The British Museum

World Conservation and Exhibitions Centre

First Energy Efficiency Plan

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Executive Summary

This document is based on the Energy Statement which was produced by Arup and issued with the planning application documentation in October 2009.

This document describes the aspirations of the WCEC project to reduce energy consumption and carbon emissions as far as possible.

It describes the method of calculating the carbon emissions produced by the proposed building and by a comparable notional building as defined by the National Calculation Methodology. It quantifies the target reduction in carbon emissions - compared to the notional building - which are to be met by the project.

More detail on how these reductions in energy are to be achieved is included in the Energy Statement as described above.

The Museum is taking a holistic approach to reducing energy consumption – and carbon emissions - by considering not only how the energy consumption for the new building can be minimized through its design, but also how the Museum's energy consumption across the entire Bloomsbury site can be significantly reduced over time.

Energy related design features of the new WCEC include:

- Benefits from passive design such as careful placement of the different functions within the new building to minimize energy consumption and maximize the benefit of natural daylight where this is of greatest benefit.
- Natural lighting wherever possible with controls to automatically dim or turn off electric lighting where and when there is adequate daylight. Presence detection will be installed so that lights turn off automatically when a room is not in use.
- The main items of building plant will be designed with maximum energy efficiency in mind; heat recovery systems for example being employed on all ventilation systems.
- Variable speed fans and pumps will be controlled by BMS to closely track demand.
- Close control over fume cupboard air extraction volumes will be possible, thereby greatly reducing energy consumption.

The Museum is committed to investigating the feasibility of using low carbon and renewable technologies on the Bloomsbury estate, including the long-term upgrading of existing plant and equipment, some of which will be reaching the end of its useful life over the next 10 years.

The Museum will work with Camden to reduce its carbon footprint over the long term and aspires to reduce total CO_2 emissions from the Bloomsbury Site to 25 - 30% of its current levels by 2050.

Initiatives to reduce carbon emissions through estate-wide means will be assisted where possible by the World Conservation and Exhibitions Centre. The World Conservation and Exhibitions Centre will be designed for future connection to new centralised Bloomsbury Site heating and cooling systems as well as to future district energy networks.

The primary aim for the project is to reduce the energy usage of the building as far as possible by good design and by incorporating energy efficiency measures. At this stage a Part L carbon emissions reduction of approximately 26% is estimated (15% of total Part L plus non-Part L loads) compared to the baseline. This reduces total annual carbon dioxide emission from 680 to approximately 580 tonnes. Further improvements are aspired to and will be pursued during the next design phase.

A BREEAM pre-assessment has shown that the World Conservation and Exhibitions Centre will achieve 70% of the BREEAM energy credits available. The client and design team are exploring options which will allow the building to achieve an excellent BREEAM rating.

1 Introduction

This report describes how the proposed World Conservation and Exhibitions Centre (WCEC) of the British Museum addresses the energy efficiency and renewable energy requirements of the London Plan *(*Consolidated with Alterations since 2004) Policies **4A.3**, **6, 7** and **8**.

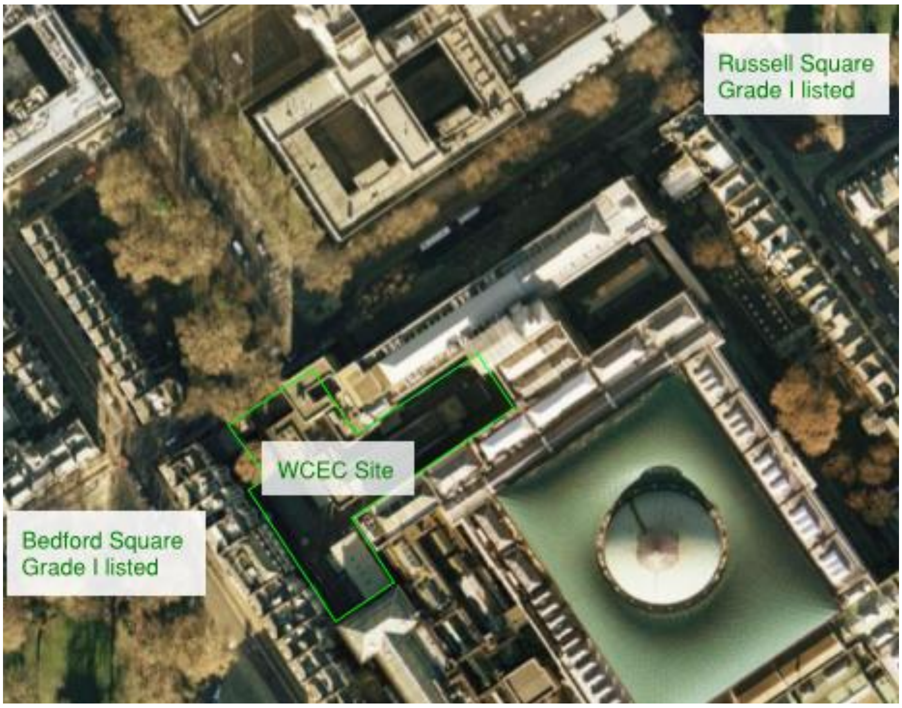
The planned redevelopment of the northwest corner of the British Museum site, the 'Site', will provide a special exhibitions space, conservation and science facilities, a new logistics hub and a new storage facility. The World Conservation and Exhibitions Centre will enable more effective use of space, improve staff working conditions and enhance the visitor experience to the Museum.

Within the new development, there will be various uses such as:

- gallery space requiring the facility to provide close control of temperature and humidity 24 hours a day during exhibitions,
- conservation studios and science laboratories,
- storage areas providing storage for artefacts and requiring various temperature and humidity conditions (depending on the artefact types) 24 hours a day for the foreseeable future,
- logistics hub, and:
- offices.

The design team will take a holistic approach to energy efficiency and sustainability applied in response to the GLA's requirements for on site renewable energy by:

- Examination of the building design
- Assessment of services plant efficiencies and low carbon technologies
- Assessment of available zero carbon technologies for incorporation into the development
- Consideration of how the WCEC fits into the British Museum campus and the future opportunities for energy efficiency and on site renewables as a campus wide strategy.

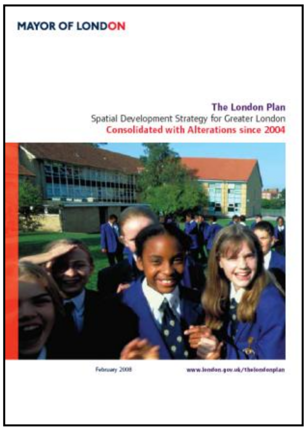


The site is located at the northwest corner of the British Museum Bloomsbury Site. This Site fills one block of the town planning grid behind residential scale buildings on Bedford Square and Montague Street. The WCEC Site is currently occupied by a number of separate small British Museum buildings. It is constrained at its eastern end by the North Range, King Edward Building and the Wellcome Wing. These buildings are all part of the Museum. At its western end are Bedford Square residences and the Duveen galleries. There is street frontage on Montague Place. A number of the buildings adjacent to the site are Grade I listed.

The British Museum has infrastructure and central plant which serve the Bloomsbury Site from two main services centres at the north east and south west of the Site. These centres are linked by water, electricity and heating infrastructure. This infrastructure is available for connection into by the World Conservation and Exhibitions Centre.

1.1 Planning Context

The UK national planning system has recently been amended to make sustainability its underlying principle, as outlined in PPS1 (Planning Policy Statement 1).



The Regional Spatial Strategy, in the form of the London Plan, reflects this with particular policies related to climate change and carbon emissions. The Plan was updated in February 2008 and is now known as *"The London Plan: Spatial Development Strategy for Greater London - Consolidated with Alterations since 2004"*.

London Plan **Policy 4A.3** states that, "*The Mayor will, and boroughs should, ensure future developments meet the highest standards of sustainable design and construction…*" Various measures are cited and those pertinent to the energy strategy include,

- *"make most effective use of land and existing buildings*
- *reduce carbon dioxide and other emissions that contribute to climate change*
- *design new buildings for flexible use throughout their lifetime*
- *avoid internal overheating and excessive heat generation*
- *minimise energy use, including by passive solar design, natural ventilation, and vegetation on buildings*
- *supply energy efficiently and incorporate decentralised energy systems (Policy 4A.6), and use renewable energy where feasible (Policy 4A.7)*
- *minimise light lost to the sky, particularly from street lights*
- *avoid creation of adverse local climatic conditions*
- *promote sustainable waste behaviour in new and existing developments, including support for local integrated recycling schemes, CHP and CCHP schemes and other treatment options."*

London Plan **Policy 4A.4** states "*The Mayor will, and boroughs should, support the Mayor's Energy Strategy and its objectives of improving energy efficiency and increasing the proportion of energy used generated from renewable sources*."

This document serves to provide the requirements as stated further in Policy 4A.4, "*The Mayor will, and boroughs should, require an assessment of the energy demand and carbon dioxide emissions from proposed major developments, which should demonstrate the expected energy and carbon dioxide emission savings from the energy efficiency and renewable energy measures incorporated in the development, including the feasibility of CHP/CCHP and community heating systems. The assessment should include:*

- *calculation of baseline energy demand and carbon dioxide emissions*
- *proposals for the reduction of energy demand and carbon dioxide emissions from heating, cooling and electrical power (Policy 4A.6)*

- *proposals for meeting residual energy demands through sustainable energy measures (Policies 4A.7 and 4A.8)*
- *calculation of the remaining energy demand and carbon dioxide emissions."*

London plan **Policy 4A.6** states, "*The Mayor will and boroughs should in their DPDs require all developments to demonstrate that their heating, cooling and power systems have been selected to minimise carbon dioxide emissions. The need for active cooling systems should be reduced as far as possible through passive design including ventilation, appropriate use of thermal mass, external summer shading and vegetation on and adjacent to developments. The heating and cooling infrastructure should be designed to allow the use of decentralised energy (including renewable generation) and for it to be maximised in the future.*

Developments should evaluate combined cooling, heat, and power (CCHP) and combined heat and power (CHP) systems and where a new CCHP/CHP system is installed as part of a new development, examine opportunities to extend the scheme beyond the site boundary to adjacent areas.

The Mayor will expect all major developments to demonstrate that the proposed heating and cooling systems have been selected in accordance with the following order of preference:

- *connection to existing CCHP/CHP distribution networks*
- *site-wide CCHP/CHP powered by renewable energy*
- *gas-fired CCHP/CHP or hydrogen fuel cells, both accompanied by renewables*
- *communal heating and cooling fuelled by renewable sources of energy*
- *gas fired communal heating and cooling"*

London Plan **Policy 4A.7** states, "*The Mayor will and boroughs should in their DPDs adopt a presumption that developments will achieve a* ***reduction in carbon dioxide emissions of 20% from onsite renewable energy generation*** *(which can include sources of decentralised renewable energy)* ***unless it can be demonstrated*** [our emphasis] *that such provision is not feasible. This will support the Mayor's Climate Change Mitigation and Energy Strategy and its objectives of increasing the proportion of energy used generated from renewable sources by:*

- *requiring the inclusion of renewable energy technology and design, including: biomass fuelled heating, cooling and electricity generating plant, biomass heating, combined heat, power and cooling, communal heating, cooling and power, renewable energy from waste (Policy 4A.21) photovoltaics, solar water heating, wind, hydrogen fuel cells, and ground-coupled heating and cooling in new developments wherever feasible*
- *facilitating and encouraging the use of all forms of renewable energy where appropriate, and giving consideration to the impact of new development on existing renewable energy schemes."*

The London Borough of Camden highlights its own requirements for the provision of energy from renewable source in its Unitary Development Plan (UDP), adopted in June 2006; specifically, Policy **SD9.C** – *Use of Energy and Resources* and **1.64**. It should be noted that if the renewable energy requirements for the London Plan are met, those for Camden would also be met.

2 Assessment methodology

An initial study was carried out using benchmarks and historical data to provide an indication of likely energy requirements. Following this further preliminary analysis was then undertaken using *IES <virtual environment>*, a specialised software suite which has been approved by government to assess the likely compliance of a building with Approved Document Part L of Building Regulations.

The assessment of the World Conservation and Exhibitions Centre's energy use and associated carbon emissions has followed the methodology:

1. Identify a suitable 'just compliant' baseline
2. Compare individual energy efficiency measure against the 'just compliant' baseline
3. Estimate combined effects of energy efficiency measure to give new 'lean' benchmark
4. Compare low and zero-carbon technologies against 'lean' benchmark

This report uses the energy-to-carbon conversion factors provided by Approved Document Part L.

3 Baseline

The baseline is derived from a model which takes as its basis the proposed geometry and space usage identified during the early stages of design development. As a starting point, default system and fabric properties were assigned. Improvements were made iteratively until the model complied with the Part L Target Emissions Rate (TER). This 'just compliant' model is used as the baseline.

This baseline model includes efficient façade and building envelope constructions and heat recovery on all major air handling units. The baseline Part L emissions are as follows:

TER	**26.9 $kgCO_2/m^2$**
BER	**26.9 $kgCO_2/m^2$**
Difference	**0%**

In addition to the Part L loads contributing to TER and BER, non-Part L loads (eg computers, lab equipment etc) are estimated to be as follows. This is based upon NCM profiles.

Non-Part L loads = 18.8$kgCO_2/m^2$

This gives adjusted target and building emissions rates as follows:

TER+	**45.7 $kgCO_2/m^2$**
BER+	**45.7 $kgCO_2/m^2$**
Difference	**0%**

A breakdown of these emissions is represented by the following graph.

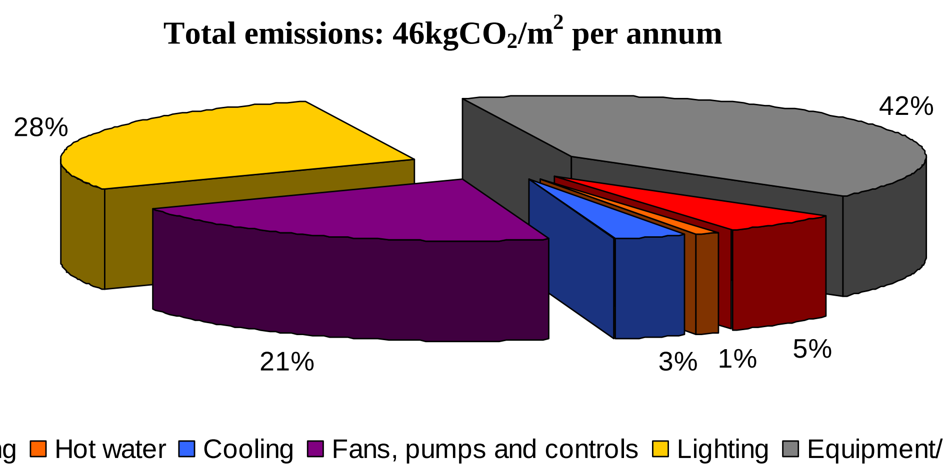


Figure 1: Breakdown of energy use for the World Conservation and Exhibitions Centre

Baseline CO_2 emissions for the World Conservation and Exhibitions Centre is in the order of 680 tonnes per annum, or 46 $kgCO_2/m^2$. If the energy consumption is broken down into natural gas and electricity, the following graphic is generated:

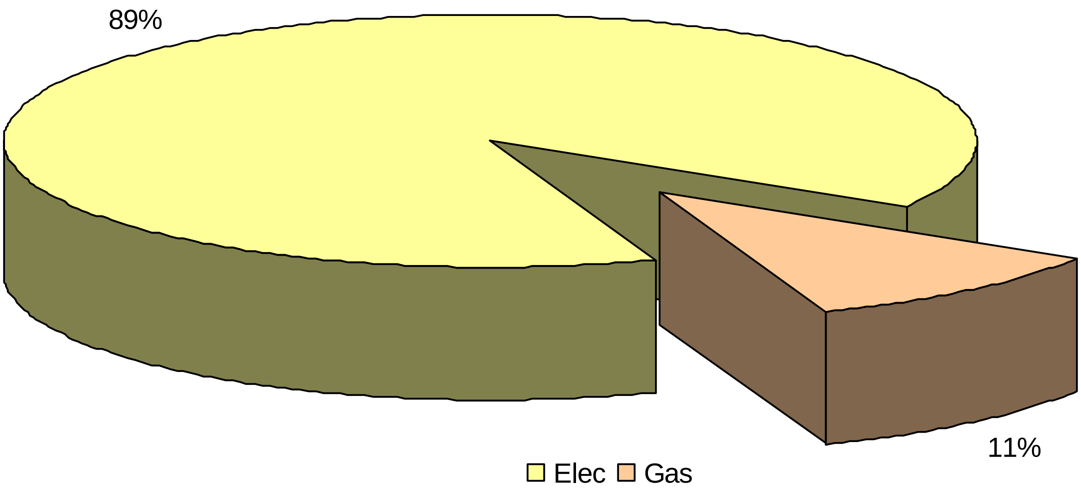


Figure 2: Ratio of electricity to natural gas

As can be seen, the World Conservation and Exhibitions Centre is primarily electricity-led, rather than gas/heat-led.

As described earlier, the baseline model includes efficient facades and heat recovery in air handling units and is compliant with Part L. From this baseline, further energy efficiency strategies were then modelled to assess their anticipated affects on carbon dioxide emissions. These strategies and their effects are described in Chapter 5.

Although efficient façade performance values were used in the model, reflecting the aspirations of the façade design, the design team have been investigating the possibility of further improvement to the façade performance during the design progression. Further improvements to the facade performance criteria are being specified. Once these have been confirmed by the successful facade contractor, an updated model can be run.

It should also be noted that the gas/heat requirements will, of course, be derived from the existing Bloomsbury Site-wide heating system rather than from stand-alone plant on this development.

4 Building Design - Passive Measures (Be Lean)

This chapter describes the passive, building form related measures which affect energy consumption and CO_2 emissions. The building design can have a large impact on the energy consumption. For this project, the passive measures can be considered in four categories:

- Orientation – affects solar gain
- Plan depth – affects depth of daylight penetration
- Façade – affects heat loss and heat gain
- Location of building functions – affects energy usage.

All these elements of the design of the WCEC have been used beneficially to the project and in a way which reduces energy consumption and therefore carbon emissions. Detailed descriptions are included in the Energy Strategy Report.

5 Building Design - Energy Efficiency Measures (Be Lean)

As a publicly funded institution, it is very important to the Museum to minimise energy costs. This adds further importance to the environmental implications of designing a low energy solution. Every effort is being made to reduce energy use where possible while ensuring that the functions being carried out in the development are not being compromised.

In the Energy Statement we describe the measures which have been investigated and incorporated to reduce energy consumption and carbon dioxide emissions. Where these have been explicitly modelled the estimated saving is given in comparison with the baseline model. The figures obtained by analysing the primary measures are summarised below.

5.1 Assessment of Energy Reduction Measures

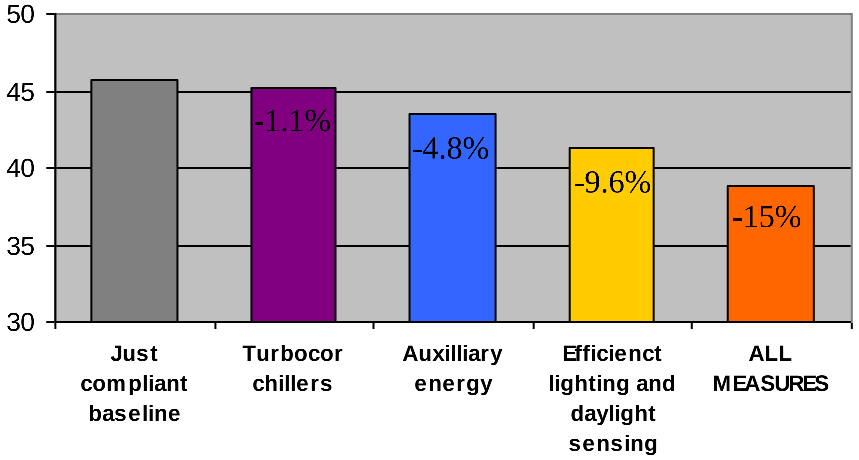
A number of improvements were added to the baseline model described in Chapter 3, and the analysis rerun to assess the impact of each measure.

These measures are not, of course, cumulative, so to finalise the comparison, a model with all the proposed improvements was analysed to calculate the anticipated energy consumption and carbon dioxide emissions.

The models tested and results achieved were as follows:

Model	**Carbon dioxide emissions savings**
Baseline model	-
Baseline plus high efficiency chillers	1.1%
Baseline plus improvements in auxiliary energy by use of VAV, Variable speed, improved controls	4.8%
Baseline plus improved lighting and lighting controls	9.6%
All above measures incorporated – new ‘be lean’ baseline	15.1%
All above measures incorporated plus future improved heating efficiency following boiler replacement	17.1%

These savings are represented by the following graph:



In Part L terms the difference between target and building emissions rate is as follows:

TER	26.9 $kgCO_2/m^2$
BER	19.8 $kgCO_2/m^2$
Difference	26.3%

With the addition of the non-Part L loads which are assumed to have remained the same (18.8$kgCO_2/m^2$) the adjusted emissions rates are estimated to be as follows.

TER+	45.7 $kgCO_2/m^2$
BER+	38.8 $kgCO_2/m^2$
Difference	15.1%

The emissions rate of the 'lean' building translates to total building emissions of approximately 580 tonnes of CO_2 per annum.

This new 'lean' benchmark will be used in remainder of the report for the comparison of zero-carbon technologies.

During design development the impact of this measure will be assessed and the improvement in energy consumption and CO_2 emissions evaluated.

6 Low Carbon Technology Assessment (Be Clean)

The Energy Strategy report described the low carbon technology options available at present and the options which could be used on the WCEC site.

The technologies described include:

- Combined Heat and Power
- Connection to District Heating/CHP locally
- Biofuels
- Waste Heat
- Fuel Cells
- Ground source heat pumps
- Basement heat pump system

The innovative matching of a cooling load in the development to the heating requirement in the basement storage areas by embedding heat-pump coupled pipework in the basement walls was investigated during stage E. Because of the cool requirements in storage and science areas in the basement, there is a very small temperature difference between the storage areas and surrounding ground. This has meant that there is little to no benefit in energy terms in running an energy 'sink' system in basement areas. This idea is therefore not being continued further.

7 Zero Carbon Technologies (Be Green)

A preliminary qualitative analysis of available renewable technologies has been made. This is in line with the London Plan and the suggested assessment procedure, *Integrating renewable energy into new developments: Toolkit for planners, developers and consultants*.

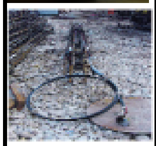
	Item	Renewable Energy Source Options	Feasibility For Further Consideration	System Description	Design Considerations	Comments
	1	WIND LARGE SCALE TURBINES	No		The city-centre location precludes the inclusion of large scale wind turbine in terms of physical constraints.	
	2	WIND SMALL SCALE	Yes	Maybe possible to locate turbines on the roof of the new building.	•Structural Viability •Noise •Availability of wind resource •Visibility issues	•Horizontal turbines need space to turn. •Vertical turbines tend to generate less energy than conventional machines
	3	PHOTOVOLTAIC ROOFTOP	Yes	Stand alone panels or roof mounted.	•Requires roof space; might displace plant space for conventional systems. • Solar shading from adjacent buildings? •DC Power generated	Generally high capital cost for low return in CO2 savings
	4	PHOTOVOLTAIC CLADDING	No		The Building is likely to have little unshaded southerly facade	
	5	SOLAR HOT WATER	Yes	On the roof	•Requires roof space; might displace plant space for conventional systems. • Solar shading from adjacent buildings? •Might compete with CHP	Significant proportion of hot water demand can be met with medium grade heat from CHP all year round.
	6	BIOMASS HEATING	No - Not as part of WCEC project. May considered for BM Site Wide strategy		•Biomass boilers require large fuel storage facilities •Security of fuel supply chain.	•Development is located in the heart of London raising concerns over fuel delivery. •Issues of local pollution.
	7	BIOFUEL CHP	No - Not as part of WCEC project. May considered for BM Site Wide strategy		•Lack of proven technology at small-scale •Fuel storage and delivery	•Problems of delivering large quantities of fuel to the centre of London to maintain 24hr operation. •Storage of large volume of inflammable liquids under a building
	8	GROUND SOURCE HEAT PUMP GROUNDWATER BOREHOLES	No - Not as part of WCEC project. May considered for BM Site Wide strategy	Extraction and reinjection borehole(s) required within site boundary	•Long term thermal degradation of boreholes. •Prediction of yields uncertain - needs site testing.	Annual thermal balancing required from ground source.
	9	GROUND SOURCE HEAT PUMP ENERGY PILES	Yes - as basement heat transfer within structural scheme.	Network of closed pipe loops in basement walls	Usable load limited to heat input required.	Annual thermal balancing required.

Table 1: Renewable Energy Technologies

8 Detailed renewables assessment

The renewable options deemed feasible at the initial assessment stage have been looked at in more detail with savings estimated to provide a basis for further comparison. The options looked at in detail and described in the Energy Strategy Report are:

- Photovoltaic cells
- Wind turbines
- Biomass boilers
- Solar hot water

Of these, roof mounted photovoltaics are being retained for inclusion in the next stage of the design.

9 Conclusions

Of the renewables options discussed in the Energy Strategy report and referred to in the preceding section, large-scale wind turbines and photovoltaic cells mounted vertically on the façade of the building have been discounted. After further consideration, building integrated small wind turbines have also been discounted.

Biomass and Biodiesel technologies generally incur storage and deliveries of large amounts of fuel to the site and the removal of ash from the site. Connection to the existing estate-wide heating circuit precludes the need for heating and therefore biomass and biodiesel technologies in the World Conservation and Exhibitions Centre. While it would be possible to install these technologies in the World Conservation and Exhibitions Centre and therefore provide a significant renewables contribution to energy usage, this would be neither an environmentally friendly nor sensible solution for this project, rather a duplication of existing plant just to reach the renewables target.

Photovoltaic and solar thermal technologies depend on the availability of roof space to be viable. A preliminary assessment suggests that roof space is available and these will be assessed further in concert with the design team and aspirations of the client. The PV panel installation examined in this report is estimated to yield a saving of approximately 2.8% over the ‘lean’ benchmark.

Of the low carbon technologies, ground source technologies depend on the suitability of the soil, geology and hydrogeology of the site and tend to require a number of surveys to establish their viability for a site. Generally, the heat removed from the ground should be replaced over a period of time; therefore the cooling and heating should be balanced. Open loop systems generally require two boreholes at a distance of 100 m apart to allow for abstracted water to be returned to the aquifer. This cannot be accommodated solely on the WCEC site and is not being progressed.

The innovative matching of a cooling load in the development to the heating requirement in the basement storage areas by embedding heat-pump coupled pipework in the basement walls was investigated during stage E. It was found that there is little to no benefit in energy terms in running an energy ‘sink’ system in basement areas because of basement conditions. This idea is no longer being pursued.

A reduction in carbon dioxide emissions from the baseline using the renewable and low carbon technologies relevant to this project do not produce a 20% saving but are likely to contribute a saving of 5-6%. Due to the constraints of the site, it is unlikely that the full renewables target can be met without incorporating heating related measures. As previously stated, local heating related measures such as biomass and liquid bio-fuel technologies are not the optimum heating solution for the World Conservation and Exhibitions Centre given its connection to the existing estate-wide heating system. The Museum is investigating options for reducing the carbon dioxide emissions of the estate-wide system. Improvements here will be of greater environmental benefit than a solution restricted to the World Conservation and Exhibitions Centre.

While investigations into renewables continue, the primary aim for the project is to reduce the energy usage of the building as far as possible by good design and by incorporating energy efficiency measures. At this stage a Part L carbon emissions reduction of 26% is anticipated over the baseline through energy efficiency measures alone. This is equivalent to a 15% reduction over total building loads. Further improvements will be aspired to during the next design stages.