

**A Summary of Greenhouse Gas
Management of the Science Museum
Climate Science Exhibition Project**

For the Science Museum, London

A report by Small World Consulting Ltd

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**An associate company of
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1 Introduction

1.1 The Climate Science Exhibition Project:

The Climate Science Exhibition was developed with the aim of providing an innovative visitor experience about climate change, consisting of a high-profile gallery in South Kensington with associated multimedia, web and events. To address the ever more apparent challenge of climate change efforts were made to reduce the impact of the exhibition itself, looking at various components of the project to reduce emissions without compromising the visitor experience.

Small World Consulting was commissioned to advise the project team on its own carbon management and of the design and delivery of the project. The intention was to bring integrity to the project through practical management of the issue and in doing so to instil a culture of carbon awareness into every aspect of the exhibition. The intention was for the exhibition project to become a model of practical carbon management in exhibition design.

1.2 This report:

This report provides an overview of our work to manage the climate change impacts of the project, including the design, construction and delivery over the planned five year life of the exhibition.

1.3 An approach to practical carbon management

Our approach was based on the following principles:

- The inclusion of the supply chain emissions as well as those from direct energy use.
- Using broad estimates of climate change impacts to inform the relative attention given to different elements of the project. Standard conversion factors were used to estimate the direct emissions from fuel consumption and electricity use, whilst input-output analysis combined with financial forecasts were used to give initial estimates of the carbon in supply chains.
- To supplement the overview of impacts from the whole project, separate studies were carried out to explore key decisions in greater detail. These included;
 - an analysis of energy use in the project offices,
 - an analysis of embodied energy of different construction materials,
 - an analysis of embodied carbon, operational carbon and costs of different projection, lighting and electronic display options.
- Climate change information was factored into project design and management decision making, alongside a full range of other criteria including other sustainability criteria as well as cost and performance issues. Effort was targeted towards areas of greatest climate impact and those offering the best opportunities for significant mitigation actions. Some consideration was also

given to the potential to enhance the exhibition through the visible use of practical lower carbon technologies.

2 An initial estimate of the climate change impact of the exhibition

A cursory study of the likely climate change impact of the entire project was made at the outset to provide a broad management perspective, to enable the identification of hot-spots and the effective targeting of effort. The estimate used input output analysis combined with financial budgets and estimates of direct energy consumption over the five year lifetime of the exhibition.

The likely impacts was estimated at around 2,500 tonnes CO₂ equivalent; around 1.25kg per visitor based on 2 million visitors over the 5 year lifetime¹.

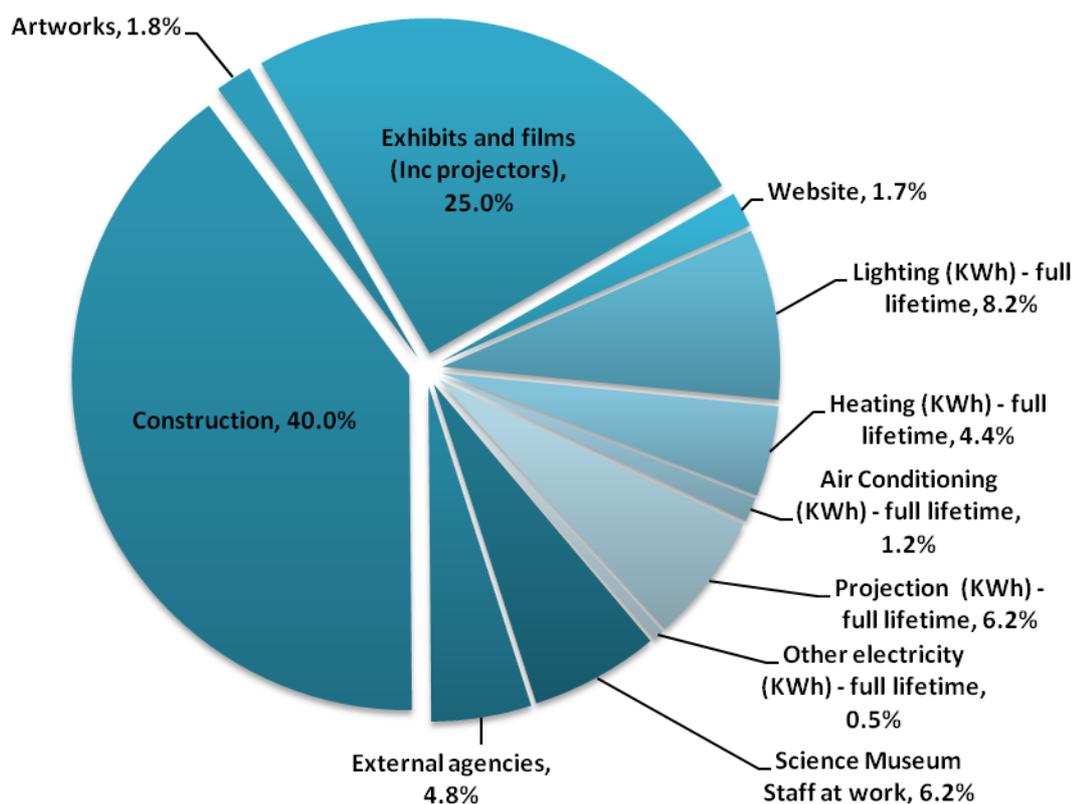


Figure 1: An estimate of total greenhouse footprint of the Climate Science Project over its 5 year lifetime (Total 2,500 tonnes CO₂e).

(see Appendix A for the initial greenhouse gas footprint estimate.)

¹ Based on 400,000 visitors to the climate science exhibition per year.

2.1 Key areas for attention

As a result of the initial study the following areas were targeted for action;

- contractors in construction process,
- projection and LCD screens,
- construction materials,
- the climate science exhibition project team,
- office energy use.

3 Carbon management actions

3.1 Managing the embedded carbon in construction materials

Interestingly, whilst the physical construction of the exhibition was thought to be responsible for around 40% of the lifetime climate change impact of the project, only a small proportion of this was estimated to come from the emissions embodied in the materials. Nevertheless, the choice of materials offered the possibility to support emerging low-carbon construction technology and to provide visual evidence of practical carbon management.

Several materials were considered for the floor, walls, ceiling and table displays. These including plywood, strand oriented board (OSB), Ecosheet², Acrylic/plaster sheeting, Corian surfacing product, Formica, polystyrene blockwork, fibre glass, honeycomb cardboard panels, and reusable scaffolding. (see appendix D for the summary of alternative materials and appendices E and F for more detail on the suitability of Ecosheet).

Materials were considered for their functionality, cost and broader environmental credentials as well as their embedded carbon.

3.1.1 Materials selected

The Tectonic Plates were conceived as a single continuous folding sheet material that would provide the principle material and support for all of the exhibits within each exhibition zone. While Ecosheet was given a considerable amount of attention during design development, in the end FSB plywood emerged as the safest option in terms of having a well-established history of fabrication techniques that would ensure the structures lasted the lifetime on gallery. On a schedule of materials issued to CM by the Crighton Carbon Centre, Plywood scored reasonably low in terms of CO₂e/unit. Softwood (which also rated well) and plywood

² Ecosheet emerged as a particularly interesting new material; made from recycled mixed plastic waste. It was felt important to support this new material if possible, even though its use as the main flooring and walls facing was ruled due to uncertainty over its long term functionality. The decision was taken to use it in a fairly small part of the exhibition where it could be a practical demonstration of a sustainable technology (and the exhibition's commitment to their support) without exposing the exhibition to significant risk. Its performance will be monitored for the duration of the exhibition.

formers were used to provide additional structure concealed beneath the plinth. These were all finished in a tough polyester lacquer as a neutral and robust finish to take projection.

Apart from the Tectonic Plates, other installations in the gallery include the entrance monolith and low level wall, gallery seating and a free-standing pavilion providing seating at touch screen terminals. These were areas where we wanted to have timber as a natural material for construction and finish. Softwood timbers emerged as a sustainable choice that we wanted to use on gallery because it added a tactile experience for the visitor. Spruce, supplied by Eurban, was specified as it had particularly good credentials as fast growing timber from well managed sources and Eurban have a preference for integrated sawmill manufacturing plants local to the UK. The sheets are cross-laminated and bonded with non-formaldehyde adhesives.

3.1.2 Construction Process

The Science Museum committed to working closely with their key contractors in ensuring that the exhibition on Climate Change embodies the principals of carbon management and is as low carbon as practically responsible.

- Sustainability criteria were built into the tender brief, designed to emphasise attention to the indirect and dispersed nature of the carbon footprint of construction.
- This way the ethics and practises of the tenderers have been qualitatively analysed to assess their commitment to sustainability.

(see Appendix G for the sustainability update containing details on the tender review and interview questions for main contractors and Appendix H for the overall contractor review.)

3.2 Staff education and engagement

We ran a series of lunchtime workshops, consisting of talks and discussions over the winter of 2009/2010, open to all staff in the museum and contractors. The sessions covered an introduction to carbon footprint concepts and methodologies, climate change impacts in perspective, and special focuses on food, travel, and procurement.

3.3 Projection and electronic displays for the exhibition

The total carbon impacts of different equipment (and models) were estimated over the lifetime of the exhibition to feed into the decision making process alongside performance and cost.

The main components are the emissions required for manufacture of the machines and the energy use over the five years of exhibition life. It was recognised that to some extent, machines contribute to heating and lighting and this was factored into our estimations. Recommendations were as follows:

- The Panasonic PT-DZ6700U was selected for the bulk of the projection in the exhibition as a carbon efficient option, in addition it was a good model for both cost and performance,
- In addition it was recommended that the project remained open to advancements in LED technology to avoid the risk that traditional technologies would look increasingly out of place and to continue our attempt to embrace emerging lower carbon technologies.
- Later in the project 8 Casio XJ-A145 LED projectors were added. Over the course of the project these had become affordable, and are sufficiently bright to ensure quality within the gallery conditions. These lamps last 10,000 hours and provide the Museum with the opportunity to test this lower carbon footprint option over the course of the exhibition.

(see Appendix A for analysis of projectors and Appendix G for the sustainability update containing the details on the analysis of exhibition carbon and costs from LCD screens.)

3.4 Lighting in the exhibition³

Different lighting designs were investigated to provide a good experience for visitors and to use efficient light sources. The following measures were taken to limit the carbon footprint of lighting:

- LED lighting was used throughout the exhibition to provide an atmospheric blue glow. They are fully controllable for output and should have at least a 50,000 hour life meaning they may use less than ten times as much energy as a comparative design tungsten-halogen lamp. The entire blue effect was achieved for less than $2\text{W}/\text{m}^2$.
- Gallery spotlighting typically uses tungsten-halogen lamps for their narrow focus & colour-rendering properties. They are cheap and widely available, however they are also relatively inefficient sources. For the Climate Science Gallery, these were replaced for LED sources and metal-halide sources. For 24 fixtures (a typical quantity used to light display objects) around 2kW in energy costs are saved per hour, the load is reduced by around 80%, and lamp-life by around 300-400% (metal-halide lamp life of around 12,000 hours versus typical tungsten-halogen lamp of around 4,000 hours).
- The general gallery lighting used new florescent lamps saving approximately 5% in energy costs per feature and providing a better lighting performance than older models.

³ Information provided by dha design.

- Object lighting throughout the displays has been provided using LED lamps saving approximately 80% of power compared to typical display case using a fibre optic installation.

3.5 The footprint of the project team

This was identified as a small component of the overall footprint and connected to the positive impact that exhibition could have on the public understanding. If the quality of staff work was to suffer as a result of their carbon management activities any carbon saving would clearly be a hollow victory. The challenge was to find smart ways of being carbon efficient. The following actions were recommended:

- close scrutiny of any need for flights,
- agree a range of simple everyday behavioural changes, to target hotspots in the footprint,
- encourage the Science Museum as a whole to engage on the greenhouse gas footprinting exercise and to develop a carbon management system,
- engage museum staff from other teams to encourage greater discussion and make carbon management a common place activity,
- encourage staff to engage in a structured consideration of their own personal climate change impacts.

(See Appendix B for summary of full report on climate change impacts of the project team.)

3.6 Office energy use

It was recognised that the relative footprint of the studio was small but some simple changes in daily activity could produce large reductions in proportionate terms. Furthermore there was thought to be scope for a multiplier effect in that these improvements could well be applied to other offices in the museum. The main actions identified were as follows.

- A simple big saving was to be made by routinely unplugging computers and monitors at the end of the day. The purchase of some inexpensive desk-based junction boxes was recommended to save people crawling on the floor.
- The suggestion was made that some modifications to the lighting would have significant reductions; replace T8 bulbs with T5s, introduce PIRs with manual over-rides and split each of the main lines of lights into two under separate control to increase personal lighting for those who wanted it.
- Unplug the printer when not in use, or at least at the end of the day.
- Source an insulated kettle and consider replacing the fridge for a more efficient model.

Individuals in the office have made several of these changes to their daily activities. Since the initial report a Sustainability Manager has been appointed by the Museum and these recommendations have also been fed into an action plan for the whole organisation.

(See Appendix C for summary of report on findings and recommendations for reducing energy use in Studio 66.)

4 Appendix A: Science Museum Climate Science Exhibition Works: Sustainability Update – (9 December, 2010)

4.1 Initial assessment of the greenhouse gas impact of the climate change exhibition.

We have been working to create an overall picture of the climate change impact of the exhibition over its lifetime, so that we can target our efforts based on a combination of impact and urgency with which decisions are being taken.

It is not a precise science, but our current best estimate is shown below.

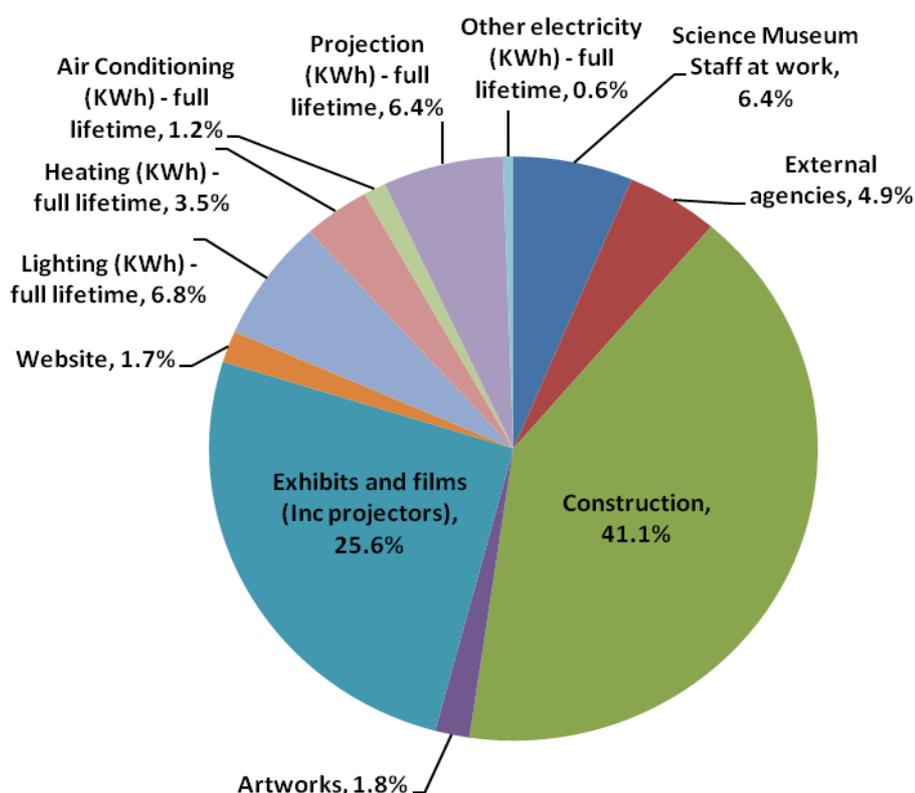


Figure 2: An estimate of the greenhouse gas footprint of the Climate Science Exhibition over its five year lifetime (% of 2,500 tonne CO₂e total).

To put things in perspective, the overall impact of the exhibition looks like being around 2,500 tonnes CO₂e. That is 1kg per visitor, based on 2.5 million visitors⁴.

Projection and the construction in the gallery are the two areas we have started looking at so far.

⁴ The 2.5 million visitors referred to here is the initial estimate of the number of visitors to the climate science exhibition over its lifetime. This estimate was subsequently revised to 400,000 visitors per year or 2 million over 5 years. Both estimates exclude website visits and other events relating to the climate science project.

4.1.1 Projection

We have been estimating the total carbon impact of different models over the lifetime of the exhibition, to feed into the decision making alongside performance and cost. The main components are the emissions required for manufacture of the machine with lamps and lenses and the energy use over the five years of exhibition life. To some extent, projectors replace heating and lighting and we have tried to factor this in.

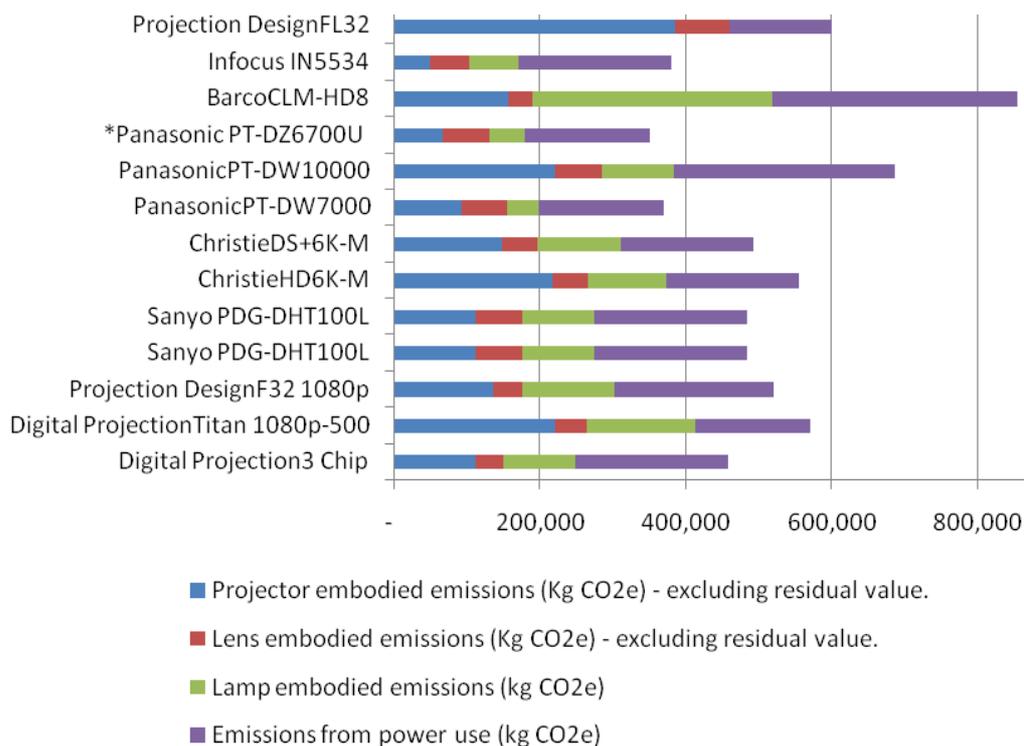


Figure 3: The footprint of projection options over the exhibition lifetime (Kg CO₂e)

The favoured projector looks like being the Panasonic PT-DZ6700U. As far as we can tell this looks good from a carbon perspective and well from the point of view of cost and performance.

LED technology is moving on quickly and there is high investment in this area. There is a risk that traditional technologies will look increasingly out of place to visitors as the exhibition goes on.

The LED projector that was tested did not provide a bright enough image for the proposed application but the quality of the image was encouraging. We will look for opportunities to use one of these within the gallery - demonstrating where projection is moving towards in the future and showing the exhibition’s responsiveness to emerging lower carbon technologies.

Interestingly, LED projection was not strikingly more energy efficient because more projectors are required to compensate for their lack of brightness.

Overall it looks as if we are going to have a defensible position over the management of emissions from projection.

4.1.2 Construction

We are starting to look at this now. From a carbon point of view, the key questions are:

- which materials?
- how much is required?
- how much are they 'used up' by the exhibition rather than re-using existing products and returning them ready for re-use elsewhere?
- at the end of life can things be recycled or will they go to landfill?

We have given Casson Man a simple model for entering in the different design options from which we can then estimate the carbon implications. We have started to use input from an architectural technologist and the Crichton Carbon Centre.

4.1.3 Staff and consultants

Between us we make a significant contribution (best estimate 11.5%). The biggest components are probably office energy consumption and travel.

- Our energy audit of Studio 66 revealed some incredibly simple ways of making big cuts in electricity use. These just need implementing.
- I have agreed to run some short sessions various carbon topics for museum staff. The first one will be on Carbon and Food.
- It is part of the carbon management of this exhibition that we all look to play our part, so all consultants are invited to engage with this. In the first instance two simple principles to work from are
 - Don't do anything that makes life dull or gets in the way of productivity
 - Do start actively challenging the ways that things have always been done and look for simple ways of changing the way you work.

5 Appendix B: Summary of findings and recommendations from climate Science project team report (July 2009).

(see full document for references and notes on conversion factors.)

5.1 This report

This report sets out to deliver key information that will allow the Science Museum's Climate Science Project team to manage its GHG emissions in a structured way, and to communicate and engage both staff and visitors.

5.2 Methodology

Appendix B contains a detailed account of the conversion factors used.

5.2.1 Footprinting principles

Whilst the term 'footprint' is used in various ways, we are using it to mean the sum of the direct emissions and the indirect emissions that arise throughout supply chains of activities and products. Many assessments of emissions concentrate primarily on direct and readily visible or easily measured emissions, such as those that leave an organisation's chimneys and vehicle exhaust pipes or can be monitored by meters. The inclusive treatment of supply chain emissions, as presented in this consumption based assessment, differs from more standard production-based assessments. It gives a more complete and realistic view of impacts, despite the complexities and uncertainties that are involved. Footprints of this kind are therefore essential metrics for those interested in managing the climate change impacts that result from their activities and purchases.

As an example, the footprint of electricity consumption includes components for the emissions associated with fossil fuel extraction, shipping, refining and transport to power stations, as well as those resulting from the electricity generation process itself. It is worth noting that these factors are not included in standard conversion factors issued by Defra. To give another example, the footprint of vehicle travel includes, on top of components for direct vehicle emissions, components for the extraction, shipping, refining and distribution of fuel, components for the manufacture and maintenance of cars, and so on.

5.2.2 Boundaries of the study

The study covers the core activities of the Climate Science Project Team and its supply chains.

The following are specifically included in the study:

- electricity and gas consumed by the team in their normal place of work,
- staff business travel,
- staff commuting travel,
- office consumables,
- other consumables,
- IT & telecommunications services,
- depreciation of embodied GHG emissions in capital assets,
- other services.

The following are specifically not included in this study:

- the emissions embodied in the buildings themselves,
- activities of staff other than at work,
- customer travel,
- normal food consumed by staff at their normal place of work.

5.2.3 Inclusion of Kyoto greenhouse gases

This assessment considers all six gases covered in the Greenhouse Gas Protocol, expressed in terms of carbon dioxide equivalent (CO₂e), i.e. the sum of the weights of each gas emitted multiplied by their global warming potential (GWP) relative to carbon dioxide over a 100-year period.

5.2.4 Treatment of high altitude emissions

High altitude aeroplane emissions are known to have a higher global warming impact than do their low altitude counterparts. Although the science of this is still poorly understood, this study has applied a multiplier of 1.9 to aircraft emissions, to take account of their higher impact. This is the figure suggested in Defra (2008) *Guidelines for Company Reporting on GHG Emissions*. The figure can also be inferred from the Intergovernmental Panel on Climate Change's Fourth Assessment Review (IPCC 2007). Some sources advocate applying multipliers to aviation emissions as high as four.

5.2.5 Greenhouse Gas Protocol guidelines

We have followed the reporting principles of the Greenhouse Gas Protocol published by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) (Ranganathan *et al*, 2006).

The Greenhouse Gas Protocol provides a choice of three scopes for emissions reporting. Scope 1 covers direct emissions from company-owned vehicles and facilities. Scope 2 includes net emissions from energy imports and exports, such as electricity. Scope 3 includes other indirect emissions resulting from company activities, as detailed by the boundaries of the study. This report includes all Scope 1 and 2 emissions and an extensive treatment of Scope 3 emissions throughout supply chains of business activities and purchases.

5.2.6 Reporting approach

Estimates of emissions have been derived by applying conversion factors to data on fuel and energy consumption, travel, and purchases of products and services.

Direct emissions associated with fuel consumption on the premises from electricity consumption and from most transport have been calculated using conversion factors provided by Defra in their *Guidelines for Company Reporting on GHG Emissions* (2008). However, the Defra figures do not take account of supply chain emissions other than those produced at the point of electricity generation, and these need to be considered separately.

For the estimation of supply chain emissions from products and services as well as in the production and transportation of fuels, this report draws primarily upon environmental input-output analysis (EIO).

EIO combines economic information about the trade between industrial sectors with environmental information about the emissions arising directly from those sectors to produce estimates of the emissions per unit of output from each sector. The central technique is well established and documented (for example Leontief, 1986; Miller & Blair 1985). In the UK, the main data sources are the Combined Supply and Use Matrix for 123 sectors and the UK environmental accounts, both provided by the Office of National Statistics (ONS). The specific model used for this project was developed by Small World Consulting with Lancaster University. This model augments the basic approach to take account of such factors as the impact of high altitude emissions that are not factored into the environmental accounts and the effect of imports. We have also used price indices to take account of changes in the economy in the time lags that occur in the production of ONS data.

Three main advantages of EIO over more traditional process-based life cycle analysis (LCA) approaches to GHG footprinting are worth noting:

- EIO attributes all the emissions in the economy to final consumption. Although, as with LCA, there may be inaccuracies in the ways in which it does this, it does not suffer from the systematic underestimation (truncation error) that LCAs incur through their inability to trace every pathway in the supply chains (Lenzen, 2001; Nässén *et al*, 2007).
- EIO has at its root a transparently impartial process for the calculation of emissions factors per unit of expenditure, whereas LCA approaches entail subjective judgements over the setting of boundaries and the selection of secondary conversion factors.
- Through EIO, it is possible to make estimates of the footprints resulting from complex activities such as the purchase of intangible services that LCAs struggle to take into account. This report is therefore able to assess the impacts resulting from all university expenditure.

One of the limitations of EIO in its most basic form is that it assumes that the demands placed upon (and therefore the direct emissions from) other sectors by a unit of output within one sector are homogeneous. As an example, a basic EIO model does not take account of the carbon efficiencies that may arise from switching the expenditure on paper from a virgin source to a renewable source without reducing the actual spend.

In order to mitigate this weakness, we have drawn upon LCA. Overall, therefore, this report uses a hybrid methodology, drawing upon the strengths of both LCA and EIO approaches. Where appropriate this study has applied adjustment multipliers to the EIO-derived conversion factors in order to reflect known differences between the carbon intensity (in Kg CO₂e per £) of this team's procurement from a particular sector, and the average GHG intensity of that sector's output.

5.2.7 Uncertainties

The complexity of supply chains and the difficulties in obtaining accurate data dictate that footprinting can only offer a best estimate rather than an exact measure, and the figures in this report should be viewed in that context. We have operated from the principle that it is more informative to make best estimates of even the most poorly understood components of the footprint, and to discuss the uncertainty openly, than to omit them from the analysis.

Overall, the results in this report should be viewed as best estimates and a broad guide to the relative significance of different components.

5.2.7.1 Uncertainties over conversion factors

The areas in which the relationship between consumption and climate change impact is best understood are gas and electricity consumption. There is relatively good consensus over conversion factors to within around 5% in these areas. The next most certain group of conversion factors are those for travel and transport. In this category, there is uncertainty over the impact of high altitude emissions and the embodied emissions in the manufacture and maintenance of vehicles, roads and other infrastructure.

Supplies and services are the areas of greatest uncertainty. As an example, credible LCAs of a particular specification of paper typically differ by factors of around 50% depending on the specific practices employed in the particular mill in which it was manufactured. It would also be possible for two detailed studies of exactly the same process to arrive at significantly different estimates, depending on the precise assumptions made.

5.2.7.2 Uncertainties over data

Data has been gathered by the Science Museum's Climate Science Project team. Where ideal data sets could not be found, estimates were made.

Electricity and gas consumption was accurately known from meter readings for the whole Science Museum. It was then allocated to studio 66 proportionally to the amount of space it occupies. The estimate for studio 66 was then allocated proportionally to the team by the number of full time equivalent staff there were on the team compared to the whole of studio 66.

Where data on commuting to work was incomplete estimates were made over the number of trips likely to be taken to work during the period January to March. This period was taken to be representative of the whole year.

Extraordinary business travel was treated as one off travel for the purposes of this footprint and not as typical for the four month period Jan-April 2009.

Where mileages on business travel were incomplete these were estimated from relevant maps.

Where a return journey was indicated, mileages given for day to day business travel data was assumed to be the total return trip distance and not the one way distance.

Office consumables and services were apportioned between all staff that work in Studio 66, and then scaled up appropriately to reflect the amount of time the Climate Science Project team spend on the project and the amount of time spent out of the office.

5.3 Results

5.3.1 Overview

The annual greenhouse gas footprint of the Climate Science Project team and its supply chains is estimated at 20.7 tonnes CO₂e per year.

Business travel was responsible for 49% of the total footprint with air travel making up the majority of this (44% of the total footprint). Electricity was responsible for 19% of the total footprint while gas made up 8%. Commuting contributed 9% to the total footprint. The remainder came from services (6%), office consumables (5%) and capital asset depreciation (4%), with postage making an insignificant contribution of 0.1%.

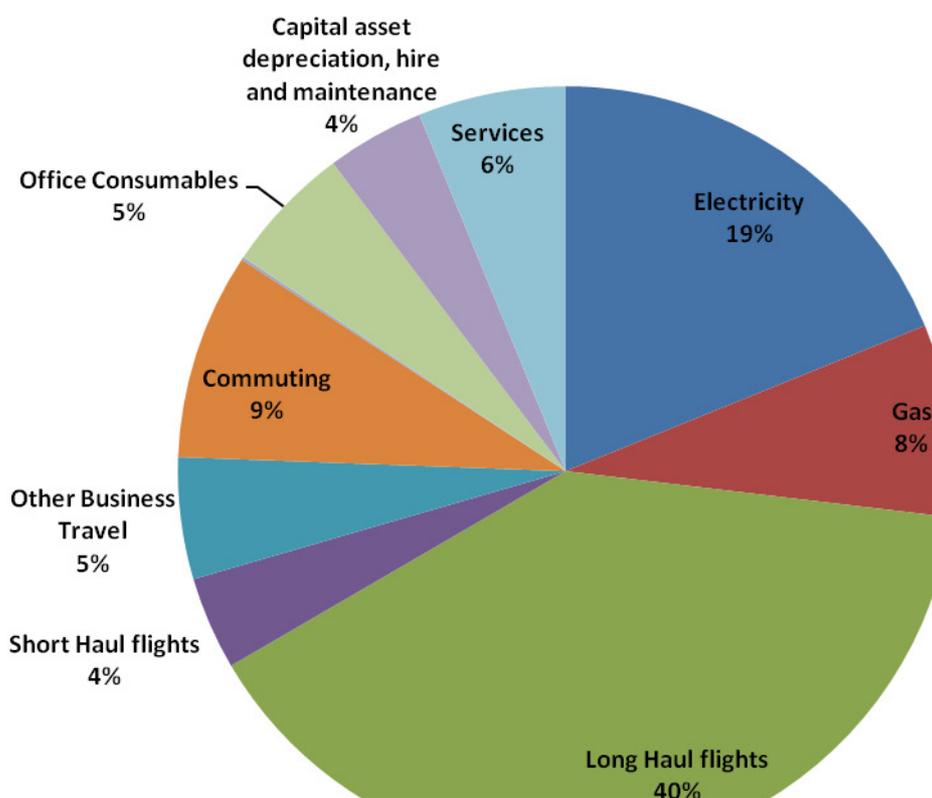


Figure 4: The Climate Science Project Team’s Greenhouse Gas Footprint of 20.7 tonnes CO₂e

5.3.2 Perspective

Once emissions imported from overseas production and international transport are taken into account, we estimate that the consumption footprint of the UK is around 18 tonnes CO₂e per capita (50kg per day). On this basis the Climate Science Project Team’s footprint is equivalent to the annual footprint of around 1.2 UK citizens.

With an estimated 2.7 million visitors per year, the Climate Science Project has great potential to ‘transform how people think, talk and act about climate change’. In order to mitigate one year’s footprint of the project each of the 2.7 million visitors who see the exhibition would need to make a saving of some 8g CO₂e each. This is roughly equivalent to the footprint of boiling just enough water for one small cup of tea or using one paper towel.

The footprint of the project team is clearly very small compared to the positive impact that it can have on public understanding. The importance of managing its own impact without compromising the exhibition lies in the integrity and first hand understanding that this will bring to the team’s work.

5.3.3 Breakdown of the footprint

The largest components of the footprint are as follows.

5.3.3.1 Business Travel (49% of total footprint)

The biggest contributor was long haul flights (82%), consisting of 3 flights to the US. Short haul flights contributed 8% and national rail contributed 3%. A further 3% was from hotel stays and 2% from international rail. Bus, tube and taxi’s accounted for the remaining 2%.

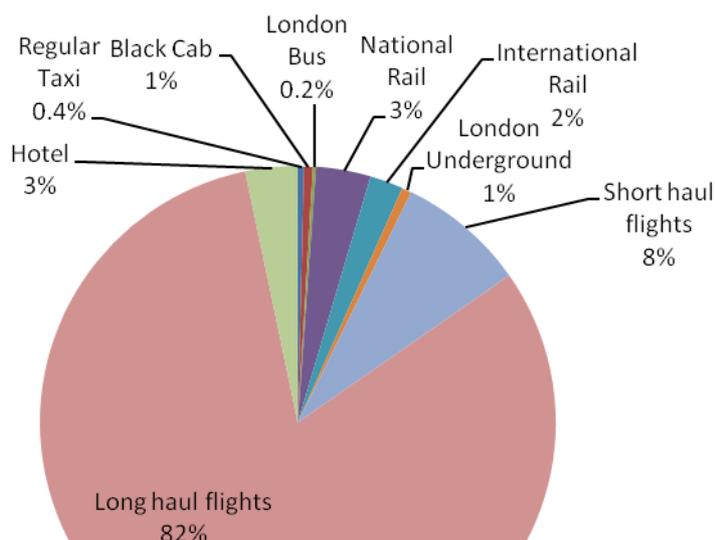


Figure 5: Breakdown of emissions from business travel

5.3.3.2 Electricity and Gas (27% of total footprint)

This is the next largest category contributing to the footprint and is split between electricity (19% of the total footprint) and gas (8% of the total).

5.3.3.3 Commuting (5% of total footprint)

This breaks down in tube (74%), bus (20%), train (6%) with one negligible journey by car share.

5.3.3.4 Services (6% of total footprint)

IT Services contributed 82% of this figure. Other business services (conference fee) contributed 15% to the services footprint with telecommunications making up the remaining 3%.

5.3.3.5 Capital Asset Depreciation (4% of total footprint)

Depreciation and maintenance of computers made up 58% of this, with depreciation of equipment contributing 42%.

5.4 Recommendations

The footprint of the project team is clearly very small compared to the positive impact that it can have on public understanding. If the quality of their work were to suffer as a result of their carbon management activities, any carbon savings would clearly be hollow victory. However this reasoning should not be taken as an easy excuse. The challenge is to find smart ways of being carbon efficient. The importance of the team managing its own impact lies in the first hand understanding of carbon issues that this will bring to team members and the integrity that it will bring to their work.

We recommend the following:

- Flights should come under particularly close scrutiny, with the value of trips carefully assessed, and the alternatives given careful consideration (For example video conferences, on-line conference participation and phone calls, all of which also save time and money)
- The development of everyday low carbon practices in the office (such as cutting out screen savers and routinely turning screens off when getting up from a desk, printing sparingly and double sided). We recommend that these be developed and shared throughout Studio 66 and beyond. These actions will be more powerful if they are informed by a simple electricity study of the way electricity is consumed within Studio 66.
- The team should seek to influence the Museum to take the following steps:
 - a greenhouse gas footprinting exercise (to include the entire consumption footprint),
 - staff engagement including a lively internal education programme,
 - the development of a museum-wide carbon management system to include energy management and low carbon procurement.
- Members of the team could be encouraged to undertake a (voluntary) personal carbon footprint assessment and management exercise encompassing the whole of their lives outside work.

6 Appendix C: Summary report of findings and recommendations for reducing energy use in Studio 66 (Sept 2009).

This report estimates the different types of electricity consumption in Studio 66 and makes suggestions for reduction. The figures are not precise. They are based on sampling the power consumed by appliances, power ratings of lighting tubes, and crude estimates of usage patterns.

Whilst the figures here are based on assumptions that may be far from perfect we believe the results are robust enough to illuminate the key issues. They point to some encouragingly simple ways of making dramatic reductions. Even more interestingly, the simple suggestions presented here may well be equally applicable to other offices in the museum.

The overall breakdown of electricity consumption is shown below along with suggested actions and savings.

	Annual consumption (KWh)	% of total	Potential actions	Possible saving (KWh)	Saving (% of current total)
Lighting	3757	25%	<ul style="list-style-type: none"> Introduce PIRs with manual overrides. Split each of the main lines of lights into two under separate control Increase personal lighting for those who want it. 	1300	9%
			<ul style="list-style-type: none"> Replace T8 bulbs with T5s (33% saving based on Booths' estimate) 	766	5%
Computers	6400	42%	<ul style="list-style-type: none"> Unplug at the end of the day instead of just switching off. 	2577	17%
Monitors	4000	26%	<ul style="list-style-type: none"> Unplug at end of day Get rid of screen savers: a blank screen is better. 	2550	17%
Printer	580	3.8%	<ul style="list-style-type: none"> Unplug at end of the day. 	380	2.5%
Fridge	250	1.6%	<ul style="list-style-type: none"> Consider replacement 		
Kettle & microwave	130	0.9%	<ul style="list-style-type: none"> Source an insulated kettle. 	16	0.1%
Other	80	0.6%			
TOTAL	15200	100%		7590	50%

The annual greenhouse gas footprint of the above consumption is about 9,100 Kg CO₂e of which 4,600 Kg can be saved by taking the above actions.

Lighting

We understand there have been notable reductions in recent months by breaking the routine of always having all lights on. There are still outstanding efficiency issues:

- Different people require and enjoy different lighting levels yet only two switches control the T8 tubes in the main room.
- The T8s are relatively inefficient at 58W per tube. Some costs will be associated with replacing and adding adapters to the existing fittings.

Computers and monitors

Astonishingly, most PCs and monitors burn significant power when switched off but not unplugged. Since the machines spend the vast majority of the year in this state we estimate that monitors in the office consume most of their power when switched off and computers themselves also consume nearly half their power when in this state.

	Total energy used when switched off	Total energy used when switched on
Computers	44%	56%
Monitors	64%	36%

The good news is that a very simple big saving can be made by routinely unplugging computers and monitors at the end of the day. The purchase of some inexpensive desk-based junction boxes will save people from crawling on the floor.

Based on a sample of just two days, we estimate that the equipment in Dave Patten’s office uses 560 KWh per year, or 3.7% of the electricity consumed by Studio 66. He already routinely unplugs at night, and this is good.

Printer

Although more detailed monitoring over a longer period of time might give a more accurate result, we estimate that the printer uses two thirds of its energy use when the office is empty. The simple solution is for the last person out to switch it off at the wall.

Kitchen

- The kettle is a small contributor to Studio 66 emissions. It often contains spare boiled water. This saves time when the office is busy and drinks are frequently being made, but we recommend sourcing an insulated version. This will save power and reduce the time taken to make a drink. On quiet days more care should be taken to fill only to the required level.
- Although the fridge is probably not the most energy efficient design, the benefits of replacing before the end of its life will be marginal given the embodied emissions of manufacture.
- The microwave is an efficient way of cooking and probably helps to reduce waste.

Fans

These consume 40W at maximum power. At times they *might* be an efficient way of reducing temperature differences around the office which we heard are sometimes problematic.

Key assumptions

- 22.6 full time equivalents spread themselves between 31 workstations with 36 computers.
- On an average day the main lights, 58W T8s, are on for 4 hours, this having recently been cut from the practice of having them on all the time.
- Computers and monitors are switched off but not unplugged at the end of the day.
- We only modelled four states for a computer: unplugged, off but plugged in, ‘on’ and ‘intensive use’ and we assumed that if used during a day they would typically spend 7.5 hours on plus 30 minutes in intensive use.

7 Appendix D: Summary of alternative construction materials (December 2010)

Request: Small World Consulting
Project: Environmental Product Credentials
Completed: Mark Mckenna



Outline:

Question from Craig Riley, Casson Mann Ltd-

Ideally a closed-loop recycled / recyclable material that functions as a standard flooring or builders board to replace plywood, mdf, sterling board etc.

Product Options:

It is important to note that, when considering the environmental credentials of construction materials, you should not only consider the embodied energy & carbon properties, but the health impact during its life through VOC (Volatile Organic Compound) emissions (off-gassing).

(a) Plywood-

Plywood is a type of manufactured product made from thin sheets of wood, called plies or wood veneers. The layers are glued together so that adjacent plies have their wood grain at right angles to each other for greater strength. A common reason for using plywood instead of plain wood is its resistance to cracking, shrinkage, twisting/warping, and its general high degree of strength. Generally, Plywood;



- can be fabricated using FSC Sourced timber and is reusable,
- resins when used in plywood are non VOC off-gassing (but harmful in manufacture),
- is often sourced from outside the UK & Europe.

(b) OSB Board-

Oriented strand board, also known as OSB, waferboard, Sterling board (UK) and SmartPly (UK & Ireland), is an engineered wood product formed by layering strands (flakes) of wood in specific orientations. Its strength properties are ever becoming closer to those of plywood. Generally, OSB board;



- often uses recycled wood products,
- is reusable,
- has a high embodied energy,

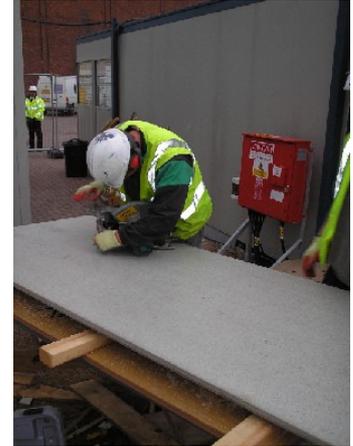
- large quantities of VOC's are released during manufacture, however only 10% is released during service life.

Potential Alternative:

(a) 'Eco-Sheet'

EcoSheet engineered panels are made from 100% recycled plastics. The natural characteristics of polymer are utilized to manufacture hard-wearing, smooth-faced, versatile boards suitable for a variety of applications in construction. Ecosheet is engineered to perform as an alternative to imported plywood, or to virgin plastic panels, yet in turn are fully recyclable at end-of-life.

EcoSheet is manufactured using a new technology called Powder Impression Moulding (PIM). This process enables production of EcoSheet from low-grade, mixed, waste-plastics – materials which are notoriously hard to recycle and therefore invariably end up being land-filled or incinerated. The process also allows EcoSheet panels to be recycled at end-of-life, thereby offering a complete closed-loop solution for all customers.



Guardian on line - 5th March 2009 - EcoSheet, a recycled alternative to plywood

*The Guardian names "Ecosheet" as one of "five great ideas from the world's biggest green building show (Ecobuild 2009-Earl's Court London) to quote: "Flogging a plywood substitute to the construction industry might score low on eco-chic, but this recycled plastic sheeting, made entirely from old mixed pvc free plastic, is something of a wonder product. It's tough, lighter than ply, impermeable to water, ideal for hoardings and concrete formworks and **at the end of its useful life makers 2K Manufacturing will come and pick it up, turn it into new boards and offer a rebate on future orders.** Still not wowed? You can paint on it, cut it using standard carpentry tools and it boosts much-maligned plastic recycling schemes."*

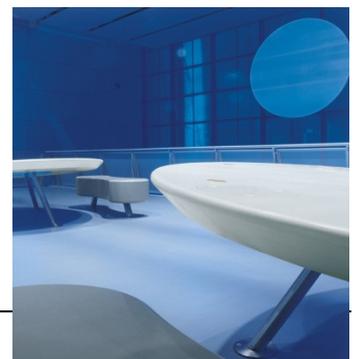
Acrylic/Plastic Sheeting- General Information:

Acrylic, also known as *poly methyl methacrylate* (PMMA), is a clear, colorless transparent plastic with a higher softening point and better impact strength. The principal commercial processes for the production acrylic sheets are extrusion and casting. Approximately 10% waste acrylic is produced in the product manufacturing process- waste scrap. Recycling of acrylic waste scrap within the production process is an option that can reduce the generation of waste through production.

(a) Alternative- Corian Surfacing Product

Corian® has the substance to create impressive, large-scale designs, while also offering the durability, ease of cleaning and minimal maintenance that these spaces require in the long-term.

As confirmed in the Structural Engineers Materials list, Corian is a solid surfacing material produced by DuPont that consists of 1/3 acrylic resin and



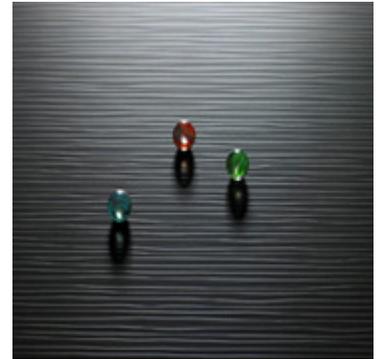
2/3 aluminium trihydrate, a mineral derived from bauxite ore. Generally, Corian Surfacing Products;

- DuPont™ Corian® solid surfaces and Corian® adhesive all have low VOC content
- Can easily be repaired and renewed, thus minimizing the desire or need to replace and dispose
- Can also be removed, re-cut and either reinstalled as a new design or reworked into new products.

(b) Alternative- Formica

Formica is a brand of composite materials manufactured by the Formica Corporation. The product is essentially a heat-resistant, wipe-clean, plastic laminate of paper, acrylic or fabric with resin binders. Generally, Formica products;

- Have High degree of Formaldehydes used in material manufacturing process.
- Range of wood veneer laminates is produced using reconstituted veneers sourced from an FSC accredited suppliers.
- Produce dust waste which is often used to generate heat for the products manufacturing facilities.



Both of the above products have their own benefits; however the Corian is the preferred product.

Polystyrene Blockwork- General Information:

To reiterate the Structural Engineers materials list, expanded polystyrene is comprised of 98 per cent air. This means that it one of the most lightweight high impact materials available. Being such a lightweight product, polystyrene can reduce fuel consumption in transportation and delivery. Expanded polystyrene is completely free of VOC's such as formaldehydes. If cutting is done efficiently, this can limit the amount of product waste generated.

(a) Polystyrene with fibreglass coating

Polystyrene PS foam (expanded polystyrene) is mainly used in packaging, construction, for insulation, lightweight ceiling tiles and sometimes even as polystyrene building blocks for concrete to be poured into to create walls (*ICF Insulating Concrete Formwork*).

Aside from the benefits above, the flexibility in shape & form makes polystyrene such a well received product for use in public spaces such as exhibitions & galleries.



The major disadvantage of a polystyrene block (expanded polystyrene) is that 0% of the product can be recycled and is non-biodegradable. It is for this reason that serious consideration should be given to alternative products prior to using this product- depending on practicality & intended use. The extent of use should also be a big factor in the decision making process. Providing that polystyrene blocks can be re-used for many other exhibitions in the same form, the impact this product has may be better than initially anticipated.

Fibre-glass coating:

The coating as specified in the Structural Engineers materials list is not considered necessary to prevent damage by Styro-Tech Ltd, manufacturer of Polystyrene PS products. There was no reference to an anticipated polystyrene manufacturer in the materials list supplied.

Alternative-

Note that an alternative system solution has not been recommended. However, with further information on the exact use of the product within the exhibition, an alternative option can be offered.

Honeycomb Cardboard Panels- General Information:

The light weight and rigidity of honeycomb cardboard make it the ideal core material for non-load bearing partitions and office screens that are strong and easy to handle on site. Cardboard honeycomb combines readily with hardboard, plywood and plasterboard and is uniquely suited to both straight and curved panels. It also has a high resistance to changes in ambient temperature so that the risk of warping is greatly reduced. This product/material can be fully recycled, but it depends on whether or not harmful binding agents are used.



Embodied Greenhouse Gas emissions in materials

The figures here are drawn from the Inventory and Carbon and Energy (University of Bath) data base and LCAs held by the Associate of European Plastics Manufacturers.

Material	EC CO ₂ /kg
Standard UK Plywood	0.81
Oriented Strand Board (OSB)	0.51
'Eco-Sheet', manufactured by 2D Manufacturing Ltd	1.6 (general figure for recycled plastic)
Formica	Unknown as yet
Corian Surfacing Product	Unknown as yet
Expanded Polystyrene (without coating)	3.3
Thermoformed expanded polystyrene	4.3
Fibre glass wool	1.4
Epoxy resin	5.9
Honeycomb Cardboard Panels	1.6
Glue Laminated Timber	0.65

8 Appendix E: Science Museum Climate Science Exhibition Works: Sustainability Update – (7 Jan, 2010)

Construction Materials

Ecosheet looks promising from a sustainability point of view and offers the potential for the exhibition to support a useful new technology but there are serious questions over its fitness for purpose and the manufacturer's ability to deliver to the original timescale. (See below: *Ecosheet - Further assessment*): Other materials are therefore also still under investigation.

The use of reusable scaffolding is excellent from a sustainability perspective.

Tenders for the main contractor

Sustainability has been built into the tender brief with the following wording, designed to emphasise attention to the indirect and dispersed nature of the footprint of construction.

"This project is fully committed to minimising the climate change impact of its activities including those in its supply chains and outsourced activities. A key factor in the tender analysis and selection process will be the contractor's ability to demonstrate that they too are committed to this objective whilst working on this project. Tenderers are therefore to include details describing clearly how they propose to do this".

Small World has agreed to comment on the tenders and can suggest questions for interview as required.

Transport and carbon talk.

Mike is giving a short talk on this with discussion 1300 – 1345 in the New Meeting Room. All are welcome.

65" screens

We have not yet had information on these, but are ready to look at the carbon and costs of different options when this is available.

Ecosheet Product – Further assessment

- The major advantage of this product is that all plastic collected is recycled, including PVC. According to WRAP, only 19% of all UK plastic is currently recycled, with the remaining 81% sent to landfill. Furthermore:
- The recycling process itself is thought to be less energy intensive than standard plastic recycling. A process called 'Powder Impression Moulding' (PIM) is used to form Ecosheet and this requires lower temperatures than conventional plastic recycling. 2K Manufacturing claim that they are the first company in the world to use this process for recycling although we have not been able to source any information that substantiates this.
- The Plastic comes from waste recycling, all within a relatively small 30mile radius, transported by lorry.
- The main plastic recycling stages are: sorting, shredding, washing, melting. Note that there is less energy consumed in the sorting process of plastics as all are deemed usable.

2K Manufacturing do not currently have actual or anticipated embodied Carbon/ Energy values. This is in part due to the fact that full manufacturing doesn't commence until March 2010. However it is possible to make estimates. The following table gives plausible estimates, based on data from Defra, Wrap and assumptions about the manufacturing process.

Process	CO ₂ e/Kg
Virgin plastic sent to landfill	3.4 Kg CO ₂ e / Kg
Closed loop conventional recycling	1.6 Kg CO ₂ e / Kg
UK typical (19% recycling)	3.1 Kg CO ₂ e / Kg
Ecosheet, closed loop. (Assuming 100% recycling and 50% less energy intensive process compared to conventional recycling)	0.75 Kg CO ₂ e / Kg

Production capacity

- Current production is running at 7-8 x 3m² boards per day. This board is primarily used for sampling purposes. Larger scale manufacturing is due to commence in March 2010. 2K Manufacturing estimate that they would be able to produce 650 m² for the Museum by the end of February, a further 600 m² in March and higher quantities after that.

Contact

For more technical details 2K Manufacturing can be contacted on 07909 111995

9 Appendix F: Science Museum Climate Science Exhibition Works: Sustainability Update – (12 Feb, 2010)

Construction Materials

The use of Ecosheet is looking ever more viable and likely. The Crichton Carbon Centre are helping to clarify outstanding technical questions (see their further notes, below). The use of Ecosheet will give important support to an emerging low carbon technology, cut the footprint of the exhibition a little and will provide a story for use in the exhibition itself and in PR.

In conjunction with this some wood may be used and we have advised a little on the sustainability of different options; plywood, OSB, and sawn timber. The right kind of sawn timber will almost certainly be the most environmentally friendly option and will provide a further good story.

Tenders for the main contractor

Mike is on standby to read through the tenders when they come through and to comment. If necessary, I may be able to attend interviews, but doubt this will be necessary.

Tenders for exhibits

The same process as we are using for selecting the main contractor is being used to build sustainability into the procurement of exhibit developers.

65" screens

We have not yet been involved in this process, but remain on standby when the time is right.

Crichton Carbon Centre's Further Notes on Eco Sheet

CCC conducted further investigation into the characteristics of Ecosheet. You specifically highlighted 2 following issues, to which the responses are given below.

1. Ecosheet Additive(s)

Initial product investigations indicated that a mineral additive would be required for the 'ecosheet' product to meet fire class 1 (BS476).

Following your query regarding its environmental credentials, 2K Manufacturing confirmed that the additive, named Aluminium Hydroxide Sulphated, is an inorganic, nontoxic additive. Further to this, the additive is one which has been developed specifically for 2K Manufacturing by a company called 'Ecotard'.

2. Plastic Waste

Initial product investigations indicated that a significantly higher percentage of waste plastic is used in the fabrication of Ecosheet over other recycled plastic products. Your query related to the

condition (hygiene, toxic?) of the plastic waste. 2K manufacturing have confirmed that the material is completely safe to handle and use in the construction process. Furthermore:

- No organic matter is used in the composition of the Ecosheet board
- No food packaging is used
- Most sterilisation of plastic due for recycling is done at 120°C. The plastics used for Ecosheet are sterilised at a temperature of 220°C.

However, the plastic used for the product cannot be classified as 'sterile' as for this to be the case, 2K would have to add 'anti-microbial' (poison) which they do not.

Fire Testing

Recent discussions with 2K Manufacturing have resulted in confirmation that they are working with 'Warrington Fire' to gain Fire classification 1 for Ecosheet (Certified to BS476). They anticipate testing next week (Note that this company are one of a limited number in the UK who can provide BS476 certification).

10 Appendix G: Science Museum Climate Science Exhibition Works: Sustainability Update (12 March, 2010)

Postscript: Note that "B"'s documentation relating to sustainability was not sent as a PDF and was therefore missed from the analysis below. However it was included into the selection process at a later stage.

Construction Materials

With the use of Ecosheet once again becoming contentious, we are look into the possibility of some rapid tests at Lancaster University to improve our understanding of its performance. The use of Ecosheet, if it can be achieved, will give an important dimension to the exhibition and its sustainability credentials.

Tenders for the main contractor

We have fed in our assessment of the tenders and suggested questions for interview. (see below)

LCD screens

Below is an initial analysis of costs and carbon associated with different screen options.

Projectors

The number of these has reduced to 12, and this is good news from a climate change perspective.

PR

There have been some interesting exchanges with the press office about the footprint of the exhibition and it is important that messages are carefully positioned especially in terms of what we are claiming about their accuracy.

Tender Review and Interview Questions for Main Contractor

The Science Museum has committed to working closely with their key contractors in ensuring that the exhibition on Climate Change embodies the principals of carbon management and is as low carbon as practically responsible. Ensuring that contractors are committed to these principals is critical to achieving these objectives.

Organisations demonstrate their understanding of and commitment to environmental best practice in a variety of ways. These can include environmental policies, plans and procedures, accreditation and external verification, case studies and internal expertise. With regard to the Science Museum Climate Change Exhibition, regard to climate change commitments on supply chain and materials are particularly relevant.

Key Best Practice Indicators

0 Not mentioned or evidenced

- 1 Mentioned
- 2 Evidenced
- 3 Exemplar

Tender					
Criteria	A	B	C	D	E
Environmental Policy	2	0	2	2	2
Environmental Management System	1	0	3	2	2
ISO 14001	0	0	2	0	0
Waste Management Plan	2	0	3	2	1
Display Materials Reuse /Recycling	2	0	2	2	0
FSE Timber Procurement	1	0	2	1	0
Energy / Water Awareness	0	0	3	0	1
Carbon Management Plan	0	0	1	0	0
Company Carbon Footprint	0	0	3	0	0
Sustainable Materials Procurement	2	0	2	1	0
Summary Score (out of 30)	10	0	23	10	6

Summary

Of the five tenders, contractor “C” demonstrated a clear commitment to sustainable practices whilst “B” seemed to ignore the issue. The other three tenders responded to sustainability criteria in a fairly minimal way. There might be value in pre warning interviewees that you are looking for more in this area than was apparent in most of the tenders.

Suggestions for Interview Questions

Environmental Management:

- Q *How will you engage with your supply chain and subcontractors on environmental issues?*
- Q *Has your organisation assessed the likely impacts of climate change impact of its work and looked at how this can be minimised?*
- Q *Has your organisation analysed its own carbon footprint? How has this affected your practices and procurement procedures?*

- Q *In delivering this contract, what are the most critical environmental and climate change impacts for you to manage and how will you do so?*
- Q *How will your organisation ensure that minimum waste goes to landfill, both during the construction, and post exhibition?*
- Q *How open will your organisation be to collaboration with the museum on the adoption of sustainable practices in the delivery of this contract?*

Suggested References and Guidelines

1. PAS 2050 - Assessing the life cycle greenhouse gas emissions of goods and services (<http://www.bsigroup.com/en/BSIGroup/sectorsandservices/Forms/PAS-2050-Form-page/>)
2. Carbon Trust - Achieving smart, energy efficient office buildings through the supply chain (<http://www.carbontrust.co.uk/Publications/pages/publicationdetail.aspx?id=GPG365&respos=0&q=supply+chain&o=Rank&od=asc&pn=0&ps=10>)
3. Carbon Disclosure Project – Supply Chain (<https://www.cdproject.net/en-US/Programmes/Pages/CDP-Supply-Chain.aspx>)

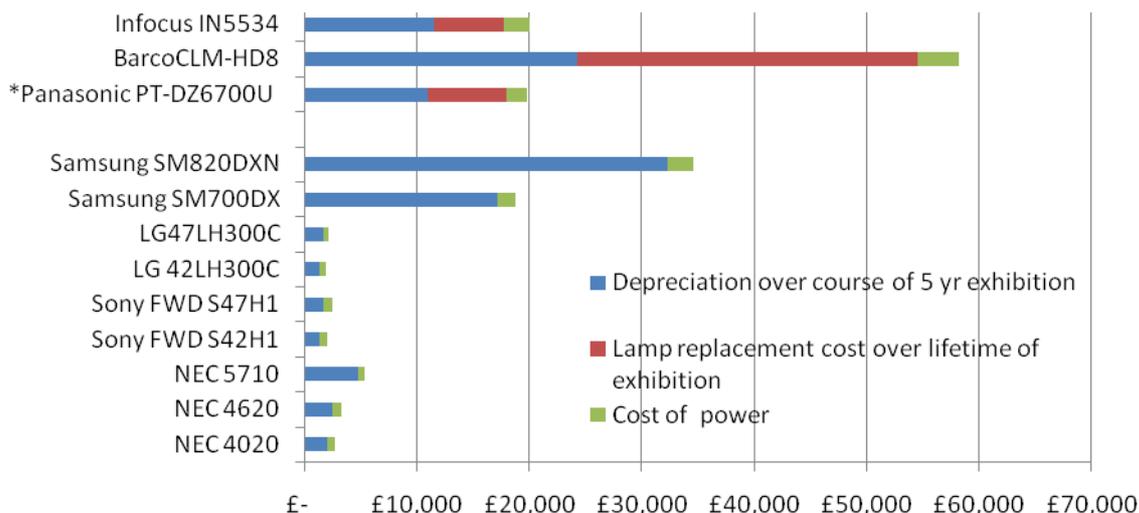
Analysis of exhibition carbon and costs from LCD screens

In the same way that we looked at projectors, we have estimated the total carbon impact of different LCD screen models over the lifetime of the exhibition, to feed into the decision making alongside performance and cost considerations. The main components are the emissions required for manufacture of the screen and the energy use over the five years of exhibition's life. As with projectors, to some extent, screens replace heating and lighting and we have tried to factor this in.

For comparison we have also included 3 projectors, including the one selected for the bulk of projection in the exhibition (Panasonic PT-DZ6700U)

Costs

The cost analysis assumes each screen / projector has a lifetime exactly as long as the 5 year exhibition. We assumed 10 hours per day on maximum power 363 days per year and electricity at 10p per unit rising to 15p over the course of the exhibition. Costs of LG models are estimates.

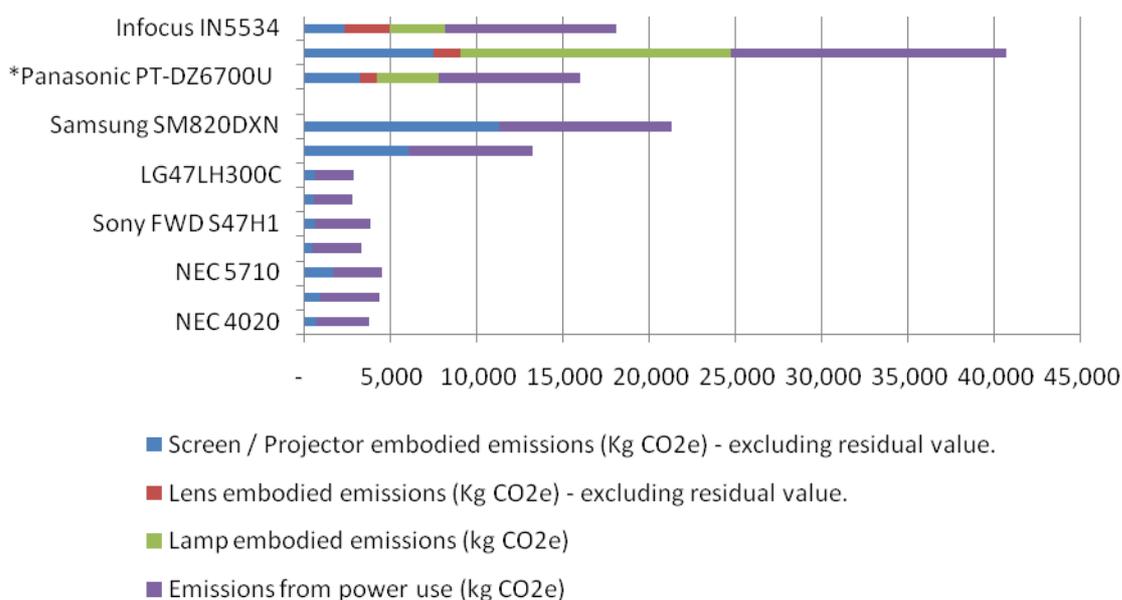


The full exhibition costs of various screen options alongside 3 projectors (top 3) over the exhibition lifetime (per screen / projector)

Carbon

Our analysis considered embodied emissions as well as electricity consumption, with some consideration given to the usefulness of heat generated as well as the impact of unwanted heat in summer increasing the need for cooling. The carbon intensity of electricity (including power station supply chains) was set at 0.6 kg CO₂e / kWh, falling to 0.5 over the course of the exhibition. Embodied emissions were crudely estimated using input-output analysis to arrive at a conversion factor of 0.35 kg/£ retail value for screens and projectors and 0.52 Kg CO₂e per £ for lenses.

Except in the case of the Samsung models and NEC5710, electricity consumption clearly dominates the carbon footprint. In these three models the two factors are roughly comparable.



The full exhibition carbon footprint of various screen options alongside 3 projectors (top 3) over the exhibition lifetime (per screen / projector)