HOARE LEA

Royal Cornwall Museum.
Cornwall.
Royal Institute of Cornwall.

SUSTAINABILITY
DECARBONISATION STRATEGY

REVISION 01 – 03 MAY 2024

Audit sheet.

Rev.	Date	Description of change / purpose of issue	Prepared	Reviewed	Authorised
01	03/05/2024	For issue	E. Jolly	T. Brown	G. Jones

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Contents.

Executive summary.

This document has been produced on behalf of the Royal Cornwall Museum to identify potential measures that could be considered to decarbonise the operational demands of the building. The Museum have set a target to be carbon neutral in operational emissions by 2030.

The study was completed in two stages:

1. Site survey and assessment of baseline conditions.
2. Desktop assessment to calculate potential energy demand and carbon emissions saved through the proposed measures.

Baseline and Business as Usual (BAU).

Hoare Lea used metered data from the year 2022-2023 to determine the Business as Usual (BAU) case for the building, i.e. if no interventions were implemented. This demonstrated that in 2030 the predicted carbon emissions from operation would be ~35tCO_2.

A dynamic thermal model was created using IES software to create an operational energy model which provided insight into the energy profile of the building. The model indicated that although fabric performance can be considered poor due to the ages and Listed status of the building, the dominant demands arise from lighting and unregulated demands.

Interventions.

Following the site survey and discussions with the building management team, a number of measures were identified for the building that could be implemented to reduce emissions. These measures were grouped into three categories:

1. Works in progress – Funding allocated and being implemented.
2. Planned (not confirmed) – Funding to be released to enable implementation.
3. Additional – Measures recommended by Hoare Lea for consideration.

Iterative analysis was undertaken using the dynamic model to determine the predicted energy savings should each measure be implemented. This was then used to forecast the potential carbon emissions to the year 2050 using the Future Energy Scenarios (FES) dataset produced by the National Grid.

It can be demonstrated that, should all measures be implemented, the predicted emissions in 2030 could be reduced by ~77% to achieve emissions of 8tCO_2 from operation.

Although this study has not been able to demonstrate that carbon neutral by 2030 could feasibly be achieved, a significant reduction could be realised.

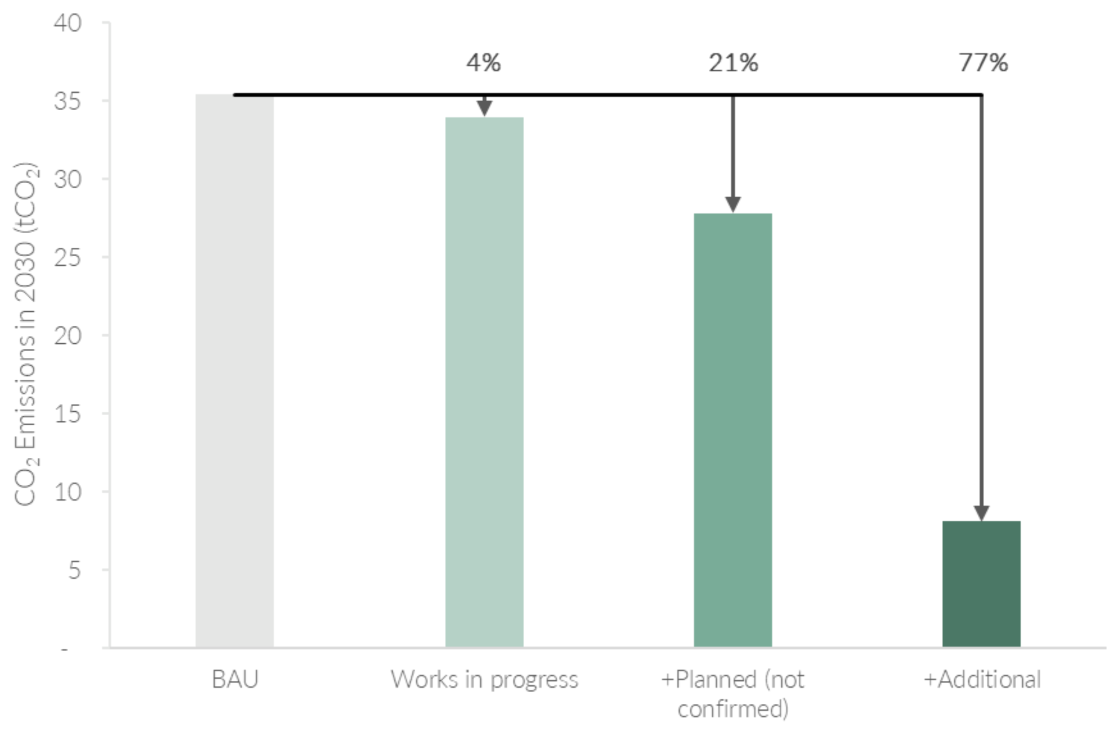

Figure 1: Predicted carbon emissions in the year 2030.

1. Boundary condition and baseline.

Within this first stage of assessment, Hoare Lea have undertaken a survey of the building as well as collated and analysed metered data for the period August 2022 to August 2023. This metered data has been used to determine a Business As Usual (BAU) for the building.

Two important concepts when considering organisational carbon emissions are the boundary condition, (i.e. what operational emissions are to be reported) and the baseline against which progress can be measured.

The boundary condition for this study was set out in the Strategy briefing document and has been subsequently refined in consultation with meetings and according to the availability of data.

The baseline year is critical to establishing a trajectory toward net zero, understanding progress to date and assessing the performance of carbon reduction measures.

1.1 Boundary condition.

The boundary for the Strategy is defined by a combination of the emissions sources to be included and the organisational boundary to be considered.

Emissions sources

The Operational Estate element of the Strategy focuses on Scope 1 and Scope 2 stationary emissions, as defined by the GHG Protocol. The emissions sources covered by the boundary have been refined during the development of the Strategy and informed by the availability of data. The emissions sources included in the boundary condition are summarised in Table 1.

Table 1: Emission sources covered by the baseline.

	Included in boundary	Excluded from boundary as outside of brief	Excluded from boundary due to data availability
Scope 1	Fossil fuels used in operational buildings including gas, LPG, burning oil and heat network	Fossil fuels used in fleet vehicles Fossil fuel used in equipment (such as grounds maintenance kit)	Biomass fuels Fugitive emissions (leaks of refrigerants to atmosphere)
Scope 2	Purchased electricity for the development	*Other purchased energy*	Electricity export (e.g. excess generation by photovoltaic panels)
Scope 3		Flights Hire vehicles Grey fleet (staff vehicles used for business) Other business related travel (e.g. commuting) Procurement Water and waste-water Operational waste Construction and demolition waste	
Outside of scopes			*Biomass fuels*
Key: Included Excluded			

Not relevant

1.2 Baseline.

The baseline year for this assessment is August '22 – August '23 based on metered data provided. However, with the adoption of a carbon neutral target, this original base year becomes less relevant, as targets become somewhat decoupled from the baseline. This gives Scope 1 to 2 emissions of 82.23 tCO_2e.

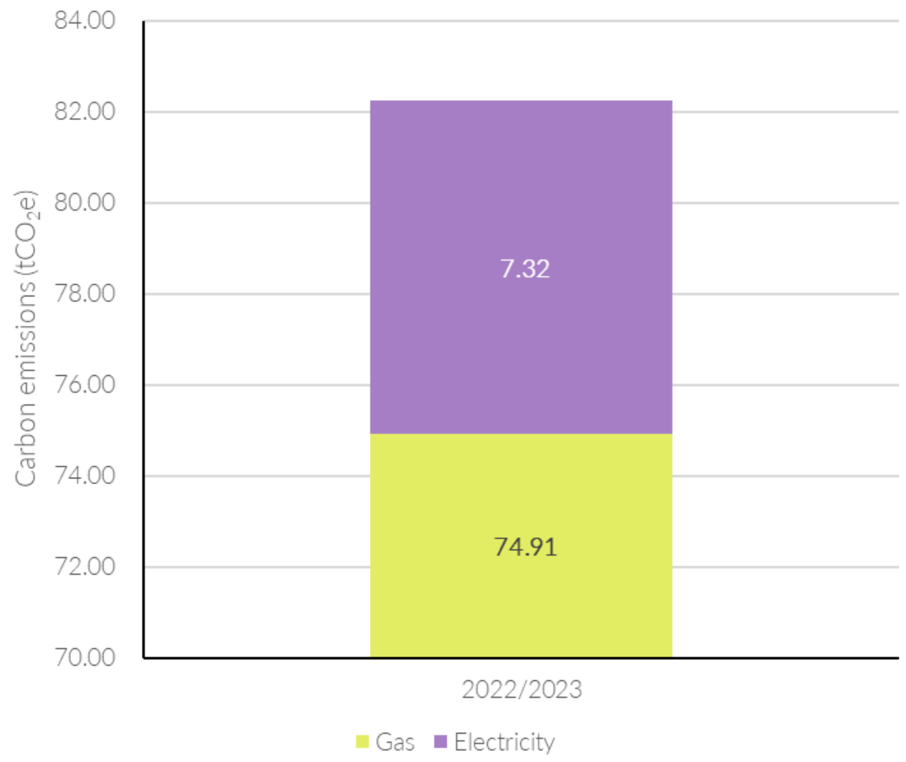

Figure 2: Proposed new baseline year emissions.

1.3 Business as Usual (BAU).

Having established a target trajectory (i.e. carbon neutral by 2030), it is useful to understand what a Business As Usual (BAU) forecast of future emissions might look like by comparison, taking into account relevant external factors (such as the continued decarbonisation of the national electricity grid). As with any forecast, there is inherent uncertainty as assumptions may not be accurate, plans change, and so on. To account for this the future BAU forecast is presented here as a range.

A key variable is the rate at which the UK electricity grid decarbonises. The grid emissions for Future Emissions Scenario steady progression have been used, adjusted to smooth the reduction between now and 2050 over time.

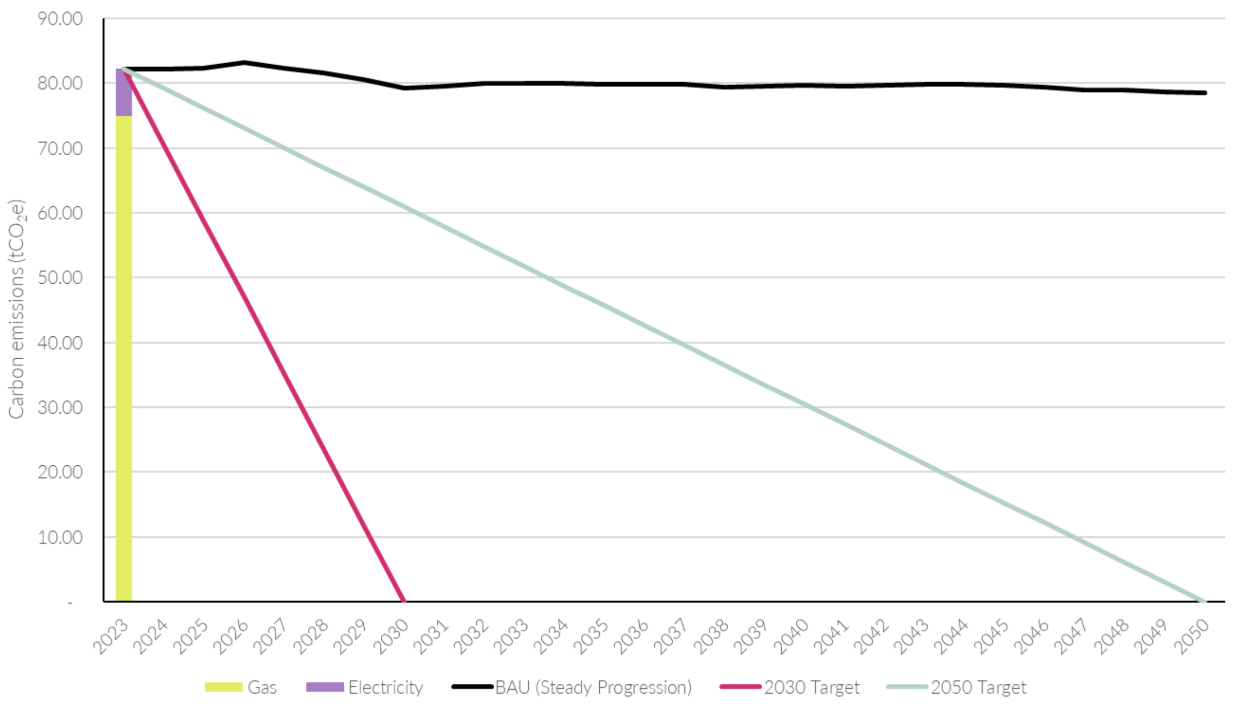

Figure 3: Business As Usual emissions scenarios between 2023 and 2050.

1.4 Emissions factors.

In line with Defra's environmental reporting guidelines, historic emissions factors applied in the study have been sourced from the 2023 set of the UK Government Greenhouse gas reporting conversion factors. With the exception of grid electricity and the heat network (discussed in the following sections), emissions factors for the future projections have been assumed constant from the 2023 reported value[1].

Electricity

The Future Energy Scenarios (FES) document, produced by the National Grid, discusses how the UK's energy landscape is changing. The FES 2023 makes projections of how the mix of generation in the grid is likely to change between now and 2050 – the year by which the Climate Change Act 2008 set the target of reducing the UK's CO_2 emissions by 80% from 1990 levels. This target has now been revised to be Net Zero in light of the Committee on Climate Change's recent report and the declaration of a Climate Emergency.

The latest version, FES 2020, discusses these projections in four scenarios and Figure 4 combines these future trajectories with the actual carbon intensity of the National Grid over the past 12 years. The reported emissions associated with electricity generation have fallen steeply since 2012 and in three cases, the FES 2023 scenarios see carbon factors trending towards zero by the early 2030s. This is on the basis that FES 2020 have deemed it necessary to offset other industries such as freight, shipping and aviation, which will be unable to reduce their carbon emissions to zero. Offsetting the emissions of other industries will involve Carbon Capture and Storage (CCS) technologies on a significant scale in order for the UK as a nation to meet net zero carbon by 2050. It is important to note that CCS technology is not currently commercially demonstrated at a large scale, but the FES 2023 studies are useful as future forecasts.

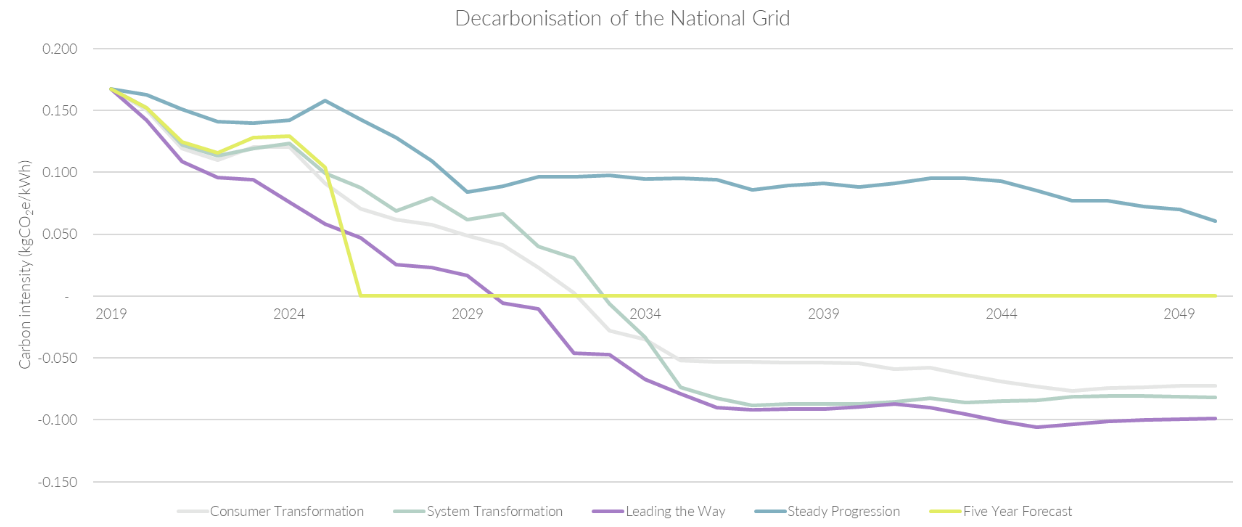

Figure 4: Historic and future projected carbon factor for the National Grid. Sources: *BEIS Green Book* (historic carbon factors); *National Grid Future Energy Scenarios (FES) 2023* (future projected carbon factors).

In recognition of the decarbonisation of the national grid, a future projection has been made for grid electricity. A smoothed series has been modelled between last known year for historical data, 2023, and the projected steady progression factor for the study end year, 2030, to prevent a sharp drop between historic and predicted emissions in year one of the forecast. The 'steady-progression' pathway projects the slowest credible FES decarbonisation pathway and thus represents a conservative position for future emissions.

The table below shows the grid electricity emissions factors calculated using the steady progression smoothed approach for future years (note that 2017/18 to 2019/20 figures in the steady progression smoothed data set are UK Government Greenhouse gas reporting conversion factors).

[1] https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting).

Table 2: Emissions factors for grid electricity.

Short year	FY	Steady progression/ $kgCO_2e/kWh$	Steady progression smoothed/ $kgCO_2e/kWh$
2017	2017/18	-	0.352
2018	2018/19	-	0.283
2019	2019/20	-	0.256
2020	2020/21	-	0.233
2021	2021/22	0.151	0.219
2022	2022/23	0.141	0.204
2023	2023/24	0.140	0.190
2024	2024/25	0.142	0.175
2025	2025/26	0.158	0.161
2026	2026/27	0.142	0.146
2027	2027/28	0.128	0.132
2028	2028/29	0.109	0.118
2029	2029/30	0.084	0.103
2030	2030/31	0.089	0.089

1.5 Understanding the building.

The Royal Institute of Cornwall is a museum and therefore will require specific building controls and need to provide a welcoming and engaging environment. Furthermore, the museum houses a large collection of art and historical artifacts of cultural importance that need specific storage and display requirements to reduce risk of damage.

Known future changes

A key part of the future emissions landscape is driven by the programme of capital projects which include refurbishments and funded projects.

Our current understanding of planned works to the building include the following:

- Improvement to toilet facilities
- New entrance door
- Improvement to circulation areas
- Extended mezzanine level for café/bar/performance space
- Upgrade to existing plant with intention to move away from combustion/fossil fuel plant
- Refurbishment of reception and retail areas
- Refurbishment of exhibition areas to improve display quality and interactive options
- Relocation of offices areas.

1.6 Outcomes from site survey.

Existing services

- Space heating provided by gas boiler. Catering facilities using electric and not connected to gas supply. Some areas have direct electric panels rather than radiators, therefore a proportion of the space heating provided by electricity.
- Hot water provided by point of use heaters and storage calorifiers. Storage vessels heated via gas boiler therefore proportion of gas demand is from domestic hot water use.
- WC areas have some extract ventilations units which discharge direct to external air. Systems vary in age and condition. Not all areas are mechanically ventilated.
- Office areas generally do not have mechanical ventilation. Ventilation provided by openable windows where present.
- Some areas provided with air conditioning units which can provide heating and cooling.
- Controls are minimal throughout the building, with majority located at plant side and are manual.
- Lighting provided through a mix of LED and fluorescent fittings. LED is mainly isolated to some display lighting and areas that have undergone recent upgrade.

Recommendations

- Replacement of gas boiler with Air Source Heat Pump. This can be used for heating and hot water where required. Greater savings would be achieved if this applied to all space heating and hot water but would require pipework installation for areas that are not currently served via a wet system. Space would need to be allocated for associated plant.
- Replacement of extract ventilation in the WC areas and linked to occupancy control.
- Review of ventilation strategy for office areas as not all spaces are served adequately. Where mechanical ventilation is proposed, heat recovery would be recommended to reduce further demand.
- Consideration of PV panel installation to provide onsite generation of electricity if moving to an all-electric system.
- Review of controls to services to reduce wasted energy use.
- Upgrade to lighting to ensure low energy lighting throughout the building. Introduction of sensor controls where appropriate to reduce demand when unoccupied.

2. Decarbonisation assessment.

Using drawings provided and detail collated during the site survey, a dynamic model was produced in IES software using CIBSE TM54 methodology.

2.1 Modelling parameters – Existing performance.

Building fabric.
Table 3 below summarises the building fabric specification, based on assumed performance considering the age of the building and RdSAP benchmarks.

Table 3: Building fabric specification.

Parameter modelled	Value
External wall U-value (W/m^2.K)	2.1
Roof U-value (W/m^2.K)	3.5
Ground / exposed floor U-value (W/m^2.K)	1.2
Internal wall to unheated space U-value (W/m^2.K)	0.26
Door U-value (W/m^2.K)	2.0
Window U-value (W/m^2.K) (Including frame)	4.8 single glazed
Window g-value	0.5
Air permeability (m^3/hr/m^2 at 50 Pa)	15

Weather data.
CIBSE Test Reference Year (TRY) weather data sets are generally used for energy analyses. TRY weather sets are composed of 12 composite months which are chosen to be most representative of each month. The Plymouth CIBSE Test Reference Year (TRY) weather data set has been utilised for this model as the closest and most relevant climate.

Occupancy.

Occupancy density
Sensible and latent heat gains per person has been taken from the range of values provided in CIBSE Guide A: Environmental Design, i.e. 75 W/person (sensible) and 55 W/person (latent).

Table 4: Room occupant density.

Room	Occupant density	Daily profile	Occupancy
Circulation	Transient	-	-
Main museum area	5 m^2 / person	10:00 – 16:00[2]	100%
Office	10 m^2 / person	08:00 – 18:00[1]	100%
Plant rooms	-	-	-
Stores / cupboards	-	-	-
WCs	Transient	-	-

[1]Monday to Friday (excluding bank holidays). 25% occupancy at lunchtime (13:00 – 14:00).

[2] Tuesday to Saturday

Heating.

Heating systems
LTHW pump power densities are modelled as per NCM standard values for variable speed pumping.

Table 5: Heating systems.

Heating system	Details
Gas boiler	Heat source: Gas boiler – Generator efficiency: 90% (heating)
LTHW Radiators / radiant panels (Rads)	Heat source: Direct electric – Generator SCoP: 1.0

Heating set points
Table 6: Room heating set points.

Room	System	Set point	Profile	Set-back
Circulation	Rads	20°C	09:00 – 17:00 [1]	15°C
Office	Rads	20°C	09:00 – 17:00 [1]	15°C
Plant rooms	-	-	-	-
Store	-	-	-	-
WCs	Rads	20°C	09:00 – 17:00 [2]	15°C

[1]Tuesday to Saturday - 1-hour warm-up period.

Cooling.

Cooling systems
Table 7: Cooling systems.

Cooling system	Details
Cooled air units	Offices only - SEER: 3.50

Cooling set points
Table 8: Cooling set points.

Room	System	Set point	Profile	Set-back
Circulation	-	-	-	-
Office	Air Units	23°C [2]	08:00 – 18:00 [1]	28°C
F&B	-	-	-	-
Plant rooms	-	-	-	-
Reception	-	-	-	-
Store	-	-	-	-
WCs	-	-	-	-

[1]Tuesday to Saturday. 2 hour cool-down period.

[2]No humidity control assumed.

Lighting.
All lighting modelled as high efficiency LEDs with Light Output Ratio (LOR) of 0.95. Office areas benefit from daylight dimming. External lighting is modelled in accordance with the planning lighting strategy and is modelled to be on when dark.

Table 9: Room lighting schedule.

Room	Lighting efficacy (lm/W)	Design illuminance (lux)	Profile	Utilisation factor
Display lighting	30	100	10:00 – 16:00 [1]	90% (3)
General lighting	60	400	08:00 – 18:00 1	82%(2,4)

[1]Tuesday to Saturdays.

Lighting controls have been assumed to be manual in all cases, i.e. no presence detection.

Mechanical ventilation.
It is understood that there is currently no mechanical ventilation provided in occupied areas of the building.

Infiltration
In addition to the above mechanical systems, air changes due to infiltration are outlined below. A higher infiltration rate for the reception has been assumed to account for door openings during operating periods.

Table 10: Infiltration rates.

Building zone	Details	Profile
Whole building	0.55 ach [1]	24/7

1. From CIBSA Guide A, corresponds to air permeability of 15 $m^3/m^2/h$ at 50 Pa.

Lifts.
Lift energy demand is estimated based on an assumed typical lift installation.

Table 11: Lift schedule.

Lifts	Profile
2 x 4kW passenger lift. Standby power: 52W Lift duty: Low (<100 starts/day)	24/7

1. Tuesday to Saturday.

Domestic hot water.
Domestic hot water for handwashing and cleaners cupboards are provided by gas boiler and point of use units.

Table 12: Domestic hot water usage assumptions.

Hot water end-use	Details	Description
Handwashing	3 l/person/day	– CIBSE Guide G guidance for hot water usage in office buildings. – Delivery efficiency: 95%
Cleaning	10 buckets / day	– Assumed 10 x 10 litre buckets per day (Mon-Fri).

Small power & equipment.
Office small power loads are estimated at 120 W/desk in accordance with the BCO report: Small Power Use in Offices (2009). The table below summarises the assumed appliance loads and resultant diversified peak load per appliance.

Equipment energy use for ground floor F&B as per the NCM standard usage for retail eating and dining areas.

Table 13: Small power appliance schedule.

Room	Appliance	Qty	Profile	Average load
Office	Desk equipment	8 m^2 / desk	09:00 - 17:00 [1]	120 W / desk
Office	Photocopier	1 / floor	09:00 - 17:00 [1]	220 W
Office	Fridge freezer	1 / floor	09:00 - 17:00 [1]	120 W
Office	Coffee machine	1 / floor	09:00 - 17:00 [1]	350 W
F&B	NCM Part L templates			

1. Tuesday to Saturday

2.2 Existing building performance.

Once modelled, the energy profile of the building could be better understood to see where areas of focus could be made.

As seen in Figure 5, the building is non-thermally led with greatest demand arising from lighting and unregulated demands. For the purpose of this assessment, measures have been considered that relate to regulated demands only, i.e. space heating, hot water, fixed lighting, fans & pumps and cooling.

Unregulated demands are linked to small power and equipment, e.g. IT equipment, non-fixed lighting and lift use, which is linked to specification and/or procurement of the building operator rather than design interventions. Although these elements were not considered within this assessment, it is recommended that when equipment is to be procured or replaced, energy efficiency is considered to ensure demand is limited.

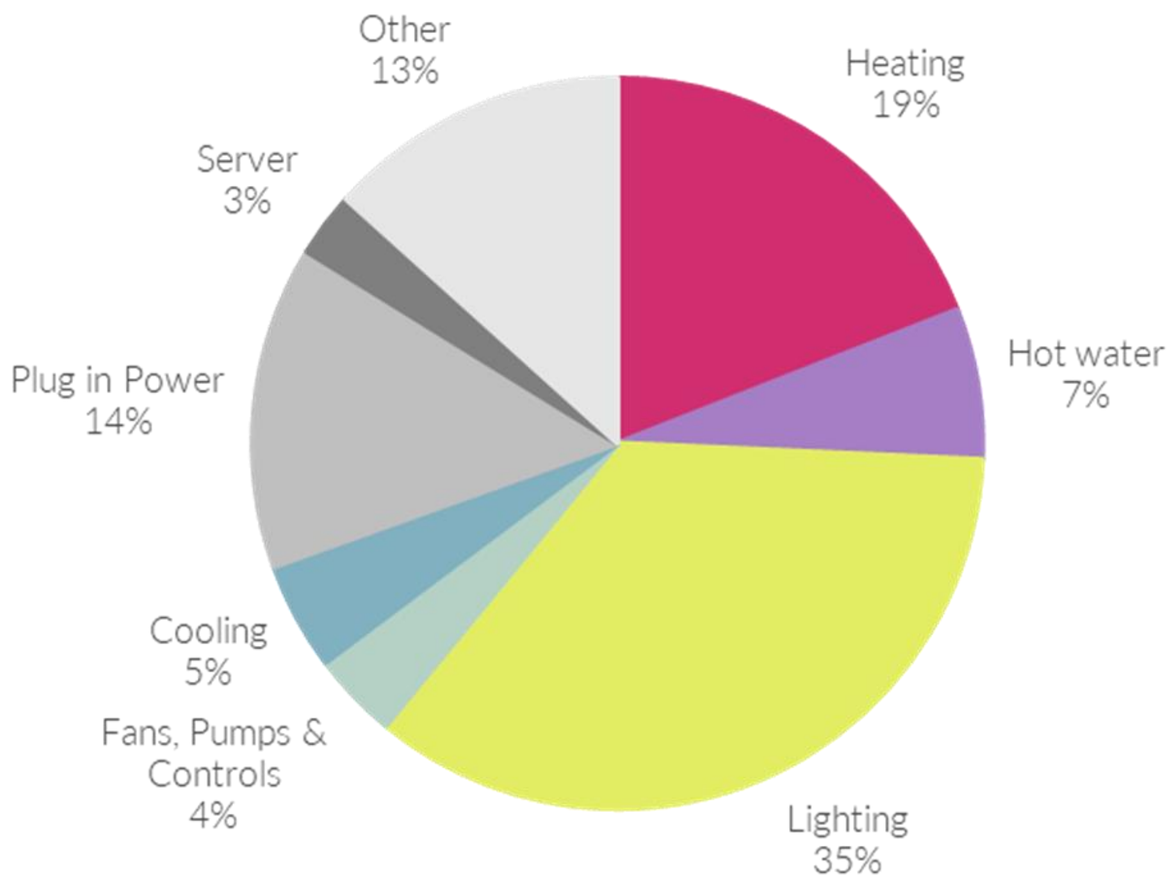

Figure 5: Energy demand by end use.

2.3 Measures assessed.

Table 14 outlines the measures that were considered within the assessment following a review of the existing building performance, recommendations from the site survey and discussions with the Museum.

These measures were grouped into three categories:

2. Works in progress – Funding allocated and being implemented.
3. Planned (not confirmed) – Funding to be released to enable implementation.
4. Additional – Measures recommended by Hoare Lea for consideration.

Table 14: Measures assessed.

Works in progress	Planned (not confirmed)	Additional
– Lighting upgrade (2023/24) – Roof replacement & upgrade (2024/25)	– PV installation – Upgrade to Galleries and back of house (BOH)	– Electrification of thermal demand – Improvement to building fabric* – Replacement of water fittings to reduce water consumption.

*Discounted due to feasibility (see separate section).

Modelling inputs for measures

Measure	Model input/specification
Lighting upgrade	General lighting - Increased lighting efficacy to 80 lm/W Display lighting – Increased lighting efficacy to 60 lm/W No change to lighting controls
Roof replacement/upgrade	Roof U-value 0.16 W/m^{2}K (insulation thickness: 200mm, insulation conductivity 0.02 W/mK) Flat Roof U-value 0.18 W/m^{2}K
PV installation	Roof area: 560m^2 Panel efficiency: 130 kWh/m^2 Panel power output: 450W Pitch: 30-45° Orientation: West/East
Upgrade to Galleries and BOH	Not modelled as separate iteration. Considered in "Additional" measures
Electrification of thermal demand	Replace gas boiler with ASHP Heating efficiency: 300% Hot water efficiency: 300% All other controls and parameters as per existing.
Building fabric upgrade (additional to roof upgrade)	Walls U-value: 0.30 W/m^{2}K Heat loss floors U-value: 0.20 W/m^{2}K Window U-value: 2.0 W/m^{2}K (secondary glazing) Air permeability: 8 m^3/m^2.hr @50Pa

Measure	Model input/specification
Sanitary fitting replacement*	WC: 4 litres/flush Wash hand basin taps: 4 litres/minute Kitchen taps: 6 litres/minute Dishwasher: 13 litres/cycle

*Not all fittings would impact the energy demand of the building (e.g. WCs) however would reduce water consumption which should be considered as a separate environmental impact.

Fabric improvement - Discounted
Following discussions with the Museum team and considering the Listed status of the building, the fabric improvement measure was discounted from the assessment. Justification for this is provided below.

Internal insulation to external walls
Would require significant internal insulation to achieve target U-values that can be very intrusive and require elements of the museum to be out of operation for large periods of time. External insulation would not be feasible due to listed status.

Insulation to heat loss floors
Can be very intrusive and difficult to achieve in existing buildings. May only be achieved in certain areas of the building (e.g. basement). Given building massing, it is not anticipated that significant savings would be achieved if perused.

Replacement of windows or installation of secondary glazing
Products are available that meet heritage requirements that are double glazed which would significantly improve the existing performance. however, this would require elements of the museum to be out of operation for large periods of time and can incur a substantial CAPEX to implement. A less intrusive option would be to install secondary glazing to the existing units. However, this would only be appropriate in areas where windows are not openable and have an internal recess to allow the additional frames to be fitted. This option would also need to be approved by a Heritage Officer before implemented.

Improvement of air permeability
This parameter is dependant on other improvements to the fabric to be undertaken to reduce infiltration through the fabric.

2.4 Energy savings.

For each measure, the model was updated iteratively to demonstrate the potential savings that could be achieved. These are presented in Table 15.

Table 15: Proposed energy savings.

Category	Measure	Predicted energy saving (kWh/yr)	Saving compared to BAU (%)
Existing performance		421,671	
In progress	Lighting upgrade	14,995	4%
	Roof replacement/upgrade	2,453	1%
Planned (not confirmed)	PV installation	72,800	17%
Additional	Electrification of thermal demand	225,187	61%
	Sanitary fitting replacement	2,735	1%

2.5 OPEX savings.

To present the potential operational cost (OPEX) savings per year based on Table 15, fuel prices of 6.04p/kWh and 28.6 p/kWh have been used.

Although the energy savings from replacement of the gas boiler with ASHP demonstrates the highest energy saving (~61%), due to the cost of electricity being over four times greater than that of gas, it is anticipated that the OPEX for that measure would increase. However, this could be offset through the installation of PV if the energy generated is used on site.

Table 16: Indicative OPEX.

Category	Measure	Gas OPEX	Electricity OPEX	Total	Reduction
Existing performance		£22,324	£14,890	£37,214	-
In progress	Lighting upgrade	£22,324	£10,601	£32,925	12%
	Roof replacement/upgrade	£22,176	£14,890	£37,066	>1%
Planned (not confirmed)	PV installation*	£22,324	-5,931	£16,393	56%
Additional	Electrification of thermal demand	£0	£46,602	£46,602	-25%
	Sanitary fitting replacement	£22,159	£14,890	£37,049	>1%

*Assumed that electricity generated is used on site

2.6 Carbon savings.

Using the results presented in Table 15, the predicted annual carbon savings have been determined. These are presented in Table 17.

Table 17: Proposed carbon savings.

Category	Measure	Predicated carbon emissions savings ($kgCO_2$/yr)	Saving compared to BAU (%)
Existing performance		58,941	
In progress	Lighting upgrade	56,845	4%
	Roof replacement/upgrade	58,598	1%
Planned (not confirmed)	PV installation	46,326	21%
Additional	Electrification of thermal demand	22,776	61%
	Sanitary fitting replacement	58,559	1%

2.7 Carbon trajectory.

In the same approach used to determine the BAU carbon trajectory, the savings have been grouped into the three categories of “In progress”, “Planned (not confirmed)” and “Additional”. These have been presented against the BAU trajectory up to 2050 in Figure 7 overleaf.

This trajectory has been developed based on the following indicative or agreed timescales for the proposed measures to be implemented, dictating when the indicative savings would be realised.

Table 18: Proposed implementation timescales.

Category	Measure	Year of implementation/ completion
In progress	Lighting upgrade	2024
	Roof replacement/upgrade	2024
Planned (not confirmed)	PV installation	2024
Additional	Electrification of thermal demand	2025
	Sanitary fitting replacement	2025

It is anticipated, based on the FES carbon intensity trajectories (Steady Progression) and the predicted savings, that by the year 2030 the Museum would not reach carbon neutral in operation through any of the three scenarios. However, if all measures were implemented carbon emissions would be reduced to ~8tCO_2 compared to the BAU of ~35tCO_2.

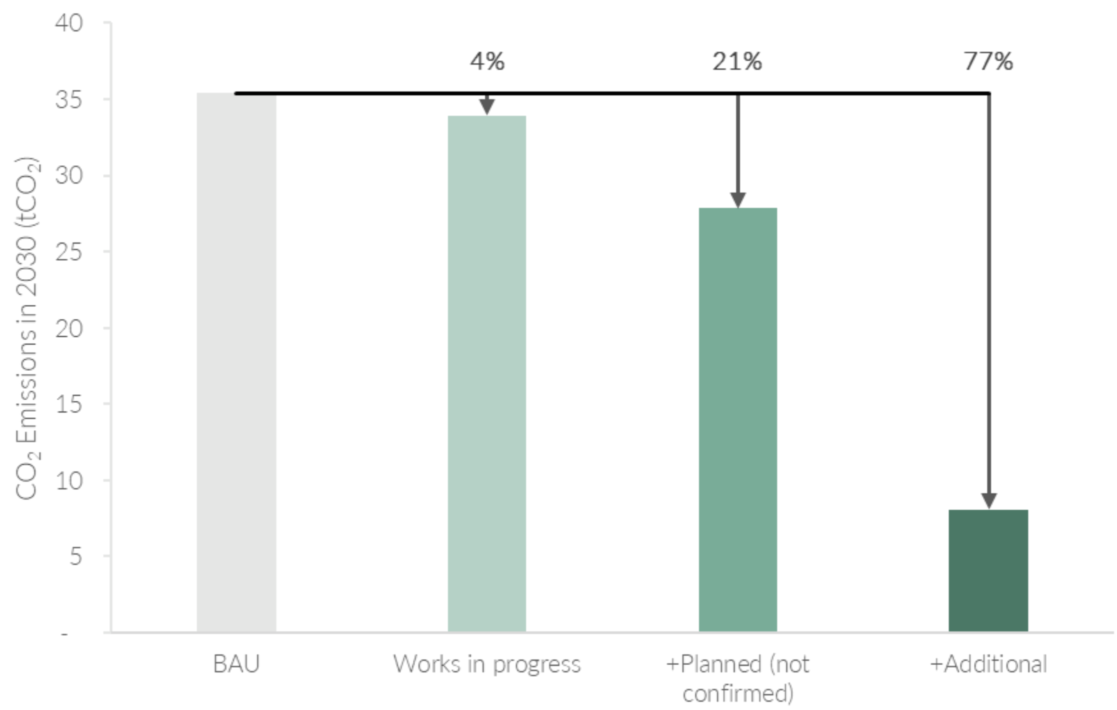

Figure 6: Predicated carbon emissions in 2030.

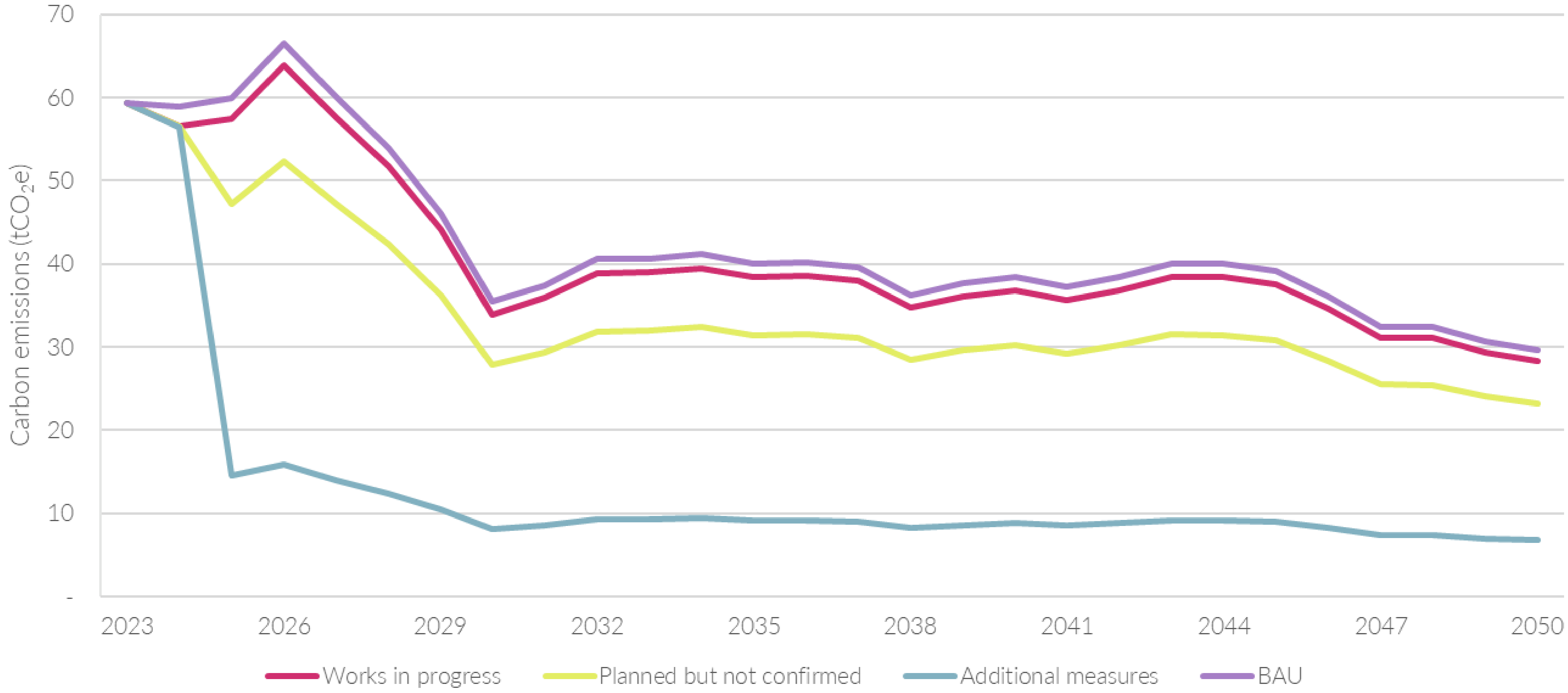

Figure 7: Predicated carbon trajectory.

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