Sustainable Collections Environments

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Abstract

English Heritage has undertaken several sustainability campaigns and initiatives that involve specific measurements. Research has developed and validated a series of tools to predict showcase carbon usage. Embedded carbon has been calculated for showcases. Measuring carbon usage for wet (hot water) heating systems can be complex when separating environmental control from areas in other usage, with surface temperature monitoring of radiators being used. Two exercises have been carried out to assess and remove unnecessary environmental control equipment. An important gap in existing knowledge is the carbon footprint of interventive conservation treatments. A standardised program is underway to collect such information for paintings conservation.

Keywords

Climate control, Energy, Showcases, Silica gel, Interventive treatment.

Introduction

In the early 90's there was a growing understanding of unsustainable costs of conditioning systems. This preceded the green thinking that is much more widely accepted today. Energy efficiency research and measures were introduced into the British Museum at that time.

There are several different measures now used for sustainability. Energy cost is the oldest. Carbon usage simply converts the energy units using standard conversion factors. Many institutions now publish data including the carbon usage. Although, many countries publish this data per area of building, which can be misleading with non-uniform height, which is common for historic buildings.

Embedded or stored carbon is fairly straightforward to calculate and uses mass and average table values for common materials. Carbon footprint or lifecycle greenhouse gas emission are much more complex and requires several decisions to be made regarding splitting costs and offsetting. Standards such as ISO 14072, 14040, 14044 and BS PAS 2050 do exist (ISO, 2006a and b, 2014BSI 2011). Wider environmental impact assessments or life cycle assessments, LCAs consider all resources used and waste generated. It is essential to be aware of exactly how figures are calculated, if they are to be compared. Evaluating these within an institution using the same method will give valid indications of improvements. However, when undertaking such an exercise, the question generally arises: how do our calculations compare to other similar institutions? To answer this question, understanding the different methods used can be critical.

This paper will consider data generated for environmental control for collections in English Heritage. If preventive conservation is inadequate, objects will accrue damage. Conservation and cultural heritage ethics will ensure these objects are then conserved. This situation differs from many industrial life cycle greenhouse gas assessments. The life cycle greenhouse gas emissions of interventive conservation treatments are generally not known. Although the field is actively working on developing LCAs for interventive treatments, the author could not find any published data, beyond a blog reporting an assessment for silver. Monitoring for paintings conservation is underway within English Heritage.

English Heritage has now established a cross departmental Sustainability Board and overall policy. Individual strategies are being developed.

Object Requirements

The exact tolerance of objects to environment can have a great effect on the conditioning required and hence, sustainability. Most historic houses have never met the tight RH and temperature bands used in some museums. Despite this, many collections survive very well in these conditions. For many aged and especially archaeological materials, the scientific underpinning for their response to the environment is weak (Thickett & Lankester, 2012). A sampled audit of the entire English Heritage collection of approximately 500,000 objects, indicated those materials that were most damaged (Xavier-Rowe & Fry, 2011). Research has been prioritised to these materials. For archaeological iron, the most damaged material, research has concluded, considering curatorial value and resources and risk, that 16% RH is a suitable value to keep stored collections below and 30% is suitable for displayed collections. The lower RH is certainly possible in display situations with careful design, and English Heritage has built showcases that achieve this, but this is much more resource intensive. Most preventive conservation is based on common conditions for materials groups, i.e. keeping archaeological iron below 16%. It is clear that archaeological iron, as well as several other materials, has great differences in reactivity towards the environment (Thickett, 2012). If methods can be found to determine the stable and more reactive objects, then the preventive conservation can be tailored to the objects, saving resources (Thickett, Csefalvayova, & Strlič, 2011). For archaeological iron and copper alloy objects in collections (not freshly excavated), oxygen depletion testing will identify those objects requiring dry display and those that can safely withstand RH values up to 70%. This can have significant resource-saving capabilities, see examples in Table 1, later.

Showcases

It is significantly more effective and efficient to condition the small volume of showcases than condition an entire room. For rooms, public access especially in high numbers, limits room air tightness and directly effects the humidity and temperature of that space. This massively increases the capacity and energy needed to condition a space, compared to a showcase of similar volume.

Passive control can be readily modelled in most situations. Given the air exchange rate of the showcase, its volume, type and amount of sorbent, and a years' worth of room RH data, the internal RH can be accurately predicted to sufficient precision for most uses (Thickett, 2018). With a known control band (and data on initial dried silica gel RH), the lifetime between changes for cases can be determined within 5%. The calculations have been extensively validated with real data from over 80 showcases. This data can be used to help calculate carbon footprint. English Heritage has sites with conditioned cases spread over England and 5 sites with ovens to dry silica gel. The carbon footprint for maintaining the environment within the showcases has been calculated, partial results and the totals are shown in Table 1. There are over 30 sites and only partial results were shown for brevity. The distance between the site and the nearest store with a silica gel drying oven is calculated and the number of round trips per year calculated using the spreadsheet. The total mileage was converted to carbon dioxide equivalent. This initially used New European Drive Cycle (NEDC) data for the exact car model used. The second set of data (corrected carbon footprint) used World Harmonised Light vehicle Test Procedure (WLTP) data. The energy and carbon dioxide footprint of the silica gel and its drying were assessed and considered insignificant compared to the other sources. For new showcases the embedded carbon was calculated using mass of steel, laminated glass and MDF (used in plinths only), from manufacturers showcase drawings or 3D models.

Table 1 – SITES

	Year installed	Number of showcases	Total mass glass	Total mass steel	Total mass MDF (plinths only)	Showcase Embedded Carbon (kg)	Mass of dry silica gel	Distance (miles)	Visits per year	Person days/year	Carbon footprint (kg over 20years)	Corrected Carbon footprint (kg over 20years)
Battle Abbey	1990s	6	-	-	-		300	122	3	6	586	1333
Cleeve Abbey	1970s	3	-	-	-		80	322	3	6	1786	4063
Chesters Roman Town	1970s	21	-	-	-		350	172	2	4	510	1092
Pendennis Castle	1980s	2	-	-	-		30	602	2	2	1410	3208
Pevensey Castle	1970s	2	-	-	-		40	624	2	4	2490	5665
Portchester Castle	1980s	7	-	-	-		80	160	2	4	2490	5665
St Augustines Abbey	2000	4	-	-	-		130	144	2	8	490	1115
SUM SHOWN		48								36	10400	23592
TOTAL ESTATE		261									61366	139206
Battle Abbey	2018	6	65	18	21	425	22	122	1	1	-	356
Cleeve Abbey	-	3	-	-	-		0	322	1	1	-	938
Chester Roman Town	2009	11	121	38	28	648		172	1	1	-	502
Pendennis Castle	-	2	-	-	-		0	602	1	1	-	1754
Pevensey Castle	2003	2	25	10	8	174	40	624	1	1	-	1818
Portchester Castle	2003	4	50	20	15	349	66	160	1	1	-	466
St Augustines Abbey	2013	4	132	51	-	886		144	1	2	-	420
SUM SHOWN		35								9		8129
TOTAL ESTATE		274										68352

Figures have been calculated over twenty years. Only one set of showcases was replaced after a shorter period and perhaps thirty years would be a better horizon.

Two of the sites shown, Cleeve Abbey and Pendennis Castle, were not updated. The archaeological iron and copper alloy objects present were oxygen depletion tested and found to be stable. Hence, silica gel changes stopped from that point. There is still one visit per year from Conservation to check the objects.

The car emission data was taken from standard published tables for car models using New European Drive Cycle (NEDC). Since the vehicle emissions scandal, this data will need revisiting, but accurate data is not yet fully available. The more accurate World Harmonised Light vehicle Test Procedure data (WLTP) is becoming available, but not yet universally so. Data has been included in the second half of Table A using the Ford Focus model most commonly supplied by English Heritage's car hire supplier. The corrected values in the column show how significant the underestimate was. With new UK regulations about to come into force, all car hire mileage for the organisation will now be published. The lifetime calculation for dry silica gel is available as a spreadsheet on English Heritage's website along with instructions for its use (English Heritage).

Since 2003 English Heritage has run a program reinvigorating its displays, which often provides the opportunity to replace older, poorly performing, showcases with ones with much better air exchange rates. Methods to specify, tender, check and refit showcases to achieve the required air exchange rate have been developed. Carbon footprint calculations are now undertaken for every such project and feed into the decision making processes. Embedded carbon can be readily calculated for new showcases and results are included in Table 1 for the replacement cases installed. The figures for steel, laminated glass and MDF were taken from VTT Research (Ruuska, 2013). Of course, this is only an average figure and the intensive processing of many showcases may introduce much larger figures. Only the manufacturers are in a position to undertake the first part of a life cycle assessment. No such assessment has yet been published. At least one manufacturer offers some carbon offsetting for their showcases, but the figures do not come from a full assessment.

Passive systems sometimes cannot cope with large demands caused by aggressive environments and mechanical system with much greater capacity are useful in this instance. The demand for mechanical dehumidification can be calculated from the room RH and temperature, the case maximum RH and the air exchange rate, by calculating the amount of water vapour ingressing. If performance tables are available for the particular dehumidifier, then its run time and hence, energy usage can be calculated. This method has been validated for Munters MG50 and 90 dehumidifiers in several showcases and situations (Thickett, 2018). Many commercial dehumidifiers have excessive capacity for most showcases and frequently only run for a very short total time (0.5-6days) in a year. It can also be possible to use the output from a single dehumidifier to control several showcases, if trunking is possible. If the cases are similar in size and air exchange rate and have similar RH requirements, any of these cases can be have the single controller that activates and turns off the dehumidifier.

At the Swiss Cottage Museum, Osborne House four showcases each use six Munters MG50 dehumidifiers to maintain an environment below 65% RH. The dehumidifiers run off a Meaco humidistatic controller placed in the highest air exchange rate case of the four controlled. Dehumidified air is circulated using a Miniclima four way splitting box and 40mm hoses. Figure 1 shows the performance of four showcases. Previously, four MG 50 dehumidifiers were running into the single room. The annual energy usage for this was 7708kWhrs (the building has separate metering). The previous system performed poorly environmentally with summer RHs regularly in excess of 80%, and mould growing in several showcases. With the dehumidifiers feeding into the cases, the energy usage has dropped to 464kWhrs, a 94% reduction. The environment is much improved as shown in Figures 1 and 2.

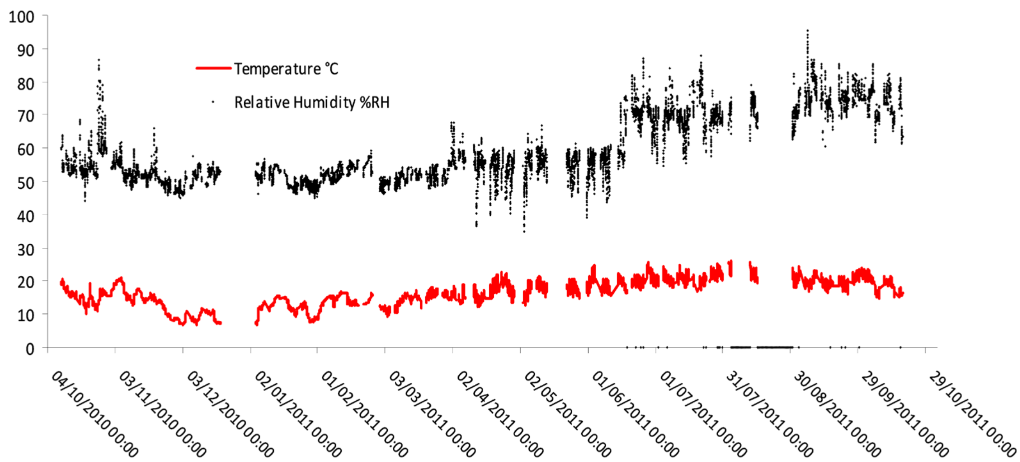

Figure 1 – Four months environmental data from four cases controlled with dehumidifier feeding into cases.

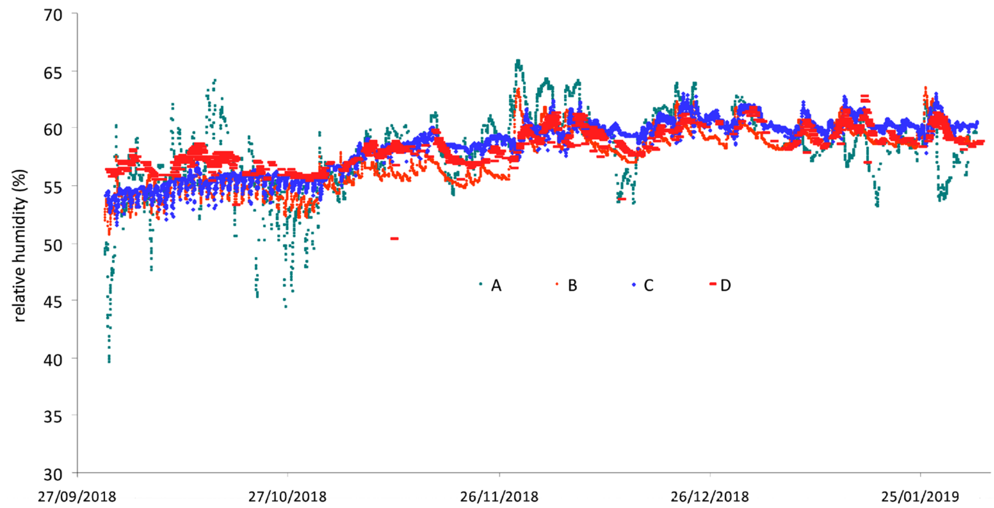

Figure 2 – Room environment at Swiss Cottage Museum with initial dehumidifier arrangement.

If very different sizes or air exchange rate cases are to be controlled, it may be necessary to use a more sophisticated control system. This can be done by taking the RH from all cases and using a logic tree to activate and turn off the dehumidifier. It may be necessary to add sorbent to some of these cases if materials sensitive to very low RH are present.

A number of small units, that can both dehumidify and humidify are now available for showcases. The manufacturers do not provide any data on the temperature effects on performance or efficiency. Extensive testing of performance of Miniclima, RK2 and MiniOne units has been undertaken at English Heritage to determine which units are suitable in which conditions. All units have relatively large humidification capacity, but limited dehumidification capacity, due to the use of peltier coolers. This particularly affects performance at higher temperatures. Energy use had been measured in 14 instances. However, the data is not thought to be comprehensive enough to draw general conclusions.

Room Conditioning

Significantly higher amounts of energy and larger equipment is required to condition RH, temperature and pollution in rooms, especially rooms accessible to the public. Understanding the exact tolerances of collections to environment can have very dramatic impacts. There is still disagreement within the conservation profession about tolerable limits, especially regarding temperature and RH (IIC, 2010). Pollution is rarely discussed, but can have dramatic impact on some collections. Silver tarnish is relatively insensitive to RH, but massively accelerated by hydrogen sulfide and carbonyl sulfide gases and dust (Kim & Payer, 1999, Thickett & Costa, 2014). In historic buildings many collections have been outside of the 'accepted' museum limits for RH and temperature for many decades, frequently their whole lifetime. The nature of historic buildings, and limitations on changes imposed by legislation and the New Orleans Charter, frequently mean they have higher air exchange rates. Many historic houses use conservation or humidistatic heating. In the UK, temperatures often drop below 10C over winter and in summer a maximum temperature setting generally means the room RHs rise with the seasonal trend. This generally means at least 65% and frequently 70 or 75%. Representative data is shown in Figure 3.

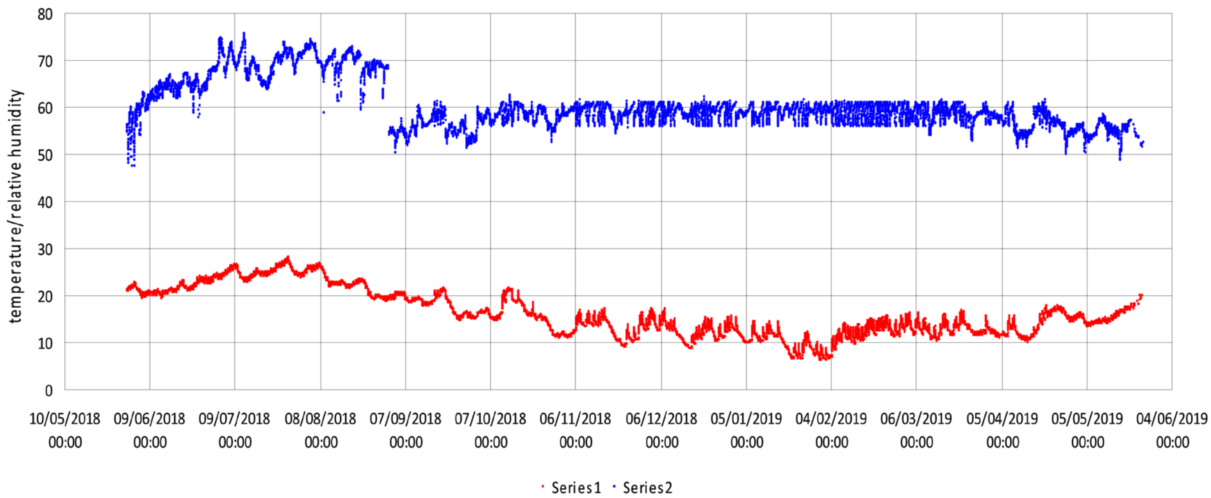

Figure 3 – Room T and RH with conservation heating.

Despite this, many collections seem to survive well. There is also increasing evidence, from scientific analyses of actual object responses in their environments, that many objects can safely tolerate very wide temperature and quite wide RH bands. Rigid constrained organic objects, such as furniture, are amongst the most susceptible to RH fluctuations. They do acclimatise to their climate, which has been recognised with the European standard EN 15787 (BSI, 2010).

Several authors have commented on the inequitable use of loan conditions, with institutions specifying very tight climate bands for inert objects such as ceramics or much tighter bands than they keep the objects in (Ashley-Smith, Umney, & Ford, 1994).

Predicting the energy cost of room conditioning is much more complex than showcases. Depending on the building, there can be significant thermal gain, evaporation or sorbent surfaces. The air exchange rate generally varies much more due to;

- Wind velocity on the building envelope
- Thermal gain
- Differences behaviour during open and closed times or periods.

Measurement can also be more complex, as many buildings are only metered at the building and not individual room level.

For many rooms with collections on open display, better controls have both improved environmental performance and reduced energy consumption. Wall mounted HVAC sensors can read the RH very differently from the room value (Thickett, Luxford, & Lankester, 2013). Interfacing the high quality Meaco radio-telemetry sensors with Building Management Systems allows better conditions near the objects. Thorough calibration is required. Conservation heating uses, on average, about a third of the energy of comfort heating. Electric radiators react more quickly than wet systems and, depending on the environment, this can have a significant effect (Thickett, 2020, IN PRESS).

Local metering provides ready data for electrical systems, but wet systems generally use a central boiler to heat many rooms. Some contain collections, others are commercial or administrative spaces. Within such buildings, the question arises: how much of the total energy (which is generally measured from fuel useage) is used for conditioning the environment for the collections? A development project at Brodsworth Hall, Yorkshire, elicited such a discussion. The wet heating system services 65 rooms, 40 with collections. Valves are controlled from a building management system collecting data from one temperature/RH sensor per four adjacent rooms. To estimate the proportion of the energy consumed by the rooms with collections, surface temperatures of the radiators were measured with platinum surface temperature probes on ACR SR002 data loggers. The average temperature of the radiators multiplied by their surface areas was used to calculate the ratio of collections to other rooms. The collections environmental control was found to consume 16% of the energy used for wet heating for the whole building. The performance of a variety of control systems in historic buildings has also been assessed (Thickett, 2020, IN PRESS).

Two exercises have been carried out within English Heritage to assess the requirement for existing environmental control equipment in rooms and in showcases. For showcases, air exchange rates were measured, calculations undertaken and for archaeological iron and copper alloy oxygen depletion testing was carried out. Several dehumidifiers were removed and silica gel reconditioning was halted in several showcases. The silica gel was left in place and not replaced, with dry gel annually or more frequently. As discussed previously, room predictions are inherently more uncertain. Several humidifiers were removed where the room RH did not drop below a safe level and no water was being used by the equipment for over two years. The HVAC system in the Waterloo Gallery at Apsley House was modified to run as a pollutant filtration and humidistatic heating system, only with no cooling or dehumidification. This has saved significant amounts of energy across the estate, with figures presently being collated.

Carbon Footprint for Interventive Conservation

Within heritage institutions, a balance has to be made between resources for preventive conservation and interventive conservation. Many institutions have developed methods to predict the amount, and hence financial cost of interventive conservation, should sufficient preventive conservation not be undertaken. If a preventive conservation measure performs inadequately, the objects will accrue damage. When considering the sustainability of the environmental control aspects of preventive conservation and potential gains from undertaking less environmental control, it is important to consider the potential increased need for interventive conservation. From a sustainability point of view, this is very difficult, as no carbon footprints or life cycle assessments have been published for treatments. However, if an object is damaged it will very likely be conserved.

In 2003 and 2009 major mould outbreaks occurred in the chalk Secret Wartime Tunnels under Dover Castle. In the first instance, the ventilation had been turned off due to unfortunate external advice. The second instance occurred as a system failure was not rectified promptly. For the second instance over 2700 objects were evacuated and a very large proportion required treatment of the large amounts of both mould and corrosion that had occurred. The carbon footprint of the travel and materials (including significant amounts of replacement structural steelwork for the tunnels themselves, which had dangerously corroded due to the very high RH values) for staff and contractors to remediate the damage was well in excess of 203 $teqCO_2$. To prevent further outbreaks, a dehumidifier was placed into the tunnels using existing trunking. The embedded carbon was 82$teqCO_2$ (the supplier had a carbon footprint for manufacture available and the transport was calculated) and the carbon dioxide equivalent per annum 6.2 $teqCO_2$ from the metered electricity used. The partial greenhouse gas equivalent of the interventive conservation was equivalent to over 15 years of dehumidifier operation.

English Heritage's collection and the organisations' needs have meant only paintings conservation is available in house within the English Heritage Trust. An assessment to PAS 2050 is being undertaken to monitor the lifecycle greenhouse gas emissions for different treatments. This will include;

Emissions from transport of paintings between site and conservation studio.

Embedded carbon for the chemicals used.

Heating, cooling, humidification, dehumidification and exhaust ventilation for the conservation studio.

Electricity use for lining table, heated spatulas, motorised easels, inspection lighting, etc.

Greenhouse gas emission from any non recyclable waste.

Greenhouse gas emissions from recycling processes.

Following PAS 2050 it will exclude transport of employees to and from their normal place of work. Other institutions are also actively working on similar assessments.

Conclusions

It is now widely accepted that we need to be sustainably conscious when considering providing environments for our cultural heritage collections. The sustainability aspects of environmental control have been amongst the first to be considered in the heritage field. Understanding the methodology used, is essential to allow inter-comparison or collating of results. Methods have been developed and tested for showcase environments and some movement has been made towards the lifecycle costs of showcases. Full figures will not be available until the manufacturers undertake assessments. For rooms, sub-metering and allocation of energy from mixed use systems is required. Unlike many situations, the life cycle cost of remedial treatment needs to be included in assessments of environmental control cost scenarios. The ethics of heritage would dictate such treatment be carried out to at least stabilise objects after environmental damage.

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Authors' *Curriculum Vitae*

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