How to Calculate the Carbon Footprint of a Painting Conservation Treatment at English Heritage

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Abstract

English Heritage (EH) manages 400 historic sites in England and cares for half a million objects ranging from pieces of archaeological bone to a Rembrandt self-portrait. Easel and wall paintings, gilded frames and gilded furniture are cared for by two Fine Art Conservators who carry out interventive treatments to objects based on conservation need. Conservation Treatments of other object types are managed by Preventive Conservators and conserved in private conservation studios. Economic and environmental sustainability are important factors in the Conservation Team's work.

In 2021 the Fine Art Conservator implemented a simple method to measure the carbon footprint of an easel painting conservation treatment, including monitoring energy use, materials, object transport and staff travel. This paper was written by conservator and conservation scientist using widely available tools and resources, without the help of a specialist sustainability expert. It represents a walk-through of the steps lay persons could take to replicate the study.

This paper will focus on methodology and a single case study. Overall results of the research will be published separately.

Keywords: English Heritage, Energy monitoring, Interventive conservation treatment, Carbon Footprint, Life cycle assessment.

Introduction:

The risk to cultural heritage from climate change has been established. (Lafrenz Samuels, Platts 2022; Pearson 2013; Lankester 2013). Therefore, awareness of carbon usage and carbon reduction programmes which aim to limit climate change should be of key interest to conservators seeking to protect cultural heritage. English Heritage has set a sustainability goal to reach net zero by 2040. This is a voluntary commitment because it is not yet mandatory for companies and organisations to reduce their carbon footprint. However, since 2013 large British organisations are obliged report their carbon emissions via the GHG protocol (DEFRA 2019)[1]. This helps companies to think about the carbon impact of their work in terms of a carbon currency or budget. ISO 14040 and 14044 provide guidelines and requirements for conducting a Life Cycle Assessment and British Standard PAS 2050:2011 provides specifications on how to conduct a life cycle emissions assessment,

[1] Since 1 October 2013 the Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013 has required all UK quoted companies to report on their greenhouse gas emissions as part of their annual Directors' Report. From 1 April 2019, quoted companies must report on their global energy use and large businesses must disclose their UK annual energy use and greenhouse gas emissions. This is required by the Companies (Directors' Report) and Limited Liability Partnerships (Energy and Carbon Report) Regulations 2018. The government encourages all other companies to report similarly, although this remains voluntary.

however these standards do not provide detailed methodology on how to do it (ISO 14040; ISO14044; BSI:2011).

The field of Cultural Heritage is also lacking a detailed standardised method for calculating Carbon Footprints and Life Cycle Assessments (LCAs). This exists for other fields such as Buildings and Architecture (RICS 2017). Whilst a conservation project generally uses far fewer resources and materials than a building project, it is worthwhile considering a conservation project in the same way because we need to reduce carbon in all fields. A *Carbon Footprint* measures the amount of carbon dioxide released into the atmosphere as a result of the activities of a particular individual, organization, or community. Meanwhile, a *Life Cycle Assessment* measures the environmental impact associated with the life cycle of a product, process, or service. LCAs take into account greenhouse gas emissions (the carbon footprint) as well as other impacts such as land use, water use, ocean acidification. It uses carbon emissions data and other factors like data on waste generation, toxicity (to humans and ecosystems), air and water quality and the effect on biodiversity. It can also be expanded to social issues like trafficking and supply chain. This is often difficult because data is lacking or supply chains are opaque, so people tend to focus on Carbon Emissions (a carbon footprint). This paper calculates the carbon footprint, not an LCA.

A conservation treatment constitutes an *activity, process or service* and different ways to undertake a carbon footprint were investigated. Several ways of carbon foot-printing cultural heritage activities have already been developed in the field. They use slightly different methodology for measuring (Lambert and Henderson 2011, Nunberg et al. 2016, Sanchez 2013, Sustainability Tools in Cultural Heritage (STiTCH) 2021, Julies Bicycle 2007, Gallery Climate Coalition (GCC) 2023). Results differ depending on how granular the data and methods are. STiTCH developed a carbon calculator tool to calculate the carbon footprint of conservation materials, although it is still in development and it is accurate for use in the USA, rather than in the UK where the current study was performed. The method described in this paper attempts to define the energy use and materials impacts for Scope 1 (direct emissions from owned or controlled sources), Scope 2, (indirect emissions from purchase of electricity for heating/cooling etc..) and Scope 3 (all other indirect emissions within a company's value chain including staff travel, procurement, waste).[2] There were shortcomings in the methodology and gaps in the data which will be expanded on in the discussion section.

English Heritage is monitoring its scope 1 and 2 emissions and is starting to monitor its Scope 3 emissions to gather data on staff travel and suppliers. It is aiming to reduce its

[2] Therefore, this method does not follow PAS 2050:2011 which excludes the transport of employees to and from their normal workplace. Transport was included as it represented something conservators had some control to change.

emissions through its organisational Climate Action Plan. In addition, a new combined equality and environmental impact assessment is being developed for use across all new projects. There is a presumption in favour of re-use of existing buildings and a developing appreciation of embodied carbon with major new projects now integrating life cycle assessment. English Heritage have a net zero target of 2040 with an interim target of 20% reduction in building carbon footprint by 2025 and 60% by 2035. This is being delivered through the Building Carbon Reduction programme.

A comprehensive carbon footprint is challenging, requires attention to detail and an in-depth understanding of all the issues involved which is why it is usually undertaken by specialists. The purpose of this study was to create a straightforward way for conservators to monitor their professional carbon footprint, without the help of sustainability or LCA specialists. Using a conservation treatment as a case study, it introduces conservators to the carbon calculators and other tools available.

Given the urgency of the climate crisis, making an accessible study like this, sometimes without the full figures or expertise, was deemed useful by the authors, to help conservators move towards sustainable thinking, realise their carbon impact and encourage them to consider sustainable choices in every aspect of their work. Like other professionals, conservators need to shift towards thinking about carbon alongside all the other values they usually weigh up when making decisions.

Previous research at English Heritage has sought to measure the carbon footprint of manufacturing, installing and maintaining showcases for historic objects, a key preventive action undertaken by the team (Thickett 2019). For some sites, data had also been generated on the amount of energy required for "conservation heating" (a means of controlling relative humidity through low level heating) but there was no system for monitoring the carbon cost of undertaking other types of preventive or interventive conservation measures (Thickett 2020). However, no methodology existed at English Heritage for measuring the carbon footprint of other processes.

In early 2021 English Heritage benefitted from a government grant to renovate its Collections Conservation Studio and Conservation Science Laboratory, however this did not include major upgrades to the environmental performance of the buildings. It was decided to measure the energy use of the studio to inform future upgrades and to start measuring the carbon footprint of conservation treatments to enable staff to make smarter materials choices and work towards reducing carbon costs in the future.

Materials and Methodology

Painting Treatment

A small 17th century panel painting by Adrien Ostade (450 x 377 mm) was already in-programme and was chosen for this study because it was a simple treatment which would yield quick results due to its small size. The painting required surface cleaning using cotton swabs and water, varnish removal using cotton swabs and solvents, re-varnishing with synthetic varnish (brush and spray application) and a small amount of retouching with resin-based paints. The treatment was straightforward because the painting was not greatly damaged and there was no complication with varnish or overpaint removal, which tends to rack-up hours. Of course, there is no "average" treatment in conservation, each object is unique and therefore the amount and type of materials employed, and the time required to complete the treatment will differ in every case. In the future, a range of treatments will be monitored using the same methodology to get closer to an average carbon cost for a treatment, which may be determined by the size of the object and where it has to travel from. This should help practitioners estimate for the carbon cost of a treatment, in the same way they might estimate for the financial cost of a treatment.

Conversion Factors

Activities and processes emit various greenhouse gases which are contributing to global heating including carbon dioxide, methane, nitrous oxide and hydrofluorocarbon gases. Methane warms the planet 25 times as much as carbon dioxide, and the other gases warm at different rates, so to simplify things carbon footprints are usually quantified in one metric called *Carbon Dioxide Equivalent* (CO_2e) which is the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas. Working out the amount CO_2e of is straightforward if you know the correct conversion figure to use. Unfortunately, there are many conversion figures to choose from. For this study, the amount of CO_2e was calculated using conversion factors from the UK Government Department for Business, Energy and Industrial Strategy (BEIS 2021) which is linked to the greenhouse gas protocol, the standard framework for emissions calculations and business reporting (World Resources Institute 2004). The figures are provided in an annual spreadsheet of GHG conversion factors for Company Reporting. The conversion figures cover things like Electricity and Gas, Transport and Waste and particular units must be used. Examples are given under each section[3].

Measuring Staff Time

There was no existing procedure for timekeeping at English Heritage. The conservator started to record the hours they worked on the painting to calculate how much electricity use could be allocated to the treatment taking place in the studio. Two paintings

[3] For conversion rates in other countries look at government agencies for example: United States Environmental Protection Agency. 2022 "Greenhouse Gas Equivalencies Calculator" https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

conservators work in the Conservation Studio. There are no additional security or administration staff working on site, so it is akin to a private studio. All rest breaks are taken in another building, so were not accounted for in the time log. Staff work on multiple projects and tasks in a single day. A single painting conservator carried out the treatment being studied, so the treatment was carried out a few hours a day over several weeks in November 2021. The total hours spent on the conservation treatment were logged on paper index cards and divided by 7 hour working days. This could be used in conjunction with kWhs (see Measuring Energy Section), to work out the energy used in the studio during the conservation treatment (recorded in Table 1)

The time log was also used to work out staff travel costs. The "on costs" of staff time (e.g., additional staff based off site doing HR and administration for a conservation staff member, as well as hidden things like pension cost, cannot be accounted for in the scope of this study, but were predicted to add up to 30% on staff time). The treatment of the Ostade was undertaken at the same time as the treatment of a different painting by the other conservator. Therefore, time was amortized by the number of objects being worked on simultaneously. In this case, we could reasonably assume the other painting conservator was working on one other painting at the same time, so the staff time could be halved when calculating energy usage. It is not a perfect measurement, but it gives a good indication.

Measuring Storage Time

The time each object spends in the studio is logged in a "in/out" book and on a multi-mimsy based object management system. The painting actually stayed in the studio for 191 days between 12th July 2021-19th January 2022. Eleven paintings were being stored in the studio concurrently during this period. So, the calculation for storage is:

191days x32.7 kWh x 0.21 kgCO_2e ÷ 11paintings = 191.24 kgCO_2e (Table 1)

The staff are often site-based at one of 30 sites around the country. This varies widely, but in November 2021 the studio was occupied on 18 out of 22 working days in the month. The part time staffing hours of the conservators also complicate calculations and the staff do not work weekends. Staff also undertake multiple strands of desk-based work in the studio such as administration, studio management, advisory work and outreach where the studio is being occupied, but not for the purpose of treatments. The studio is only heated to prevent freezing when staff are not in the building and there are long spells when the painting is being stored but not worked on. During these periods, the heating is operated at 16˚C (the heaters' minimum setting) to prevent freezing. A Hanwell CR30 humidifier/dehumidifier is constantly operational as well as a small fridge and emergency exit lighting. Lights and computers get turned off at the end of the day.

Using this methodology, energy use is being allocated twice (for conservation treatment and also storage) but it wasn't predicted to make a significant difference to the figures.

Measuring Staff Travel

The staff member undertaking the treatment usually travels to work by a bicycle, so their carbon emissions from travel were negligible (apart from the embedded carbon cost of the bike). Embedded carbon costs of vehicles are not usually counted as part of carbon footprint studies. However, they sometimes travel by medium sized petrol car. The other staff conservator travels by a medium diesel car. Mileage from home to work was calculated using google maps to show the comparative impact of both types of staff travel. The BEIS 2021 conversion figure of 0.18785 kgCO_2e per km for a medium petrol car or 0.16496 kgCO_2e per km for a medium diesel car was used. The figure for a medium petrol car was used for comparison (recorded in Table 1).

Measuring Object Transport

In this case, the artwork could be moved from the historic house to the studio building without transportation so there was no carbon cost. However, specialised art handling companies are usually required to move fine art, and a hypothetical carbon cost was calculated using the same methodology for staff transport and materials; logging the transporter's vehicle model and mileage for a hypothetical return journey from a London site, as well as the weight of wrapping materials -polythene, bubble wrap, tissue and tape (or foam lined wooden crate) used for packing.

If the painting being treated was from a central London site and the usual transport agents were employed, they would need to travel about 15 km to the historic site to collect the work and 14 km back to the studio. The van would also need to travel 5 km from the studio back to the depot giving 34 km, doubling to 68 km for a return journey when the painting was returned to site. Transportation is usually arranged with maximum efficiency to save on costs so this would need to be amortised to account for multiple works being transported at once. There are usually at least 2 paintings on each load, so the mileage was halved back to 34km.

The art transporters usually use a 3.3. tonne Diesel Van. The BEIS conversion figure for freight goods via a class III van (1.74-3.5 tonnes freight truck) is: 0.26529 kgCO_2e.

Therefore, a hypothetical trip could contribute:

34km x 0.26529 kgCO_2e = 9.02 kgCO_2e (recorded in Table 2).

Measuring Energy Use

The treatment took place in the Conservation Studio, which forms part of a Grade I listed site. Like most typical historic buildings, it is leaky and not energy efficient, although it benefitted from a recent roof replacement and insulation in early Spring 2021. The volume of the studio is: 298 m^3. Footprint area is 69m^2. Electricity is the only energy source. Electricity is largely used for heating and cooling, humidification and dehumidification, lighting as well as running equipment such as the extraction unit, computers, conservation tools etc. The ambient and conservation lighting is all LED. The cost of environmental control in historic houses as well as the studio at English Heritage is much less than a typical fine art museum because English Heritage has adopted much wider environmental parameters (35-65% RH) which are achievable within the constraints of historic listed buildings yet tolerable for most fine art objects.

In examples of other conservation studios, it would be possible to get energy usage figures directly from gas and electric bills. However, the energy bills for the site (which comprises a Historic House, Office, Conservation Science Laboratory as well as the Conservation Studio) were held under the organisation's central contract and based on estimates. The energy is measured for the whole site rather than for each building. Therefore, some monitoring of energy usage had to be undertaken. In addition, a single distribution board measures the energy use in the Conservation studio and the Conservation Laboratory and therefore the energy monitoring had to be separated between these two buildings. One or two additional staff work in the Conservation Laboratory at any one time.

Working with the estates team a £800 TinyTag Three Phase Power Energy Logger was installed on the phase (live) conductors serving the distribution board in the studio, which measured the energy use of both the Studio and the Laboratory. Specialist knowledge was required from the estates team and conservation scientist to interpret the data.

It was difficult to separate the exact energy running costs of the Studio and the Laboratory, but it was decided to measure the pieces of equipment in the lab which used significant amounts of energy i.e., the ageing oven (no heating or dehumidifier had been installed in this newly refurbished building at the point of the project and the other computers and analytical equipment had very low impact). The ageing oven runs continuously and is not affected by the number of people using the lab. The energy use from the Laboratory was measured by installing a £15 *Maxico Dual Tariff Power Meter* energy logger on the ageing oven. These loggers delete data after one month, so readings needed to be taken regularly to avoid loss of data. The authors would recommend using more expensive loggers which retain data for longer. This was then deducted from the overall kWh measured by the TinyTag (which amounted to 2.7 kWhs per day). The electricity was measured from July 2021 to May 2022.

The treatment was largely completed in November 2021, although the painting came into the studio in July 2021 and did not return to site until Jan 2022. As explained in the *Measuring Staff Time* section above, the paintings conservators work concurrently on multiple treatments including studio and site-based work, so the studio is not always occupied. To adjust the figures for seasonal change, a daily average of kWh for the month of November was selected as the factor. Using staff members' outlook calendars, the days of the month were separated into occupied and unoccupied days. The TinyTag logs electricity use by day. This data could be used to select occupied dates to create an average figure. On days when the studio was occupied the energy use was of course higher, so an average energy use for an *occupied* day in November of 32.73 kW per day was used to calculate the total energy use in Kilowatt Hours (kWh). This was double for the 2 days it took to undertake the treatment. However, this figure could be halved to amortise for the treatment being carried out in the studio simultaneously by the other conservator making the total energy use for the treatment 32.73kW (Table 1).

Converting kWh, to carbon equivalent (the amount of CO_2 used) depends on the source of electricity and therefore location (each country has different amounts of renewables, nuclear and fossil fuel sources) it was important to work out which published emissions factors to use. English Heritage switched to a single renewable tariff in April 2020, however, wider grid carbon was still used in the study for measurement as per Greenhouse Gas Protocol accounting standards (World Resources Institute 2004). The number of kWh were converted to a carbon cost using the same BEIS 2021 figures used in the rest of the study. The conversion figure of 0.21 $kgCO_2e$ / kWh, was used. As with conversion figures for transport, much more sophisticated methods exist but it was decided to use this figure to keep the method as straightforward as possible for non-specialists.

Measuring Materials.

Although the carbon footprint of materials was predicted to be small, it was deemed worth measuring in order to raise awareness amongst conservators of how their choice of materials impacted on carbon and other sustainability issues such as air, water and soil pollution. All materials were weighed before and after to deduce how much had been consumed by the treatment. This was entered into an excel spreadsheet and the data available from the carbon calculator tool from Sustainable Tools in Cultural Heritage (STiTCH 2021) as well as a Norwegian building Materials database (Ruusker 2013) was used to work out the $kgCO_2e$. (Table 3). Note that for the STiTCH database, liquid materials should be recorded in millilitres and solid materials weighed in kilograms and others measured in m^2.

Measuring Wrapping Materials

The painting in the study did not need to be packed for transport. At English Heritage paintings are typically soft wrapped for transport using acid free tissue and bubble wrap to make soft corners as well as polythene LDPE (low density polyethylene) sheet sealed with Vinyl tape to make an environmental seal. Timber crates or travel frames may be used where frames or paintings were more vulnerable. The wrapping materials can be worked out in the same way as other materials (see Measuring Materials Section).

A hypothetical figure for wrapping materials was given for comparison (Table 4). The conversion figure for Polythene Sheet was not available on STiTCH and was calculated using the figure from the US National Institute of Science (NIST 2022). The conversion figure for vinyl tape was not available but would not greatly increase figures because not much was used. Wrapping is not typically reused (a system which is in the process of changing), so the calculation is for two lots of wrapping.

Measuring Equipment

All equipment has an embedded carbon footprint. It is common to exclude the manufacturing impacts of larger pieces of equipment in this type of Carbon Footprint. Attempts were made to calculate "consumable" equipment such as solvent containers and brushes (Table 3). The kgCO_2e conversion factor was divided by the estimated times of potential re-use. Carrying out some calculations was not possible given the limitations of the calculators used in the study. The main consumable equipment used in this treatment were bamboo swab sticks (predicted reuse 10-100 times); paint and varnish brushes (predicted reuse 20 times); solvent bottles (predicted reuse 200 times) as well as disposable aluminium take away trays to hold varnish (used once).

Measuring the Building

The embedded carbon cost of building or converting the studio building could not be measured in the scope of this study. The building would be used for multiple treatments and its lifespan is not known. It would be more appropriate to measure the carbon footprint of the building when a conservation studio was being set up and then measure how many conservation treatments it served in its lifetime.

Measuring Waste

The study attempted to include greenhouse gas emissions from non-recyclable waste (contaminated cotton swabs, paper towel). The BEIS provide conversion figures for waste. The figures depend on whether the waste is recycled, incinerated, composted or sent to land fill. The Studio waste is recycled or incinerated. Incineration is more carbon intensive than landfill but is used to power homes. (Table 5). Waste did not feature as a significant percentage so was taken out of the overall pie charts in figures.

Results

An excel spreadsheet was used to log the measurements from each category and the percentage of kgCO_2e each category contributed was recorded (Table 6). The proportions from each category are presented as pie charts for actual GHG emissions (figure 2) and Hypothetical GHG emissions with storage (figure 3) and without storage (figure 4).

Table 1. Energy Use (Staff working time and Storage time)

Storage Days	**Average daily kWh over year**	**No of paintings stored concurrently**	**$kgCO_2e$ conversion figure per kWh**	**GHG Emissions ($kgCO_2e$) for storage period**
191	32.7	11	0.21	191.24
Days Worked on Treatment	**Nov Average kWh**	**No. of paintings being worked on simultaneously**	**$kgCO_2e$ conversion figure per kWh**	**GHG Emissions ($kgCO_2e$) for working period**
2	28 kwh	2	0.21	**5.88**

Table 2. Transport and Travel Carbon Calculator

Staff	**Round trip mileage (from home to work and back)**	**Type of Vehicle**	**Conversion Figure $kgCO_2e$ per km**	**Total GHG $kgCO_2e$ per working day**	**Total GHG $kgCO_2e$ for this treatment**
Conservator 1	12km	Bicycle	0	0	0
Conservator 1	12km	Medium Petrol Car	0.18785	2.2542	**4.51**
Conservator 2	22.km	Medium Diesel Car	0.16496	3.7116	7.42
Art transporters	34 km	Diesel Type III Van	0.26529	N/A	**9.02**

Table 3. GHG emissions of materials and small equipment

Material	**Amount**	**Amount** converted to STiTCH unit ml or kg	**Purpose**	**GHG Unit ($kgCO_2e$)**	**No. of times used**	**GHG emissions ($kgCO_2e$)**
Ethanol	2ml	2ml	Cleaning Test	0.0009	1	0.002
Isopropanol	186 ml	186ml	Varnish Removal	0.0015	1	0.279
Stoddard Solvent	2ml	2ml	Cleaning Test	0.0006	1	0.001
Paraloid B 72	0.5g	0.0005kg	Brush Varnish	5.429	1	0.002
Shellsol A	26ml	26ml	Brush wash	0.0006	1	0.016
Shellsol A	48ml	48ml	Cleaning	0.0006	1	0.029

			Spray gun			
Shellsol A	20ml	20ml	B72 Diluent	0.0006	1	0.012
Shellsol A	31.5ml	31.5ml	Laropal Diluent	0.0006	1	0.019
Cotton Wool	33.1g	0.0331	Cleaning	2.237	1	0.074
Melinex	9g	0.009	To protect labels on back	6.105	1	0.055
Marvelseal 42.5g	42.5g	0.0425	Lining existing hardboard backing	No data	1	0.055
Weight of aluminium in 1m2 of Marvelseal =68.58g 0.7m x 0.6m (0.42m2) 0.42 x 68.58= 28.8	28.8g	0.0288	Lining existing Hardboard Backing	6.92	1	0.199
Disposable Aluminium Tray	5g	0.005	Varnish receptacle	6.92	1	0.035
Paper Towel	60g	0.06	Blotting Varnish	No data	1	No data
Disposable gloves (2 pairs)	0.021g	0.021kg	PPE	No data	1	No data
Gamblin A81 retouching paints	0.5g	0.0005kg	Retouching	No data	1	No data
Methoxypropanol	20ml	20ml	Retouching brush wash and diluent	No data	1	No data
Double Sided Tape	2.5g	0.0025kg	Lining existing hardboard backboard	No data	1	No data
Laropal A81 dry resin	7g	0.007kg	Spray varnishing	No data	1	No data
Swab stick	2g	0.002kg	Making Swabs	No data	50	No data
Sable Retouching Brush	15g	0.015kg	Retouching	No data	10	No data
Hogs' hair Varnishing brush	30g	0.03kg	Vanishing	No data	20	No data
Polyethylene HDPE Solvent Dispenser	38g	0.038kg	Solvent receptacle	2.344	500	0.000178
Stainless Steel Solvent Dispenser Stopper top	84g	0.084kg	Holding solvent	3.8g	500	0.000638
Total						**0.724516**

Table 4. Hypothetical GHG emissions of Wrapping Materials

Wrapping Material	Amount used in Data source units	Conversion Factor (kg CO_2e)	Data Source	No. of times used	GHG emissions (kgCO_2e)
Acid Free Tissue	5.04 m^2	0.060 m^2	STiCH	Once	0.302
Polythene Bubble Wrap	0.066kg	2.844 kg	STiCH	Once	0.188
Polythene Sheet (low density polyethylene)	0.25kg	2.13kg	NIST	Once	0.533
Brown Vinyl Tape	0.4 m^2	Not available	n/a	Once	Not available
Total					**1.023**

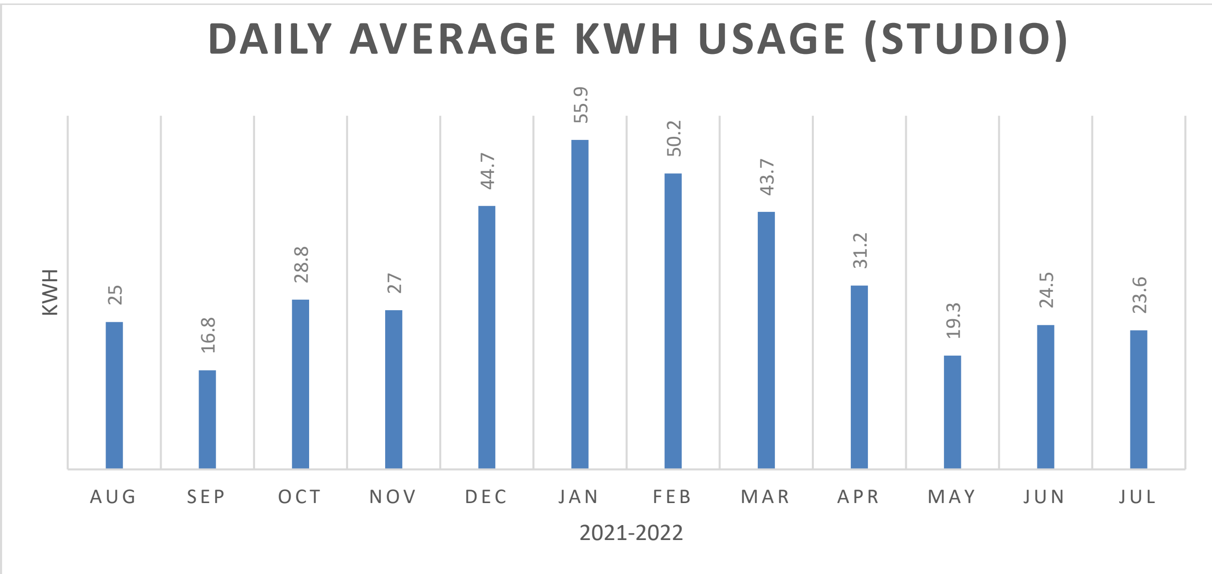
Table 5. GHG emissions from Waste

Material	Amount	Amount Tonnes	Purpose	Conversion Figure Waste (incineration)	GHG Emissions (kgCO_2e)
Disposable Aluminium Tray	5g	0.00001	Holding Varnish	21.294	0.000106
Paper Towel- not recycled	60g	0.00006	Blotting Varnish Brush	21.294	0.001277
Cotton Wool	30g	0.00003	Swabs	21.294	0.006388
Acid Free Tissue	5.04 m^2		Wrapping	21.294	
Polythene Bubble Wrap	66g	0.00007	Wrapping	21.294	0.001491
Polythene Sheet (low density polyethylene)	250g	0.00025	Wrapping	21.294	0.005324
Brown Vinyl Tape	0.4 m^2	insignificant	Wrapping	21.294	Not available
Total					**0.014586**

Table 6. Total GHG emissions of carrying out the treatment.

Category	GHG Emissions ($kgCO_2e$)
Staff working time/ Electricity	5.88
Materials	0.73
Wrapping Materials	1.02
Object Transport	9.02
Staff Transport	4.51
Storage time/Electricity	119.24
Waste	0.01
Total	140.41

Figure 1. Daily Average kWh usage in studio for 2021-22.



Average daily usage for the studio over the year was: 32.6 kWhs

Figure 2. Actual GHG Emissions by category, excluding hypothetical object transport and using actual scenario where conservator travelled to work by bicycle.

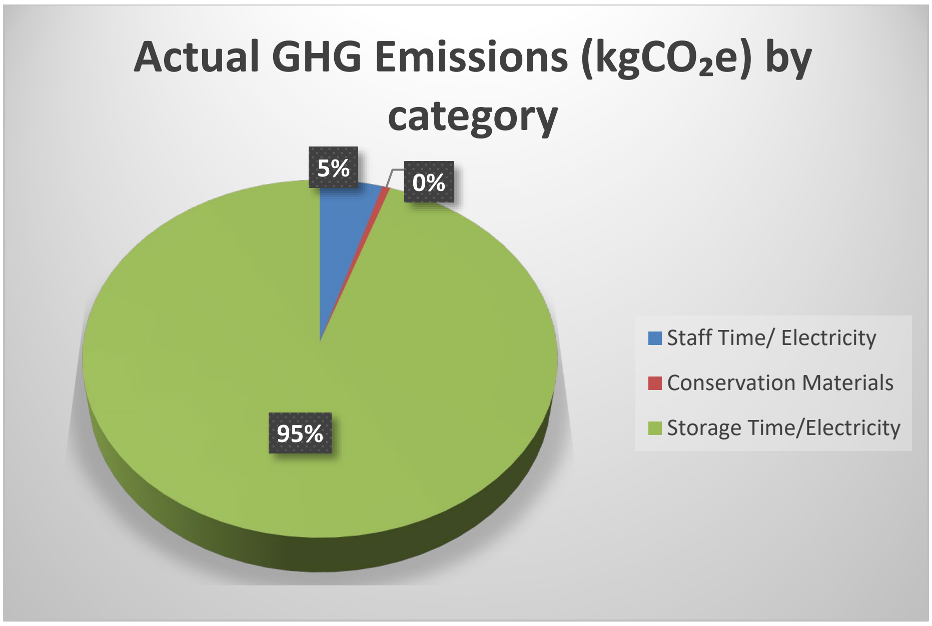


Figure 3. Hypothetical GHG Emissions by category (including storage). Includes a hypothetical measure for object transport and using a scenario where conservator travels to work by petrol car.

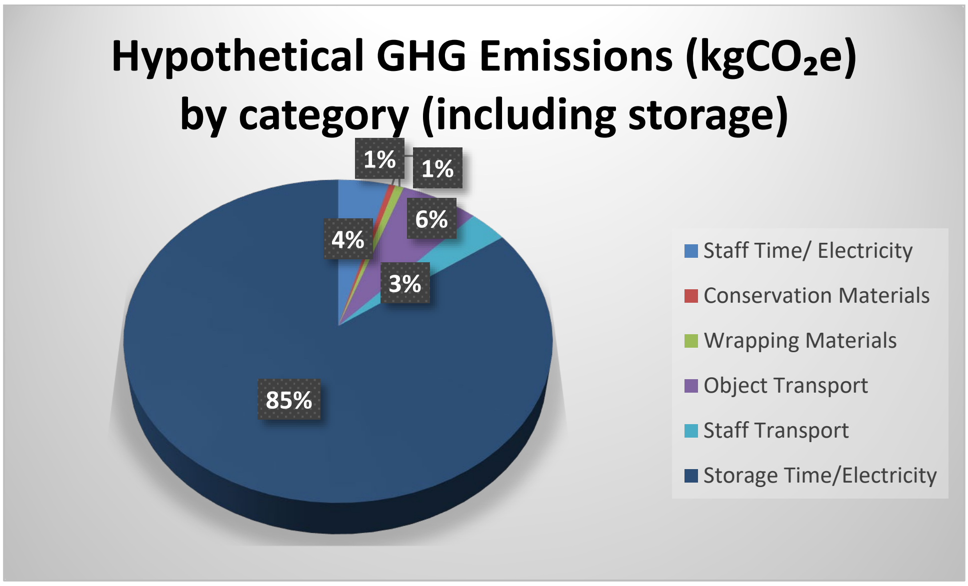
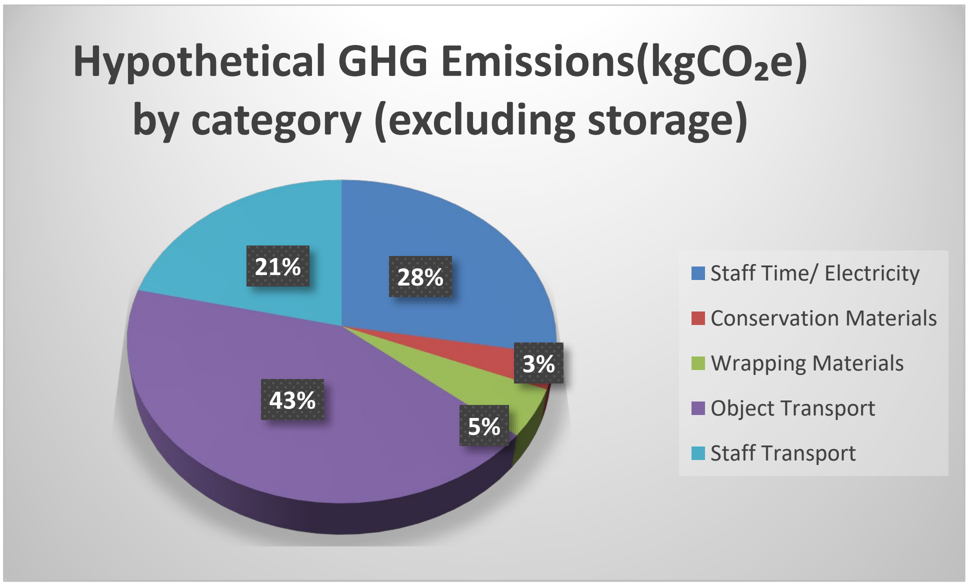


Figure 4. Hypothetical GHG Emissions by category (excluding storage). Includes a hypothetical measure for object transport and using a scenario where conservator travels to work by petrol car.



Discussion

Looking at the proportions each category contributed to the hypothetical scenario is a good way to prioritise when setting actions to reduce carbon emissions.

Object Transport

The data showed that for this short treatment, a hypothetical figure for object transport would have had the largest carbon cost. Object transport will have a lower proportional impact for a longer more involved treatment because mileage is fixed for each historic site. English Heritage already operates transport runs efficiently, consolidating as many logistics as possible. It could consider sharing transport runs with other organisations to reduce impact. Using electric transport for shorter runs will become possible in the future.

Electricity Use

Energy used to control the conservation studio environment (during storage time) had the second largest carbon impact. The storage period cannot be greatly reduced without increasing staff capacity, and if often due to consolidating transport trips and competing work priorities. Energy used to heat, cool, light and control the studio environment as well as operating equipment had the third largest impact. It would be useful to separate out the electricity used for heating. lighting, environmental control and running equipment as each is related to a different action necessary to decarbonise. This was not possible in the current study, however multiple Maxico Dual tariff power meters could be used in future on the Hanwell humidifier/dehumidifier. The disadvantage to using these monitors is that they need to be read off on a monthly basis, so it is helpful to have reminder alarms in staff calendars. They are inexpensive and readily available.

Electricity monitoring was completed for a year, which derived monthly averages for electricity consumption over a year. These may change year to year as climate change brings warmer, wetter winters and hotter, dryer summers but it gives a good baseline from which to make future calculations. If any significant energy efficiencies were made like changing the building insulation or energy source monitoring should be repeated.

The monthly average use is surprisingly low, probably because staff can easily control the heating and it is only heated to background levels to prevent freezing on unoccupied days and weekends. The studio is run completely on electricity (rather than gas) and since April 2020, English Heritage have moved onto a 100% zero carbon tariff for all its sites. Green energy tariffs are established by suppliers matching all or part of the energy you use by making purchases of renewable energy on your behalf. These could come from a variety of renewable energy sources such as wind farms and hydroelectric power stations. The theory behind this energy production is a positive step because as more organisations commit to green tariffs then the proportion of green energy will increase to meet the national and COP26 goal of net-zero by 2050. However, the carbon benefit of a ‘green’ tariff is not typically accounted for in emissions calculations since renewable generation projects would largely exist with or without these particular tariffs, therefore they are not delivering new or additional carbon savings.

The fluorescent lighting had already been replaced by energy efficient LEDs with a lamp life of 50,000 hours and the studio is heated and cooled via air source heat pumps which are more efficient in this space than a gas-powered central heating system or electrical panel heaters giving improved efficiency. The project has made staff much more aware of energy use and they have already taken small measures to reduce it. A variable speed invertor has been installed on the motor of the spray varnishing booth which enables operators to reduce the energy whilst meeting H&S specifications and lighting is now only switched on in zones which are in-use. Retrofitting options are more limited in historic buildings but the building would benefit from insulation in line with conservation & traditional building principles. In the future, it is possible that the studio could be powered by other sources such as solar panels if these could be installed sympathetically on in a historic building or ground source heat pumps if archaeology was not at risk. At present English Heritage are prioritising energy reduction at its larger sites.

The size and operations of the studio are more akin to conservators working in private practice than in a large museum, so this study could be particularly useful to conservators working in private practice. If private conservators were to replicate the study, they could use information from their electricity bills or smart meters to deduce kWhs. In large organisations like English Heritage apportioning time correctly makes undertaking studies of particular parts of the organisation difficult. In small private studios this might be easier to calculate accurately.

Staff Travel

Staff travelling by car had the next highest impact. In this case travelling by bicycle would represent a 16% carbon saving. It is difficult for staff to make changes to the way they travel due to geographic restrictions, but this data could be used to inform organisational policy more widely to encourage active travel and car sharing.

There are problems with using average data developed by the UK government for reporting because the actual carbon emissions depend on the fuel efficiency of the car. Neither data set accounts for the embedded carbon cost of manufacturing the car but demonstrates the importance of travel choice in reducing carbon footprint.

Materials

The carbon cost of materials for this treatment was low but not inconsequential (3% of the overall treatment). For more involved treatments on larger paintings, it will inevitably be higher, but will probably not factor as a significant percentage.

It was interesting to see which materials had the highest carbon footprint. Comparing the STiTCH GHG unit can be misleading because some materials are weighed in kg and some in ml. A general observation is that denser materials have the highest carbon impact. GHG equivalent Units for solids such as metals and glass are very high because of the energy used in production and recycling, and the calculations for cotton wool and Paraloid B72 are also relatively high. Solvents, tend to be much lower in carbon emissions. However, there are other environmental risks associated with solvents such as soil/air/water pollution and biodiversity loss, which means that the drive to find alternatives to solvents (especially petrochemical based ones) in conservation is still important. Although materials contributed a small amount to the overall carbon cost of a treatment, sustainable materials should continue to be investigated. It is one of the areas over which conservators have direct control. Using better materials will help meet other sustainable goals like healthy water and soil systems.

The STiTCH calculator had limitations and some data was not available (e.g. for paper towels, gamblin retouching paints, latex gloves, methoxypropanol, double sided tape and laropal dry resin). It was decided to include an incomplete set of data because the missing materials were only used in small quantities and would not greatly affect the overall carbon cost of materials.

The “consumable” and reusable small items of equipment such as bamboo swab sticks, glassware and brushes contribute a very small amount and are probably not worth calculating in this type of study. This may be a shortcoming of the calculator and it could be adapted to make it more useful. A study on reuse of materials and equipment would help with making this factor more accurate.

The Norwegian database did not include specialist conservation materials, but it was interesting to note that there were differences in the common value for aluminium, probably due to the type of energy used to manufacture and different recycling rates in EU and US. This demonstrates how complicated it is to calculate accurate life cycle assessments as non-specialists.

It is important to remember that STiTCH figures currently represent *carbon impact*, not a full life cycle assessment. Making a through carbon footprint analysis of a conservation treatment is not straightforward because there are still gaps in the data. STiTCH uses the database Ecoinvent 3.6, a commercial database of life cycle assessments for thousands of products and processes, published in Switzerland. (Ecoinvent 2003). Life cycle assessments (LCAs) are made by calculating greenhouse gas emissions emitted from "cradle to gate". A market average of where manufacturing takes place was used by STiTCH for consistency so local suppliers and manufacturers in different parts of the world may lead to higher or lower LCAs.

The STiTCH Calculator is a useful starting point, but regional calculators need to be made for use in Cultural Heritage. More in-depth calculators are already available in the field of architecture using whole life carbon assessment software such as One Click LCA (Mackenzie 2022). The current systems for calculating the LCA for conservation materials, including localised transport and delivery of a product, need to become more sophisticated to help conservators make sustainable choices between materials, and localised studies and research will assist with this. As conservators enquire more about the carbon impact of conservation materials and equipment, the manufacturers will realise the importance of producing greener products and make this information more available.

It was interesting to note that in this short treatment, wrapping materials had a higher carbon impact than the conservation materials. Re-using the wrapping could save 4% of the carbon costs depending on the number of times it was reused. It could save 10% of carbon costs of object transport.

The exercise of calculating and comparing materials will be repeated at English Heritage in future and the results will become more nuanced as understanding of supply chain emissions from purchased materials improves.

Staff have made some small changes to their practice in response to the study. For example, some types of waste solvent are now reused to clean brushes and solvent guns and wrapping materials are reused.

Waste

The treatment only produced a very small amount of incinerated waste (cotton swabs, paper towels and wrapping materials) which became insignificant as a category.

Conclusion

Future results will be replicated for other conservation activities to help staff make more sustainable choices such as reducing energy use, selecting more sustainable materials, reducing packaging and consolidating art transport trips, and choosing modes of travel. For example, logging the carbon cost of treatment projects and travel in the future may staff help decide whether it is more sustainable to work on specific projects peripatetically (at the historic site) or at the studio. It will be interesting to see if financial cost and carbon cost tally closely.

The study showed that making a basic carbon footprint study of a particular conservation process is achievable by a non-specialist. However, the research takes time and is less accurate than specialist studies because data is either not available or the scope is beyond the authors' abilities.

More generally, we need to care about our personal and professional impact on the planet. Climate change and environmental breakdown caused by the carbon emissions we generate contribute to an unstable future. The cultural heritage that conservators seek to protect is at much greater risk if we don't understand our impact and most importantly if we don't take action to reduce our carbon footprint.

Time is running out to achieve net zero by 2040. We need to be aware of our professional carbon footprint, but we can take action on the generalities we already know: Reduce consumption of electricity; retrofit existing building; install renewable energy source; increase active and electric transport and finally choose, use and recycle materials wisely.

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