carbon Performance

Total Gross Internal Area:
6,640 m²

I Annual Gas usage (2018 data):
325 MWh/yr

Total Annual Electricity Usage (2018 data):
285 MWh/yr

Total Carbon emissions per annum (2018 data):
~107 t.CO_{2e}

Total Carbon emissions per m² (2018 data):
~16 kg.CO_{2e}/m²

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Recommendations / Royal Pavilion, Brighton

This section outlines the key opportunity areas to reduce the operational carbon footprint and move towards net zero carbon. A combination of the Home Survey Tool and a site survey were used.

Quick Wins

1. Install sub-metering from Dome Energy Centre to Pavilion so heating energy can be accurately assessed.
2. Develop a ventilation control strategy to advise staff when to operate manual opening windows.
3. Replace/repair missing insulation on pipework.
4. Consider opportunities for draft proofing to doors/windows including minimizing external door opening times.

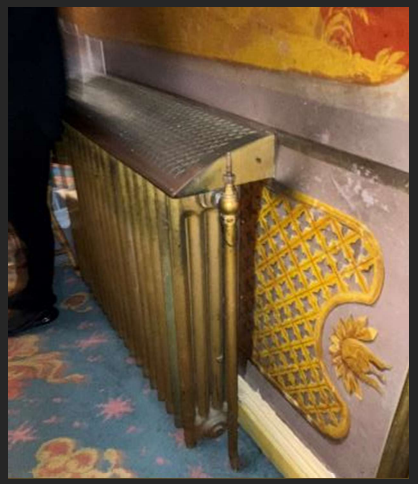
Maintenance Projects

1. Continue lighting switch from Halogen to LED.
2. Daylight and presence detection on lighting control to back-of-house spaces.
3. Increased air tightness through fabric repair and upgrades.
4. Improve heating zoning/control through installing heating zoning valves.

Capital Projects

1. Heating improvement works – to deliver appropriate temperature and humidity control appropriate for the heritage environment. Identify strategies to enable the use of low/zero carbon heating technologies.
2. Build on previous efforts to increase insulation within the building.
3. Improve secondary glazing where already provided, look for opportunities to provide more secondary glazing (within heritage constraints).
4. Develop a net zero carbon catering strategy, replace gas catering equipment.

Opportunities to improve draft proofing



No valves on existing radiators

Existing gas boiler

Opportunity to learn from previous insulation studies

Temporary conservation heating

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Costs and Carbon Savings / Royal Pavilion, Brighton

These figures are indicative and estimated based on a high-level appraisal using our experience.

Recommendation	Estimated Carbon Saving*
Repair and upgrade insulation on pipework	0.61 tCO2 (0.6%)
Carry out general draught proofing to doors and windows	2.4 tCO2 (2.3%)
Continue transition to LED lighting	0.35 tCO2 (0.33%)
Increase air tightness around wall/floor/roof junctions	4.87 tCO2 (4.55%)
Install heating zone valves	1.47tCO2 (1.37%)
Apply insulation (to up to 20% of the roof)	1.47 tCO2 (1.37%)
Secondary double glazing applied behind existing windows	7.3 tCO2 (6.82%)
Replace gas boilers with heat pump (ASHP)	40.17 tCO2 (37.51%)
TOTAL	**58.1 tCO2** (54.0%)

**tonnes CO2 saved and % improvement over existing emissions*

Feasibility Cost Review	Quick Wins	Maintenance Projects	Capital Projects
Royal Pavilion, Brighton	£270,100	£1,745,200	£1,084,300

**costs provided by* FLINT + PARTNERS

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