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**Embodied Energy of a UK office fit-out**

**By**

**Sara Abtahi**

**The Bartlett school of graduate study**

**University College London**

**A dissertation submitted in the part fulfillment of the degree of**

**Master of Science Built Environment**

**Environmental Design and Engineering**

**University of London**

**2006**

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## **Acknowledgments**

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I would like to thank my supervisor Dr. Ben Croxford for his guidance and dedication for the fulfillment of this work.

My special thanks to Mr. Matthew Herbert the director of interior design as well as Mr. Trevor Butler the head of sustainability from Building Design Partnership Consultant for their useful information and documentation pertaining to the case study also I would like to appreciate them for their guidance throughout my study.

In addition I would like to express my special thanks to my family for their further support right through my studies within all these years.

## Abstract

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This dissertation investigates the environmental impacts of interior office fit-outs in a specific office building in London namely the British Sky Broadcasting Limited, as a further detailed case study. The environmental categories are embodied energy and global warming potential; which are two of the most important indicators of the overall environmental impact of buildings. The research has shown that selecting products and materials for interior office fit-outs can have a significant affect on environmental impacts for a building. The purposes are to influence design decisions and raising the awareness of occupants, interior designers and architects to consider the overall life cycle embodied energy and global warming potential, in relation to selecting more sustainable interior office fit-outs. This project aims to estimate the environmental performance of interior office fit-outs by promoting life cycle assessment as a tool to examine their overall environmental impacts. The total embodied energy of the building production was determined using the energy intensity figures of a full range of office fit-outs. Furthermore the environmental impacts were calculated during their manufacturing process, use and final disposal according to Green guide hand book and BRE research. Consequently this study has shown that the calculated embodied energy of office internal equipments could contribute to increase the overall embodied energy of a building by 35%.

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# 1. Introduction

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## **1.1 Overview**

Global warming is becoming a major concern around the world, the release of CO<sub>2</sub> emission and other gases in to atmosphere is increasing the greenhouse effect and directing to global warming. Therefore, minimizing the overall emission of CO<sub>2</sub> in to the atmosphere, from the operation of buildings and materials arises from their manufacture process and transport of materials during refurbishment of buildings should be the main concern.

The environmental impact and energy required of office buildings have been the main concern over the recent years; therefore many investigations are beginning to use life cycle assessment to qualify primary energy, emissions, global green house gases and natural resource consumptions. Previously the main concern was focused on environmental impacts on understanding of energy use during the operational period of office buildings, in this approach a significant feature has been ignored which is known as the embodied energy of construction materials and building components, while energy used to manufacture and transport of building materials accounts for 10% of the total energy consumption in UK<sup>1</sup>. However the energy embodied in fixture, fitting and all the internal components which is used by occupant in internal layout of office buildings are rarely mentioned.

Considering the overall embodied energy that go in to the buildings have significant proportion, therefore in order to understand the overall impacts of the building, all life cycle stages should be considered from material production, manufacture to use and retirement, so assessing the environmental impacts of a complex system need an understanding of the environmental impacts from all the points. Accordingly once choosing interior office fit-outs and components, recognizing the environmental impacts of products should be the main concern, as a result determining which products are best

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<sup>1</sup> BREEAM 98 for offices – An environmental assessment method for office buildings

from an environmental point of view may seem the most important part of sustainable design decision. The core concepts of this study are closely related to the sustainable design decision of office fit-outs with respect to the environmental impacts associated with energy used throughout the extraction of raw materials, energy used during transportation and assembly of office fit-outs.

## **1.2 Purpose of the study**

This dissertation will investigate the importance of embodied energy and global warming potential in the context of life cycle environmental impacts of interior materials and components, as setting out the internal fixtures and fittings during refurbishment of an office building in UK to achieve more sustainable decisions in terms of selecting interior office fit-outs and finishes. This study mainly focused on a detailed case study of New Horizons court Refurbishment of British Sky Broadcasting Limited, following the principles of Green building and sustainable building design which are based on reducing energy in use, reducing embodied energy and CO<sub>2</sub> emissions which are the most important factors during recent decades in office interior design and refurbishment. Thus, the main concern in this project will be focused on the importance of primary energy and delivery energy known as embodied energy, as well as global warming potential due to refurbishing of the office fit outs, which are the two important indicators of the overall environmental impacts of building materials and components.

Further discussion gives background information on climate change and global warming in chapter 2, chapter 3 investigates the energy use by buildings, chapter 4 discusses embodied energy, chapter 5 presents a case study life cycle analysis of all components of an office fit-outs. Chapter 6 analysis of the case study and chapter 7 investigates the overall result review of the case study.

## 2. Climate change and Global warming

### 2.1 Introduction to Green House Gases

There is a new evidence that most of the warming over the last 50 years is attributable to human activities which have changed the composition of the atmosphere and climate change through the increase of green house gases effects as seen in figure 1, which are defined mainly as carbon dioxide, methane, nitrous oxide and ozone are occur naturally and Chlorofluorocarbons (CFCs) which are man-made chemicals, are the main principals of green house gases<sup>2</sup>.

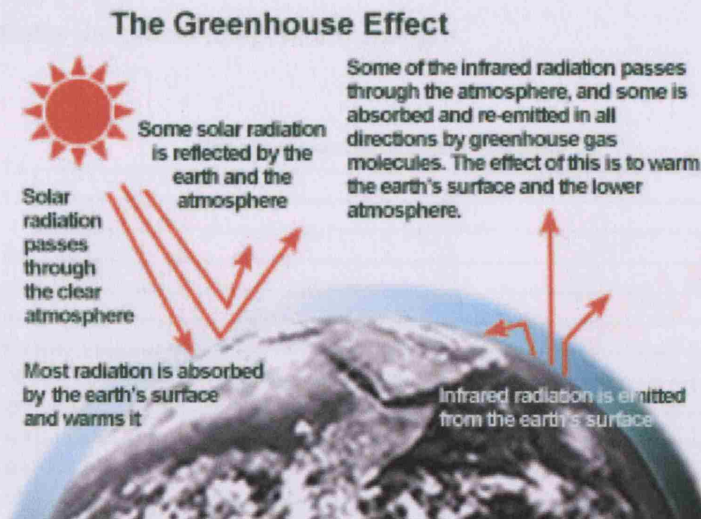


Figure1 - The green house gases effect. Source: [www.pca.state.mn.us/greenhouse.html](http://www.pca.state.mn.us/greenhouse.html)

Before the industrial revolution very few gases from human activities were released in to the atmosphere, through population growth, fossil fuels and deforestation, mixture of gases were affected in to the atmosphere. Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased by 30%, methane concentration have increased more than double and nitrous oxide have risen by 15%.

<sup>2</sup> <http://www.pca.state.mn.us/greenhouse.html>

These increments have enhanced the heat trapping capacity of the earth's atmosphere<sup>3</sup>. Therefore, in the developed world protection of the environment is becoming a critical issue for government, building developers, architects, engineers and public. The environmental concern is that the industrialized economies have significantly changed the planet's climate, ecosystem and atmosphere<sup>4</sup>.

## 2.2 Climate Change and Global Warming

Increasing the level of concentration of green house gases are likely increase the rate of climate change which are expected the average global surface temperature could rise up to 0.6 – 2.5 ° C in next fifty years and 1.4 – 5.8 ° C in the next century<sup>5</sup>. As climate warms evaporation will increase that would increase the global precipitation average. Figure 2 demonstrates the global temperature changes.

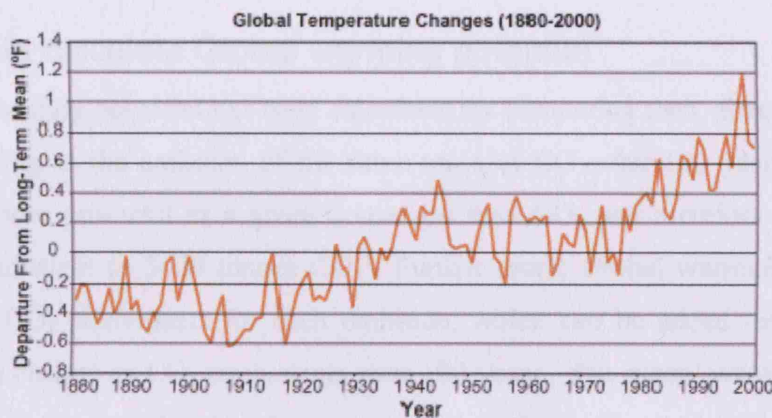


Figure 2 – Global temperature change. Source: U.S National Climatic data centre

The aim of the government is to make a reduction by 20% in UK emission of greenhouse gases below 1990 levels by 2010 whilst the Royal Institution of British Architects (RIBA) has stated that members should support the goal of reducing carbon emissions arising from building in construction and use by 30% against 1990 levels by 2010<sup>6</sup>.

<sup>3</sup> <http://www.pca.state.mn.us/greenhouse.html>

<sup>4</sup> BRE Information page- The environmental impact of buildings-Dec1991

<sup>5</sup> <http://www.yosemite.epa.gov/oar/globalwarming.nsf/content/Climate.html>

<sup>6</sup> Sustainable homes – Embodied Energy in residential property, <http://www.sustainablehomes.co.uk>

### 2.2.1 Global warming potential

The Global Warming Potential of a greenhouse gas is the percentage of global warming from one unit mass of a green house gas to one unit mass of carbon dioxide over a period of time which this is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming<sup>7</sup>. In general Global warming potentials are used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. This is based on the radiative efficiency of heat-absorbing ability of each gas relative to that of carbon dioxide, as well as the amount removed gas from the atmosphere over a period of time in relation to CO<sub>2</sub> emission. The GWP provides a creation of converting emissions of various types of gas in to the atmosphere which allows climate analysts to combine the radiative impacts of various greenhouse gases into a uniform measure denominated in carbon dioxide equivalents. In general gases known as having a green house gases effect which are include as CFCs, HFCs, N<sub>2</sub>O and methane.

### 2.2.2 How to calculate Global warming potential

The global warming potential has been calculated by comparing their direct and indirect radiative forcing to the emission of the same mass of CO<sub>2</sub> after 100 years, CFA-11 is 3400 times more powerful as a green house gas than CO<sub>2</sub> and therefore one tonne of CFC-11is equivalent to 3400 tonnes CO<sub>2</sub><sup>8</sup>. Further more; Global warming potential is measured in CO<sub>2</sub> equivalents for each emission, which can be added into the profile under climate change as CO<sub>2</sub> equivalents over 100 years. The global warming potential of different gases is associated to the amount of time they will spend in the atmosphere therefore a time scale is applied to the GWP figures, mostly the amount of radiative forcing will make over that period, as a result it would be important to recognize how long the gases will last in the atmosphere, for instance both carbon dioxide and CFC-11 are green house gases but they have different life time in the atmosphere and they will accordingly have different relative effect over different timescales. In general three

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<sup>7</sup> [http://en.wikipedia.org/wiki/Global\\_warming\\_potential#Calculation\\_of\\_GWP](http://en.wikipedia.org/wiki/Global_warming_potential#Calculation_of_GWP)

<sup>8</sup> BRE methodology for environmental profiles of construction materials, components and buildings

different scenarios are presented for global warming potential over 20 years, 100 years and 500 years<sup>9</sup>.

### **2.3 The contribution of buildings to climate changes**

The UK is responsible for only 3% of the total CO<sub>2</sub> emission of the world therefore in order to achieve a significant reduction in global CO<sub>2</sub> concentrations, we need international co-operation<sup>10</sup>. The consequence of energy use is becoming an important environmental issue for society as a whole. Without continuing supplies of energy maintaining our current lifestyles would not be possible, however fossil fuels, such as oil, gas and coal from which we generate most of our energy, are not unlimited and burning those releases carbon dioxide CO<sub>2</sub>, one of the principle greenhouse gases which are thought to be responsible for global warming. Other pollutants from burning fossil fuels are also causing problems for our environment.

Buildings accounts for approximately 50% of the energy consumption in the UK, and around the carbon dioxide produced is partly responsible for increased climate change and global warming<sup>11</sup>. There are some other greenhouse gases that are not naturally accruing in the atmosphere, which include as hydro-fluorocarbon (HFCs), per-fluorocarbons (PFCs) and sulfur hexafluoride (SF<sub>6</sub>) that are generated from buildings and manufacturing processes.<sup>12</sup>

Construction of buildings, building materials and use of buildings directly and indirectly are responsible for a large amount of the total emission of CO<sub>2</sub> in UK, about 50% of the the total CO<sub>2</sub> emission arises from heating, cooling and lighting in buildings and 10% from energy used for materials through production and transportation which is defined as embodied energy<sup>13</sup>. By reducing the embodied energy of building materials and

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<sup>9</sup> BRE methodology for environmental profiles of construction materials, components and buildings

<sup>10</sup> BRE Information page- The environmental impact of buildings-Dec1991

<sup>11</sup> <http://www.hadrianawards.com/shortlist.php>

<sup>12</sup> <http://yosemite.epa.gov/oar/globalwarming.nsf/content/Emissions.html>

<sup>13</sup> BREEAM 98 for offices-An environmental assessment method for office buildings

**maximising the energy efficiency of buildings in use it is possible to reduce emissions of CO<sub>2</sub>.**

**In order to reduce the carbon emission arising from buildings, the government in the UK is promoting energy efficiency in buildings through different kind of legislation which aimed at improving the environment, such as part L of the Building Regulations, the Energy Efficiency Best practice Program and the Home Energy Conservation Act, to reducing CO<sub>2</sub> levels which require significant improvement in energy efficiency.**

## 3. Energy attributable to office buildings

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### 3.1 Operational energy of office buildings

The UK's fastest growing energy consumption is in services part. Within this part, energy consumption is rapidly growing in office buildings, currently most of an office building energy consumption over the life time is in lighting, heating, and cooling and computer usage which identified as operational energy or building energy use. However, in a world affected by global warming and over long term of energy supplies, it is important to reduce energy use in office buildings. Therefore, analyzing the features of building's energy in-use to find practical ways of reducing energy consumption becomes a main concern during recent years.

Today's world view of energy efficiency is likely different from the energy conservation mentality of the 1970s<sup>14</sup>. In high performance office buildings, energy efficient design begins with a reduction of the building's heating and cooling loads, because the most intensive use of energy usually results from the heating and cooling of spaces whereas a careful design can minimize the need for heating and cooling through out the year, which would help to minimize the fossil energy consumption . Even though, the premises forecasters warn that energy consumption per square meter occupied is growing faster than floor space<sup>15</sup>, so improvement in design, construction and operation of office buildings could reduce the energy consumption per square meter of a space. While, some 10-20 percent of the energy used in office buildings over their life span is in the form of embodied energy which is integrated to materials, building components and within the process of building<sup>16</sup>. However, the buildings not only use energy but also take energy to construct them as well. By comparison often the energy of the items that go into the completed constructions is overlooked. Often the interior of the buildings are designed and managed by interior designers, project managers and other staffs who play a part in

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<sup>14</sup> Building energy use – <http://www.epa.gov/energystar>

<sup>15</sup> [www.cityoflondon.gov.uk/NR/rdonlyres/.../0/BC\\_RS\\_tallbuild\\_0202\\_FR.pdf](http://www.cityoflondon.gov.uk/NR/rdonlyres/.../0/BC_RS_tallbuild_0202_FR.pdf) Tall buildings and sustainability – The corporation of London – February 2002

<sup>16</sup> [www.cityoflondon.gov.uk/NR/rdonlyres/.../0/BC\\_RS\\_tallbuild\\_0202\\_FR.pdf](http://www.cityoflondon.gov.uk/NR/rdonlyres/.../0/BC_RS_tallbuild_0202_FR.pdf). Tall buildings and sustainability – The corporation of London – February 2002



organizing and designing the office environments. Therefore, efficiency in design and selection of office fit-outs that go into the constructed office buildings can make a significant difference in both economically and environmentally sound offices. While, the energies that go into the building as office fit-outs have significant impacts on environment. Therefore, examining this energy is the main consideration that goes beyond the scope of this dissertation.

### **3.2 Embodied energy of office buildings**

Office buildings are high consumers of energy and therefore the main source of carbon dioxide. It can be seen that operation of office buildings use almost ten times as much energy annually as the production and assembly of the materials and components, however this energy is still have a significant impact on our environment. The study of embodied energy of office buildings provides us an understanding of how much and where energy is used during the construction and assembly of building products and components. By comparison 5-6 percent of the UK's national energy is used to generate the building materials and components<sup>17</sup>. As buildings become increasingly energy-efficient, the energy required to construct them becomes more significant in relation to what required for running them. However, some of the modern materials consume high amount of energy in their manufacture.

The energy embodied in office buildings varying in height from a few storeys to over 50 storeys. The energy embodied in substructure, superstructure and completed elements was investigated for the following heights: 3, 7, 15, 42 and 52 storeys<sup>18</sup>, as tabulated in table 1. The two high-rise buildings have around 60 percent more embodied energy per unit gross floor area (GFA) in their materials in contrast to the low-rise buildings<sup>19</sup>.

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<sup>17</sup> BRE methodology for environmental profiles of construction materials, components and buildings

<sup>18</sup> Source:<http://buildlca.rmit.edu.au/casestud/Ee/EEmain.html#OVERVIEWCommerci>

<sup>19</sup> Source:<http://buildlca.rmit.edu.au/casestud/Ee/EEmain.html#OVERVIEWCommerci>

Code name	GFA (m <sup>2</sup> )	description
Small Office 1	6500	3 storey
Small Office 2	27350	7 storey
Medium Office	47000	15 storey
Large Office 1	99300	42 storey
Large Office 2	130000	52 storey

Table 1- Typical floor area of different size of office building – Gross floor area of m<sup>2</sup>

Source:<http://buildlca.rmit.edu.au/casestud/Ee/EEmain.html#OVERVIEWCommerci>

Figure 3 indicates the typical embodied energy values as GJ per square meter of ground floor area (GFA) for sizes of office buildings as indicated in table 1. The figure contains the total embodied energy of all the building components and also includes all materials in product systems which are commonly used, including structural group, sub structure, windows, roof and finishes. Building height was found to dictate the amount of embodied energy in the structure group elements such as upper floors, internal walls, external walls, columns and staircases, while other elements as roof, windows, substructure and finishes seemed uninfluenced. The elements breakdown for various types of office buildings can be seen in appendix 1, 2, 3, 4 and 5.

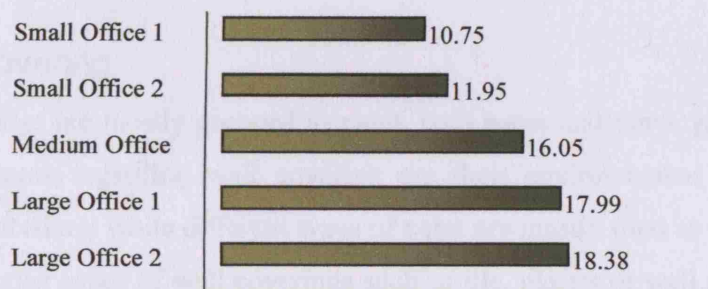


Figure 3- Commercial building case studies Embodied Energy values GJ per square meter of GFA. Source: <http://buildlca.rmit.edu.au/casestud/Ee/EEmain.html#OVERVIEWCommerci>

### **3.3 What is an office fit-out?**

Office fit-outs or office refurbishment may involve everything from selecting materials to buying interior products and components, in general an office fit-out or refurbishment may involve the removal and replacement of wall, ceiling, floor coverings and office partitioning also installing new fixtures, fittings, furniture, equipments and appliance. While there are some issues associated with the ingredients, manufacturing process, use and disposal of different production in office buildings which would be considered during selection of each product. In this dissertation office fit-outs mainly considered the following four important elements:

- Wall covering
- Floor covering
- Office furniture
- Office partition

### **3.4 Quality of fit-out**

Generally new fit-outs should be achieved cost effectively, and should be designed for maximum reuse of existing fit-outs and components and be reliable with the occupancy rate parameter to achieve more plan efficiency and a sustainable overall design.

#### **3.4.1 Wall covering**

The wall coverings are mostly grouped as paint, wall paper and vinyl, plasters and tiles. The main concerns regarding wall covering are their environmental impacts during manufacture procedure, while different types of paint are mostly used as wall covering in contrast to the other types of wall coverings such as tile, plaster or wall paper. The main concerns regarding to selection of paints are their environmental impacts during manufacture of vinyl, acrylic and alkyd based paint<sup>20</sup>, though selecting the correct type of paint or any other wall covering will give more satisfactory in terms of sustainable design decisions.

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<sup>20</sup> Green building hand book volume 2

### 3.4.2 Floor covering

Floor coverings are always used in large amounts in office fit-outs and refurbishments; therefore selection of floor covering is a key item when looking in sustainability. Floor coverings are mostly laid on top of an underlying of concrete or beam that can be summarized as carpet tile, parquet, laminate, wooden planks, vinyl and linoleum<sup>21</sup>. There are some issues that might be considered, the energy use and the source use of the material during manufacturing process of different type of floor covering also the ease of installation and maintenance, durability and flexibility during use of the product and finally the disposal of the product after use are the main concern regarding the selection of floor covering.

### 3.4.3 Office furniture

Office furniture includes chairs, desks, tables, filing and storage cabinets and their associated components which can be made from various types of materials such as metal, wood and wood based products or composite boards, plastic and fabric. There are some environmental issues associated with office furniture regarding the energy use and resource usage of the production of each component.

### 3.4.4 Office partition

Office partitioning contains different materials including, aluminum, steel structure, pinex soft board, white board MDF, gypsum board wall, clear or opaque glass and panel finishes such as wool, wool blends, vinyl and other synthetic fabrics<sup>22</sup>, which are widely used in production of office partitions. Considerations should be given to providing privacy and notice boards in general layout of the office; mainly acoustically treated partitions should be used for meeting and conference rooms which contained additional layer of plaster board and acoustic infill<sup>23</sup>. Glass or partial glazings are widely used to improve light transmission in to the internal space.

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<sup>21</sup> A guide to sustainable office fit outs-December 2005.<http://www.mfe.govt.nz>

<sup>22</sup> A guide to sustainable office fit outs-December 2005.<http://www.mfe.govt.nz>

<sup>23</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

### **3.5 Quantity of office space and occupancy rate**

Some obligations apply to the provision of office fit-outs and must be complied with the designers and contractors. Mainly these obligations are regarded as individual work space area, support spaces as meeting rooms, conference room, reception areas, waiting area, storage and circulation space. There are some recommended maximum areas relevant to particular functions in office buildings, while the proportion of each specific area needs to be considered in order to achieve the occupancy rate. The average area per person for a separate tenancy, which is obtained by dividing the total usable office space by the total number of staff<sup>24</sup>, the highest occupancy rate for office space, is 15m<sup>2</sup> per person<sup>25</sup>. There are some other alternative office utilization measures which provide useful information on the planned efficiency of an area that give space allowance for individual fit-outs and components as following<sup>26</sup>:

- Work station            7 m<sup>2</sup>
- Desk/chair              3.8 m<sup>2</sup>
- Filing cabinets        1.0 m<sup>2</sup>
- Book case               1.2 m<sup>2</sup>
- Visitor chair            1.2 m<sup>2</sup>
- Table                    1.2 m

Also there are some recommended areas for meeting rooms and conference rooms as following<sup>27</sup>:

- Meeting room        4-6 person    10 m<sup>2</sup>
- Conference room    8-10 person   18 m<sup>2</sup>
- Meeting room        14-18 person 30 m<sup>2</sup>

<sup>24</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

<sup>25</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

<sup>26</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

<sup>27</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

### **3.6 Principle of sustainable office fit-outs**

The definition of sustainability as applied to buildings requires the following<sup>28</sup>:

- Long term energy efficiency over the life time of the building
- Respect to the environment – both global and local
- Good quality of the work environment
- Good use of resources, water and energy use
- Low financial impacts and cost effectiveness over the long term

In general the office design and fit-out should support energy efficiency and minimize life cycle cost through the selection of durable and low maintenance materials. The main concept in new office fit-out design or refurbishment is to provide maximum flexibility of internal space and minimum cost for future change<sup>29</sup>. While the greater benefit to the environment and cost saving will be achieved when sustainable principles are incorporated with the design from initial design stage, more sustainable decisions in terms of selecting sustainable products could minimize environmental impacts. The principle requirements of a sustainable fit-out are as follows<sup>30</sup>:

- Deal with large scale impacts
- Select components with the lowest environmental impacts
- Consider impacts in terms of scale, local, regional and global
- Choose a local source rather than imported materials or components

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<sup>28</sup> A guide to sustainable office fit outs-December 2005.<http://www.mfe.govt.nz>

<sup>29</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

<sup>30</sup> Office fit outs guidelines – July 2001 – <http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf>

## 4. Embodied Energy

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Embodied energy can be considered as important as operating energy due to the environmental impacts on air, water pollution, global warming and habitat destruction associated with it<sup>31</sup>. In order to reduce the total environmental impact of buildings, the impact of the materials that have gone into its construction should be considered. For this reason the concept of embodied energy originates from designing more sustainable would be critical to achieve good quality of environmental design, also become more important as building get more energy efficient<sup>32</sup>. Whether from an interior or exterior point of view, the embodied energy of the materials is the energy consumed by all of the processes associated with the production of a building. This concept represents a calculation of the amount of energy required to extract raw materials and fabricated products, process and refine them before use in product manufacture from the gaining of natural sources to product delivery, which includes the mining and manufacturing of materials and equipment, to create the materials, transport, assemble and finish them to the specific location.

### **4.1 Embodied energy in building design**

Embodied energy is a major component of the lifecycle impact of buildings and one of the features of energy consumption associated with buildings and construction materials. Every building is a complex combination of many different processed materials that contributes to the building's total embodied energy which consist of renovation and maintenance over the building's life span<sup>33</sup>, therefore the most important factor in reducing the impact of embodied energy is to design long life and durable and minimizing the overall emission of CO<sub>2</sub> to the atmosphere arising from the operation of the material, during construction process and refurbishment. It should be mentioned that embodied energy is one of the numbers of the environmental impacts due to the

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<sup>31</sup> <http://strategies.ic.gc.ca/epio/internet/indsid-tour.nsf/en/qq00054e.html>

<sup>32</sup> [http://www.sustainabilityworks.org.uk/guide/page.php?subsect=02\\_04\\_03#embodied](http://www.sustainabilityworks.org.uk/guide/page.php?subsect=02_04_03#embodied)

<sup>33</sup> <http://www.greenhouse.gov.au/yourhome/technical/fs31.htm>

processed building materials, thus it is relatively small compared to lifetime of operational energy from heating, cooling and lighting of buildings but still have significant impact on environmental consideration and whole life cost.

The embodied energy can be reduced by up to half with simple measures if the following items applied to the building materials<sup>34</sup>:

- Locally produced materials
- Minimally produced materials, not highly manufactured products
- Second hand materials or materials with high recycled contents, instead of using new materials

#### **4.2 How is embodied energy measured?**

In general, embodied energy is measured as a quantity of non-renewable energy per unit of building material or building component. The embodied energy may be measured as Joules (J) per unit of weight or area<sup>35</sup>. The measure of embodied energy is associated with environmental impacts of resource depletion, greenhouse gases, environmental degradation and reduction of biodiversity<sup>36</sup>. “Embodied energy is a reasonable indicator of the overall environmental impact of building materials, assemblies or systems”<sup>37</sup>. Therefore, it must be carefully weighed against performance and durability since embodied energy indicates the overall environmental impacts of materials.

#### **4.3 Life Cycle assessment**

In general, embodied energy is measured as a quantity of non-renewable energy per unit of building material or building component. The embodied energy may be measured as Joules (J) per unit of weight or area<sup>38</sup>. The measure of embodied energy is associated with environmental impacts of resource depletion, greenhouse gases, environmental

<sup>34</sup> [http://www.sustainabilityworks.org.uk/guide/page.php?subsect=02\\_04\\_03#embodied](http://www.sustainabilityworks.org.uk/guide/page.php?subsect=02_04_03#embodied)

<sup>35</sup> [http://www.cdnarchitect.com/asf/perspectives\\_sustainability/measures\\_of\\_sustainability/measures\\_of\\_sustainability\\_embodied.htm](http://www.cdnarchitect.com/asf/perspectives_sustainability/measures_of_sustainability/measures_of_sustainability_embodied.htm)

<sup>36</sup> [http://www.cdnarchitect.com/asf/perspectives\\_sustainability/measures\\_of\\_sustainability/measures\\_of\\_sustainability\\_embodied.htm](http://www.cdnarchitect.com/asf/perspectives_sustainability/measures_of_sustainability/measures_of_sustainability_embodied.htm)

<sup>37</sup> The Rule of thumb

<sup>38</sup> [http://www.cdnarchitect.com/asf/perspectives\\_sustainability/measures\\_of\\_sustainability/measures\\_of\\_sustainability\\_embodied.htm](http://www.cdnarchitect.com/asf/perspectives_sustainability/measures_of_sustainability/measures_of_sustainability_embodied.htm)



degradation and reduction of biodiversity<sup>39</sup>. “Embodied energy is a reasonable indicator of the overall environmental impact of building materials, assemblies or systems”<sup>40</sup>. Therefore, it must be carefully weighed against performance and durability since embodied energy indicates the overall environmental impacts of materials.

### 4.3.1 Life Cycle Assessment methodology

Life cycle analysis is a method used to measure the environmental impacts associated with a product system, by describing and assessing the primary energy and materials used, flows in all stages of a products life cycle which some of the impacts widely used to compare product systems as global warming potential, ozone depletion nitrification and ground level ozone creation potential<sup>41</sup>. LCA methodology can be broken down into three distinct stages<sup>42</sup>:

- Goal ,definition and scoping: a clear statement of the main purpose of the assessment, with clear definition of the functional units and description of the element and expected life time
- Inventory analysis: the calculation of the embodied energy associated with production, use, and disposal
- Impact assessment: the categorization of the inventory analysis data regarding to the impacts on natural systems

It should be mentioned that most of the current understanding of buildings related to life cycle analysis are focused on the inventory analysis stage, in order to compare the wide range of resource use and environmental impacts associated with them.

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<sup>39</sup>[http://www.cdnarchitect.com/asf/perspectives\\_sustainability/measures\\_of\\_sustainability/measures\\_of\\_sustainability\\_embodied.htm](http://www.cdnarchitect.com/asf/perspectives_sustainability/measures_of_sustainability/measures_of_sustainability_embodied.htm)

<sup>40</sup> The Rule of thumb

<sup>41</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

<sup>42</sup> determining the permissible degree of Inaccuracy in Life-Cycle Assessment Protocols, by Raymond J Cole

### 4.3.2 Life Cycle Assessment of buildings

The life cycle analysis of buildings is more complex than their ingredient materials, components, assemblies and systems. The full life cycle environmental impacts of materials and interior finishes have three distinct stages: first, the detailed assessment of production impacts and resource use, second, the impact and resource use during their useful life span of the completed design and lastly the demolition and disposal impacts<sup>43</sup>. While the first stage is only specific to the building materials and components, and the second and third stages are specific to the building materials or components and its application in the specific design. In other words the life cycle assessment of building materials and components being examined in to different stages, typically these stages are<sup>44</sup>:

- Raw materials
- parts fabrication assembly
- use and maintenance
- retirement or end of life

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<sup>43</sup> determining the permissible degree of Inaccuracy in Life-Cycle Assessment Protocols, by Raymond J Cole

<sup>44</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

The general life cycle analysis of a building product is structured as seen in table 2:

<b>LIFE-CYCLE STAGE</b>	<b>EXAMPLES OF ENVIRONMENTAL IMPACT</b>
Pre-production (mineral extraction)	water pollution air pollution damage to ecology and landscape social impacts transport Waste
Production (manufacturing of components)	water pollution air pollution Waste
Construction	water pollution air pollution damage to ecology and landscape transport Waste
In use and maintenance	water pollution local air pollution traffic generation indoor environment / health considerations environmental aspects of paint removal and repainting
end of life-demolition	ecological and landscape implications water pollution air pollution from incineration scope for recycling / amount actually recycled disposal of demolition waste

Table2- life cycle product - source: sustainable homes - Embodied Energy in Residential Property developments – A guide for registered social landlords <http://www.sustainablehomes.co.uk/EMBENG.PDF>

In view of the fact that LCA looks at all inputs and outputs in a products system over the life time therefore LCA also referred to as cradle to cradle. The Life cycle assessment of building materials and components has known as the most effective crucial, which can provides information as the above stages. It should be mentioned that in a complete LCA, all inputs (materials, energy, water) and outputs (air, water emissions, solid waste) are accounted for<sup>45</sup>. However in this study only the embodied energy and global warming potential will be evaluated, so understanding reduction of primary energy and global

<sup>45</sup>[www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

warming from a life cycle approaching is essential if an efficient reduction of environmental impact is mostly wanted.

#### **4.4 Information of LCA covered in Green guide and BRE**

This study will follow the Green building handbook guides and BRE methodology for environmental profiles of construction materials and building components which are both followed the methodology by DETR and UK construction materials and manufacture that describes in detail the consistent approach to the assessment and identification of all the impacts of all construction materials and components over their entire life span that are soundly based on life cycle assessment, to show the environmental impacts of the manufacture process of materials, generally the specifications are analyzed over the 60 years of the building design life.

Further more the profiles may be calculated for materials and building components “as built” over a nominal life time<sup>46</sup>, in general:

- Materials are presented as “cradle to gate” on a per tonne or kilogram
- Installing elements are defined as “cradle to site” that are calculated per square meter of a typical element
- Sixty years life time of elements as “cradle to grave” profile, taking in to account of their maintenance and disposal over the sixty year life, which are calculated on a per meter square

#### **4.5 Environmental impacts associated with building materials and products**

When refurbishing any type of building such as commercial, residential and public buildings, all materials should have lower environmental impacts over their life-span than those they are replacing, therefore the selection of materials and building components have an important rule in reducing energy and environmental impacts. Producing construction and finishing materials require large inputs of energy and raw resources which incurs emissions in to the atmosphere. The impacts of building materials on the

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<sup>46</sup> BRE methodology for environmental profiles of construction materials, components and buildings

environment can be summarize as three major factors Energy, Resources and Health. All materials consume energy, as mentioned before the embodied energy of materials refers to the energy used to extract, process and refine it before use in product manufacture. Therefore, there should be a correlation between the embodied energy of materials and number and type of processing steps. In the other word, the simpler the extraction, processing and refining steps in material's production, the lower the embodied energy. Furthermore the embodied energy of a material is reflected in its price, the most technically appropriate material will provide lower energy costs over the life cycle of a product.

Sustainable materials and components have following environmental attributes<sup>47</sup>:

- Reviewing and evaluating the recycled content of materials
- Specifying materials meeting sustainable content for recycled content
- Specifying materials and components which can be readily recovered, reused as close to their existing form as possible or which can be easily recycled
- Selecting materials and components with the lowest embodied energy
- Reducing transportation energy impacts by considering the use of local materials
- Selecting materials which have a longer life span before replacement
- Selecting materials that have lower maintenance and repair
- Resources must be used more efficiently, meaning that less materials must be used per capita with using renewable and natural resources

Therefore to meet more sustainable, materials and components should be remaining in the material cycle and the contents of durability, reusing, recycling must be increased.

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<sup>47</sup> A guide to sustainable office fit outs-December 2005.<http://www.mfe.govt.nz>

### 4.5.1 Material resource

In general building materials and products are derived from natural materials, which are harvested or extract and then processed. The main issue to consider is the availability and accessibility of the material resource; materials are commonly classified into non-renewable and renewable materials, which renewable materials include with regeneration cycles of decades, including as timber, flax, hemp and cork and non-renewable materials include with regeneration cycles of millennia such as stone, coal, oil and metal<sup>48</sup>. Materials can be classified as unlimited and limited resources, while sand is considered to be an unlimited resource and oil is considered to be a limited resource whereas the reserves are estimated to last between 40-100 years<sup>49</sup>.

### 4.5.2 Manufacturing process

Manufacturing process is generally required to create a usable building product since materials and productions are rarely used in their completely natural process. Manufacturing also requires energy, which is derived from fossil fuel; the environmental impacts associated with manufacturing the products can include global warming, air, water and ground pollution. there some materials that require less processing before use, which are including as timber, stone and adobe brick and consequently they have almost no pollution or waste, on the other hand manufacturing of some materials such as metal, plastic and PVC are high which are seriously environmentally damaging<sup>50</sup>.

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<sup>48</sup> <http://www.cf.ac.uk/archi/dfr/environmental%20benefits.htm>

<sup>49</sup> <http://www.cf.ac.uk/archi/dfr/environmental%20benefits.htm>

<sup>50</sup> <http://www.cf.ac.uk/archi/dfr/environmental%20benefits.htm>

### 4.5.3 Materials, energy and transport

Mainly building material requires energy during manufacture process, transport to site, maintenance and final disposal, which is mainly produce by burning fossil fuel and therefore problems associated with global warming, thus identifying low embodied energy materials are the main concern in terms of selecting more sustainable materials and building components. Selecting low embodied energy materials should be used in preference to high embodied energy materials. A significant reduction in the building's total embodied energy can be made by reducing transport requirements<sup>51</sup>. The transportation of materials from the manufacturer to the building site is generally by road and is associated with carbon dioxide emission and air pollution.

### 4.5.4 Materials in use and disposal

Maintenance of materials and components requires both energy and material and therefore has similar environmental impacts due to the construction of buildings in smaller scale, therefore minimizing requirements for maintenance by more durable design helps to reduce the life impacts of materials. The building manufacturing in the UK is responsible for 70 million tonne of construction and demolition waste every year<sup>52</sup> which most of them are sent to landfill. Therefore there are several problems associated with landfill sites, including the use of land, toxic materials leaching into groundwater, emissions of explosive gas and structural instability. Appropriate site waste segregation, designing to enable reuse and recycling and using reclaimed and recycled materials all contribute to diverting waste from landfill and other polluting waste disposal options. Building design can also encourage recycling of domestic or commercial waste by providing appropriate recycling facilities in the building.

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<sup>51</sup> <http://www.cf.ac.uk/archi/dfr/environmental%20benefits.htm>

<sup>52</sup> <http://www.cf.ac.uk/archi/dfr/environmental%20benefits.htm>

## **4.6 Reduced Waste by Re-used and recycling materials**

The reuse and recycling of building materials commonly saves about 95% of embodied energy which would otherwise be wasted<sup>53</sup>. Waste would be created in all stages of fit-outs or refurbishment during the manufacturing the products, building process, operations and disposal. At the stage where the interior fit-outs is needed to be reused would be the main concern in reducing waste at source during refurbishment in office building but if an item itself can not be reused then the recycling of existing materials would be considered, because buying a new product is likely to have greater environmental impacts than reusing existing items even if the existing materials are not made of sustainable materials and not energy efficient.

Recyclable materials are the ones that can be returned in to the manufacture and reconstituted in to new materials which can be easily identified as materials with lower environmental impact. Some materials are currently recyclable but other will be in the future through industry advancements. Consideration should be given to the ability of materials and components to be recovered and recycled, through the building's life time.

### **4.6.1 Durable Materials**

Building materials and components are maintained over their life-span, therefore recurring environmental costs usually can outweigh the primary environmental cost of producing and installing them, the selection of durable materials and components is the main concern in reducing life-cycle environmental impacts in office buildings and other building designs. Designing for durability of materials involve considering how to protect materials and components from corrosion to protract their life span also durable products with in an extended life time provide more energy efficient.

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<sup>53</sup> <http://www.cmit.csiro.au/brochures/tech/embodied>



## **4.7 Economic and social benefits of recyclable materials**

Designing buildings to be recyclable provides some advantages that can result in economic and social benefits. The practical advantages are as following details<sup>54</sup>:

- Commissioning facilitated
- Single materials offer options for repair
- Faster and easier upgrading of fabric and services
- Flexibility and ease of maintenance
- Potential for high resale value
- Selecting good quality materials, upgrading ability with high level of marketing of property
- Improved working conditions for construction workers
- Improved living or working conditions for users

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<sup>54</sup> <http://www.cf.ac.uk/archi/df/environmental%20benefits.htm>

## 5. Case Study

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### **5.1 Introduction to British Sky Broadcasting Limited: New Horizons court Refurbishment**

It was decided to select an office building that had been refurbished in UK; therefore the new and modern refurbishment of British Sky Broadcasting office building allowed me for more detailed case study of life cycle analysis and detailed calculation of embodied energy with in a new approach of office fit-outs design, consequently examining the total embodied energy in the contents of life cycle analysis and investigating the total global warming potential of office fit-outs in the B Sky B office building in UK will be the main consideration in this study, to investigate more sustainable decisions in terms of selecting interior office fit-outs. In addition helpful staff from Building Design Partnership consultant provided me useful information throughout this study.

A temporary new beginning of the British Sky Broadcasting office building is as following details:

- Client: British Sky Broadcasting limited
- Location: Londra – UK - West region in London
- Architects: Building Design Partnership
- Value: £ 27 m
- Total size: 12.919 m<sup>2</sup>
- Completion: June – September 2005
- Awards and rating: British council for offices awards 2006

## **5.2 The Brief and the Key objectives of the project**

The brief and the key objectives of B Sky B office building were given to the design team in two parts; the first part was the generic requirement for the design team in order to provide refurbished office accommodation for the four existing buildings used for approximately 1000 staff that provided by moving to New Horizon Court building, as shown in appendix 6 and 7. The second part was based on setting a quality of working environment for B Sky B staff for any subsequent building development or refurbishment which had to reflect the space requirements and standards, the specific items were included as<sup>55</sup>:

- utilizing limited palette of materials
- spaces that are responsive to occupant's requirements
- simple detailing
- maximize opportunities to integrate sustainable and environmentally friendly materials
- create a loft style aesthetic and maximizing the possible ceiling height
- significantly reduce cellular office provision
- create breakout zones, refreshment and printing facilities in each floor
- maximize facilities for expansion and contraction of staff numbers

The result of these two motivators has been a design that has taken four buildings with the extended life time of around 20-25 years with new office fit-outs and services<sup>56</sup>.

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<sup>55</sup> British council for offices awards 2006 – Building design partnership

<sup>56</sup> Building Design Partnership consultant

### **5.3 Quality of design and construction before refurbishment**

The quality of the existing buildings was typical of late 90's construction, the occupiers previously worked with in a cellular environment with long corridors and poor way finding and most of the office fit-outs were approaching the end of their design life, moreover the building fabric had problems regarding to cladding, roofing and air tightness through out the internal office buildings, the original layout typically contained of cellular office space, which was poor in terms of aesthetic, light level and quality of interior materials and office fit-outs. The materials contained of perforated metal suspended ceiling backed with acoustic insulation, grey color of walls, dull carpets and office partitioning system were very poor all over the interior arrangements which led the design to general interior repairs and refurbishment The materials that typically stripped out were separated in to material types as wood, metals, carpet, glass, carpet and insulation material<sup>57</sup>.

As shown in figure 4 the B Sky B office building has suffered from:

- poor quality and high proportion of office cellular
- low ceiling height
- Dull carpets
- Poor office partitioning system
- low lighting levels
- inadequate storage
- inflexible work stations
- poor quality of internal environment

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<sup>57</sup> Building Design Partnership consultant



Figure 4 – Quality of design and construction before refurbishment. Source: Building Design Partnership consultant

In addition the common space such as receptions, toilets, lift lobbies were also of poor quality in terms of aesthetic and materials which all counted as the negative points of the internal layout before refurbishing the office buildings, therefore the condition of the existing buildings combined with the brief from B Sky B was the key motivations that drove the design. It should be mentioned that refurbishing the B sky B office buildings were essentially a complete internal fabric strip-out back to the building structure, including ceiling, all services distribution, internal walls and partitions which in this study only the office fit-outs and fixtures would be the main concern.

### **5.4 Effectiveness and performance of design after refurbishment**

The design solution for refurbishing the building has demonstrated that poor quality of office buildings can be transformed into modern and efficient working environments all over the existing buildings with the concept of fully recyclable interior office fit-outs and fixtures, therefore by moving to NHC the B SkyB office building has reserved this with new open plan office space, rationalized storage and high ceiling height as shown in figure 5 and appendix 8. The B SkyB plan layouts have four values that are applied across all the parts of buildings as the main concepts of new refurbishing and new office arrangements which are defined as<sup>58</sup>:

- Tuned in
- Inviting
- Irrepressible
- Fun

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<sup>58</sup> British council for offices awards 2006 – Building design partnership



Figure 5 – Effectiveness and performance of design B SkyB after refurbishment. Source: Building Design Partnership consultant

### **5.5 Location of the detailed case study**

In this study, 2<sup>nd</sup> floor of the 3<sup>rd</sup> building is considered as a detailed case study, table 3 indicates the Net internal area, Gross internal area, percentage of plan efficiency, staff population and net area or occupancy rate per person of the 2<sup>nd</sup> floor of the 3<sup>rd</sup> building; the Net internal area of a building is the total internal areas, which is the floor space in square meter confined within the building at each floor, the measurement is taken from

the internal finished surfaces of permanent walls and from the internal finished surfaces, while in Gross internal area the outer or external walls are also included. Further details of Net and Gross area of the total four office buildings are available in appendix 9.

Building 3	NIA	GIA	Net: Gross	Staff population	Net area/ person(m2)
Ground	906	1.134	80%	83	10.92
First	944	1.123	84%	117	8.07
<b>Second</b>	<b>1.047</b>	<b>1.237</b>	<b>85%</b>	<b>107</b>	<b>9.79</b>
Subtotal	2.897	3.494	83%	307	9.44

Table 3 – Net/Gross internal area of the 2<sup>nd</sup> floor plan of the 3<sup>rd</sup> building. Source: Building Design Partnership consultant

As shown in figure 6 new open plan offices designed as break out zones, provided creative environment which has encouraged free and easy communication across the three buildings, the plat form work stations were adapted in preference to traditional desk arrangement, which the platforms are typically 6m long which can provide service to 6 – 8 staffs, furthermore using prefabrication components all over the building minimized works on site. More details regarding the four B SkyB office arrangements can be seen in appendix 10.

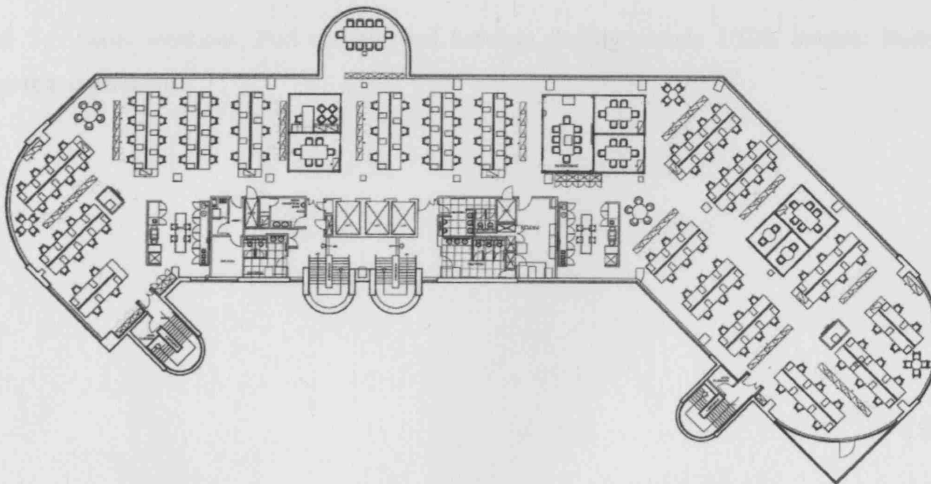


Figure 6 – Performance of new office fit-outs arrangement of 2<sup>nd</sup> floor plan of the 3<sup>rd</sup> building Scale 1/500. Source: Building Design Partnership consultant



## **5.6 Oasis location and Pod concept**

Level 2 of the 3<sup>rd</sup> building of B SkyB office complex is divided with different functions throughout the internal space as, working area, services facility, meeting and conference rooms namely as “Pod Concept” that are located in three different locations, as well as two breakout zones and kitchenette facilities as “Oasis Locations”, as shown in figure 7. Further details can be seen in appendix 11.



Figure 7 – Oasis locations, Pod concept and Services facility - scale 1/500. Source: Building Design Partnership consultant

## 6. Analysis of the case study

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### 6.1 Goal and Scope of the study

The aims of this study are to investigate the principles of sustainable fit-outs these include:

- Examining the environmental impacts of different type of interior materials and fit outs over their life time in the BSkyB office building
- Investigating the Life Cycle Assessment of the interior materials and office components
- Calculating the embodied energy and global warming potential of various type of office fit-outs through out the internal layout
- Considering the impact in terms of global impacts such as climate change and global warming
- Optimizing the overall impacts of an office fit-out

### 6.2 Methodology

As the aims set before, the study can be met with the first step in a LCA study in order to consider the product and manufacturer system to describe the methodology and calculating the embodied energy and global warming potential of various types of material. As identified in section 4.4, the procedure that would be followed in this approach is described in BRE methodology for environmental profile of construction materials, components and buildings which is the methodology by DETR and UK construction materials and manufacture, also by using Green building handbook guides, during manufacturing, transportation, construction, maintenance and replacement over the 50-60 years interior office fit outs. The life cycle analysis of the detailed case study in BSkyB office building consists of three distinct stages as following:

- Pre – use or manufacture of the production process
- Use
- End of life

### **6.3 Data Collection, product analysis and materials specification**

In general examining the past environmental impacts of the materials are irrelevant, the conservation must be based on minimizing the existing and future environmental impacts of the energy consumption, regarding to reduction of embodied energy and global warming potential, therefore the detailed study of BSKyB office building is only based on existing office fit-outs and fixtures through out the internal environment after refurbishment. Typically an office fit-outs or refurbishment may involve replacement of wall covering, floor covering, office partitioning and new office arrangements including setting up furniture, fixture and fittings through out the internal layout, in order to meet new needs of refurbishment.

This section presents the life cycle analysis and calculates the embodied energy and global warming potential of various internal materials and fit outs, approach of around 1047 square meter of the 2<sup>nd</sup> floor plan of the 3<sup>rd</sup> building of BSKyB office complex, the specification of internal materials is based on analyzing the materials and building components over the 40-60 year design life of an office building to estimate the total environmental impacts from each specification, following the Green guide specification and BRE research program.

It should be mentioned that in this study the total energy for maintenance and disposal are assumed to be zero, because comparing to all the other stages during life cycle of materials, the energy required for installation, maintenance and final disposal are considered to be negligible. Therefore it is taken in to consideration the energy required from cradle to gate, during manufacturing process of each specific office fit-outs and the delivery energy to the BSKyB office building.

As stated before, the concept of fully recyclable interior materials and fit outs applied all over the BSKyB office building arrangement, to meet more sustainable interior materials

and components as well as to identify the importance of using them more efficiently, to reduce the overall energy demand, the description of office fit-outs after refurbishment listed as seen in table 4.

Building 3 - Level 2	Description of Office Fit outs and Manufacture <sup>59</sup>	Material-per m <sup>2</sup> of Floor area
Wall covering	working area painted in Vinyl matt Emulsion paint on walls and ceiling - by Dulux	1.7
	plasterboard and 600x600mm Ceramic tile applied to walls- specification as per the floor tile - by Dulux and Domus ceramic	1.23
Floor covering	carpet tile with cushion back, specification Interface Europe all over the working area - by Altro Floors	1.3
	600x600 matt Ceramic tile covered the services area- new self leveling screed to receive – by Domus ceramic	1.17
	Rubber sheet Flooring in Oasis locations- specification Altro floors- Mondofutura Roquefort 450 – by Altro Floors	0.13
office furniture	MDF Faram bench system as working desks and laminate wood as Oasis and folding, conference table	4.2
	Aeron chairs - by Herman Miller	1
	Meeting Chairs mostly used in pod concept	0.34
	PVC Chair in Oasis location	0.02
office partitions	Combination of Glass toughened and Aluminum- Create private spaces – by Faram	6.87
	Combination of stainless steel and laminate wood - partially used in Oasis locations and service areas	0.02

Table 4 –Description of office fit-outs after refurbishment

Furthermore in this study the ratings evaluate a square meter of a typical thickness of each components over the estimated life time, then evaluating the maintenance and recycling, reuse over the interior materials life span and demolition at the end of their life time, it should be mentioned that the ratings are accounted as A, B, C and D where A rating indicate the lowest environmental impacts, B rating middle environmental impacts, C the high environmental impacts and D as the highest environmental impacts<sup>60</sup>.

<sup>59</sup> Building Design Partnership Consultant

<sup>60</sup> Green building hand book volume 1

### 6.3.1 Wall covering

The main concerns regarding to interior wall paints and wall coverings are their environmental impacts during manufacture process of synthetic vinyl, acrylic and alkyd based paint; the vinyl emulsion paint contains a coating comprised of emulsion water based easily applied and covered all the BSKyB refurbishing area. The main factor associated with the use of emulsion paints are the ingredients, manufacturing process and disposal of this kind of paint, though this type of wall covering is much safer as they contain less or no hydrocarbon solvent<sup>61</sup>, so vinyl emulsion paints meet environmental choice criteria. Table 5 indicates the type, rating, production and use of different category of wall covering following the Green guide hand book, covered up all the internal walls and ceiling in working spaces, Oasis location and servicing areas.

Production				Use	
Wall covering	Energy use	Resource use	Global warming	Durability-Maintenance	Recycling-reuse-disposal
Vinyl Emulsion paint	D	C	D	A	C
Ceramic Tile	D	B	C	A	A
Plaster board	C	D	C	A	A

Table 5 – production and use procedure of different type of wall covering after refurbishment

The production of the Vinyl emulsion paint contained petrochemical procedure that can be produced high level of energy process, using oil and gas as raw materials provide high embodied energy with the total primary energy of 152 MJ per m<sup>2</sup> of floor area and the total delivery energy of around 68.65MJ per m<sup>2</sup> of floor area during 50-60 years life time, as shown in table 6.

<sup>61</sup> Green building hand book volume 2

The manufacture process of the vinyl emulsion paint is the major source of CO<sub>2</sub>, Methane and other green house gases, therefore the extraction, transport and refining of oil can have enormous environmental impacts, while this type of paints are durable and could be easily maintained. As mentioned before the vinyl emulsion paint contained petrochemical procedure, therefore the recycling, reuse and disposal of vinyl emulsion paint would be complicated, while this type of paints are durable and widely used in office buildings.

Wall covering	Density <sup>62</sup> kg/m <sup>3</sup>	Weight kg/ m <sup>2</sup>	Primary Energy MJ/kg <sup>63</sup>	Energy MJ/m <sup>2</sup>	Total m <sup>2</sup>	Total energy MJ	Total primary energy MJ per m <sup>2</sup> of floor area	Total delivery energy <sup>64</sup> - MJ per m <sup>2</sup> of floor area
Vinyl Emulsion paint	900-1100	0.9-1.1	88.5	88.5	1797	159034	152	68.65
Ceramic tile	1600	16	2.5	40	77	3080	2.94	1.47
Plaster board	849	0.84	2.5	2.1	77	162	0.15	0.1
<b>Total</b>	-	-	-	-	<b>1951</b>	<b>162276</b>	<b>155</b>	<b>70</b>
<b>Total embodied energy = 225 MJ per m<sup>2</sup> of floor area</b>								

Table 6- Total Embodied Energy of various type of Wall Covering in 50- 60 years life times

The most important impacts of conventional tiling and plastering as wall covering through out the servicing areas are their extraction from non-renewable resources, even though ceramic tile is locally produced with low manufacturing impacts but compare to the other wall covering has higher embodied energy and higher initial impacts due to high consumption rate which in this case 2.94 MJ per m<sup>2</sup> of floor area is used as primary energy and around 1.47 MJ per m<sup>2</sup> of floor area used for transportation energy, while plastering board has lower embodied energy, with the total initial embodied energy of around 0.15 MJ per m<sup>2</sup> of floor area with transportation energy of around 0.1 MJ per m<sup>2</sup> of floor area. Both the ceramic tiling and plastering are durable and could be easily maintained. The total embodied energy that is covered up all the internal BSKyB office is 225 MJ per m<sup>2</sup> of floor area.

<sup>62</sup> [http://www.simetric.co.uk/si\\_materials.htm](http://www.simetric.co.uk/si_materials.htm)

<sup>63</sup> <http://www.vum.ac.nz/cbpr/documents/pdfs>

<sup>64</sup> Assumption throughout this research

As mentioned before, the Global Warming Potential of a greenhouse gas is the ratio of global warming from one unit mass of a greenhouse gas to one unit mass of carbon dioxide over a period of time which in this case study it is assumed to be in 50-60 years time. As a result, the Vinyl Emulsion paint has the greatest impact around 2.6 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area compare to the other wall coverings.

Wall covering	Total weight - kg	GWP kg CO <sub>2</sub> equiv./kg <sup>65</sup>	GWP kg CO <sub>2</sub> equiv.	GWP kg CO <sub>2</sub> equiv. per m <sup>2</sup> of floor area
Vinyl Emulsion paint	1797	1.5	2695	2.6
Ceramic tile	1232	1.4	1725	1.6
Plaster board	65	1.2	78	0.07
<b>Total</b>	<b>3094</b>	<b>4.1</b>	<b>4498</b>	<b>4.27</b>

Table 7- The global warming potential of various type of Wall Covering in 50-60 years time

<sup>65</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

### 6.3.2 Floor Covering

Floor coverings are one of the most important alternatives to select, as they covered large amount of areas, in this case study 910 m<sup>2</sup> of the internal floor area is covered with Interface carpet tile, due to simply maintenance and small changes through out the office environment, the Oasis locations are covered with rubber sheet flooring of around 60 m<sup>2</sup> of the floor area and servicing area has covered with ceramic tile at around 77 m<sup>2</sup> of the floor area of the office space. Table 8 indicates the type, rating, production and use of different category of floor covering following the Green guide hand book, which covered up all the internal floors in working spaces, servicing areas and Oasis location.

Production			Use		
Floor covering	Energy use	Resource use	Global warming	Durability-Maintenance	Recycling-reuse-disposal
Interface carpet tile	C	D	C	A	D
Ceramic tile	D	B	C	A	A
Rubber flooring	D	C	D	D	D

Table 8 –production and use procedure of different type of floor covering after refurbishment

The initial embodied energy and resource use of interface carpet tile are high with the total primary energy of 88.65 MJ per m<sup>2</sup> of floor area due to high consumption rate of using nylon and polypropylene and latex, mainly nylon has the highest environmental impacts due to its manufacturing procedure and using oil as non-renewable resources. The petrochemical procedure is the major source of CO<sub>2</sub> emission and other greenhouse gases, reuse, recycling and disposal of this type of material are difficult due to their petrochemical procedure. The total delivery energy for this type of floor covering is around 43.45 MJ per m<sup>2</sup> of floor area, as shown in table 9. Using synthetic rubber flooring in Oasis location consumes high energy due to its petrochemical procedure and extraction of oil as raw material, which seems the worst case in terms of selection of floor covering, it is highly energy intensive during manufacturer process, also not durable and recycling, reuse and disposal of rubber flooring would be extremely hard because of combination of polyurethane foam in this production that can be easily re-melted and re-



formed and contained high level of CO<sub>2</sub> emission<sup>66</sup>. In contrast to ceramic tile, rubber flooring consumes higher primary energy of around 8.8 MJ per m<sup>2</sup> of floor area with the total delivery energy of around 2.8 MJ per m<sup>2</sup> of floor area, while rubber flooring covered a smaller amount of floor area than ceramic tile, as seen in table 9.

Floor Covering	Density <sup>67</sup> kg/m <sup>3</sup>	Weight kg/ m <sup>2</sup>	Primary Energy MJ/kg <sup>68</sup>	Energy MJ/m <sup>2</sup>	Total m <sup>2</sup>	Total energy MJ	Total primary energy MJ per m <sup>2</sup> of floor area	Total delivery energy <sup>69</sup> - MJ per m <sup>2</sup> of floor area
Interface carpet tile	500	1.5	68	102	910	92820	88.65	43.45
Ceramic tile	1600	16	2.5	40	77	3080	2.94	1.47
Rubber flooring	481	2.4	64	153.6	60	9216	8.80	2.8
<b>Total</b>	-	-	-	-	1047	105116	<b>100.39</b>	<b>47.72</b>
<b>Total Embodied Energy = 148 MJ per m<sup>2</sup> of Floor area</b>								

Table 9- The Embodied Energy of various type of Floor Covering in 50-60 years life times

As a result of global warming potential in 50-60 years time, the total GWP for interface carpet tile has greatest impact of around 5.2 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area compare to the other floor covering, as shown in table 10.

Floor Covering	Total weight - kg	GWP kg CO <sub>2</sub> equiv./kg <sup>70</sup>	GWP kg CO <sub>2</sub> equiv.	GWP kg CO <sub>2</sub> equiv. per m <sup>2</sup> of floor area
Interface carpet tile	1365	4.0	5460	5.2
Ceramic tile	1232	1.4	1725	1.6
Rubber flooring	144	3.0	432	0.41
<b>Total</b>	<b>2741</b>	<b>4.4</b>	<b>7617</b>	<b>7.27</b>

Table 10- The global warming potential of various type of Floor Covering in 50-60 years time

<sup>66</sup> Green building hand book volume 1

<sup>67</sup> [http://www.simetric.co.uk/si\\_materials.htm](http://www.simetric.co.uk/si_materials.htm)

<sup>68</sup> <http://www.vum.ac.nz/cbpr/documents/pdfs>

<sup>69</sup> Assumption

<sup>70</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

### 6.3.3 Office Furniture

Office furniture includes chairs, desks, meeting tables, filing and cabinet storage, varied from different materials as part of interior office fit-outs in BSKyB office building which were included as, MDF or wood based products, aluminum, plastic and fabrics. One of the most important environmental issues associated with office furniture design is reducing the possible emissions from formaldehyde, adhesives and paint or finishes used in the interior fit-outs and fixtures. New concept of furniture design through out the BSKyB office buildings provided new work stations, designed for changing work position to save more space through out the internal layout. The furniture systems as office tables have completed with supporting structural frame with a series of aluminum portals supports combined with MDF in working areas, moreover laminate wood tables has covered up the meeting areas and Oasis locations, as seen in figure 8.



Company: Faram  
 Product: furnishing systems  
 Designer: Daniele Del Missier  
 Product: FRA TINO  
 Category: functional element system

Company: Faram  
 Product: furnishing systems  
 Product: Oasis and folding, conference table  
 Designer: Faram  
 Category: functional element system

Figure 8 – furnishing systems by Faram. Source: Building Design Partnership

During production of both Medium Density Fiberboard (MDF) and laminate wood as part of composite board, they intensively used high capacity of energy during manufacturer process, for the reason that both consist of synthetic resins based boards, which the resin content of MDF is greater than other particle boards at around 14%<sup>71</sup>, and manufacture of laminate wood and attachment to the board requires heat around 100°C<sup>72</sup>.

Mainly formaldehyde resin, have several impacts during manufacture, in general they have petrochemical effects based resin, therefore the production of adhesives is extremely energy consuming, as the primary raw material for synthetic resin production are from non-renewable resources such as oil and gas, so the manufacturing of this type of product is the major source of CO<sub>2</sub> emission, Methane and other green house gases, manufacturing of this type of materials is responsible for mostly half of the emissions to the environment. Table 11 indicates the type, rating, production and use of different category of office table following the Green guide hand book, which widely used all over the internal working areas, meeting rooms and Oasis location.

Production				Use	
Office Table	Energy use	Resource use	Global warming	Durability-Maintenance	Recycling-reuse-disposal
MDF	D	B	C	A	A
Laminate wood	C	D	A	A	A

Table 11 – production and use procedure of different type of office table after refurbishment

MDF and laminate wood comprised as both durable and recyclable materials, the disadvantage of using this kind of product is that, MDF is difficult to use more than 3-5 times<sup>73</sup>, it could be re-chipped but MDF consists of high level of resin contents which would create problems during recycling, furthermore production of MDF has environmental advantage of using wood in its production which is more economical than softwood, therefore MDF and laminate wood have more environmental advantages

<sup>71</sup> Green building hand book volume 1

<sup>72</sup> Plastic: surface and finish. (W.GordonSimpson, Ed.) Royal society of chemistry, Cambridge 1993

<sup>73</sup> Green building hand book volume 1

comparing to the other composite board. MDF has the greatest impact compare to the other floor covering. The primary embodied energy of MDF is around 50 MJ per m<sup>2</sup> of floor area with the delivery energy of 23 MJ per m<sup>2</sup> of floor area, as seen in table 12.

Office Table	Density <sup>74</sup> kg/m <sup>3</sup>	Weight kg/ m <sup>2</sup>	Primary Energy MJ/kg <sup>75</sup>	Energy MJ/m <sup>2</sup>	Total m <sup>2</sup>	Total energy MJ	Total primary energy MJ per m <sup>2</sup> of floor area	Total delivery energy <sup>76</sup> - MJ per m <sup>2</sup> of floor area
MDF	800	16	11.9	190.4	275	52360	50	23
Laminate wood	250	5	10.4	52	24	1248	1.19	0.57
<b>Total</b>	-	-	-	-	499	<b>53608</b>	<b>51.20</b>	<b>23.57</b>
<b>Total Embodied Energy= 75 MJ per m<sup>2</sup> of Floor area</b>								

Table 12- The Embodied Energy of various types of Table and Desk in 50-60 years life times

As a result of global warming potential in 50-60 years time, the total GWP for MDF is 5.4 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area, which has the greatest impacts compare to the laminate wood, as shown in table 13.

Office Table	Total weight - kg	GWP kg CO <sub>2</sub> equiv./kg <sup>77</sup>	GWP kg CO <sub>2</sub> equiv.	GWP kg CO <sub>2</sub> equiv. per m <sup>2</sup> of floor area
MDF	4400	1.3	5720	5.4
Laminate wood	120	0.1	12	0.01
<b>Total</b>	4520	<b>1.4</b>	5732	<b>5.41</b>

Table 13- The global warming potential of various types of Table and Desk in 50-60 years time

<sup>74</sup> [http://www.simetric.co.uk/si\\_materials.htm](http://www.simetric.co.uk/si_materials.htm)

<sup>75</sup> <http://www.vum.ac.nz/cbpr/documents/pdfs>

<sup>76</sup> Assumption

<sup>77</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

The Aeron chair is a new approach in terms of office chair design, to promote comfort for all users and to be more appropriate for every office activity as shown in figure 9, which provide high performance of adjustable and innovative suspension for computer work and general office work, it also designed with great sensitivity to interior environmental impacts. It consists of recycled aluminum, standard pellicle carbon seat material and black pivoting Vinyl-PVC arm pods, which around 94% of the chair is recyclable and made from 66% recyclable materials<sup>78</sup>, to last longer life span, so there would be less need for maintenance and replacement, different components are clearly selected and so the parts which get the most use could be easily recycled and replaced as it could be simply separated.



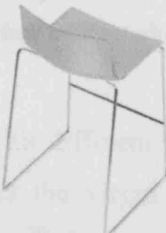
 <p><b>Aeron chair</b></p>	<p>Company: Herman miller</p> <p>Product: furnishing systems-Aeron chair</p> <p>Category: functional element system</p>	 <p><b>Meeting chair</b></p>	 <p><b>Oasis chair</b></p>	<p>Company: Wilkhahn</p> <p>Product: furnishing systems</p> <p>Category: functional element system</p>
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Figure 9 – Furnishing systems by Herman miller and Wilkhahn. Source: <http://www.aeronchair.co.uk> and <http://www.recycledbusinessfurniture.co.uk/Seats.htm>, respectively.

The Aeron chair consume less energy during manufacture by using natural resources therefore meets extremely strong sense of environmental responsibility and sustainable solutions to interior furniture design, that could provide efficient ways of protecting both the nature and internal working environment. Furthermore it designed for the use of renewable and sustainable raw materials. Table 14 indicates the type, rating, production

<sup>78</sup><http://www.aeronchair.co.uk>

and use of different category of office chair, which widely used all over the internal working areas, meeting rooms and Oasis location.

Production				Use	
Office chair	Energy use	Resource use	Global warming	Durability-Maintenance	Recycling-reuse-disposal
	B	A	B	A	A
vinyl arm pods-PVC	C	A	C	A	D
Carbon seat	-	-	-	-	-
<b>Aeron chair</b>	<b>B</b>	<b>A</b>	<b>C</b>	<b>A</b>	<b>B</b>
Leather	-	-	-	-	-
Aluminum, recycled	B	A	B	A	A
<b>Meeting chair</b>	-	-	-	-	-
PVC	C	A	C	A	D
<b>Oasis chair</b>	C	A	C	A	D

Table 14 – production and use procedure of different type of office chair after refurbishment

As mentioned before the Aeron chair has combined with different materials, recycled aluminum has 80%-95% embodied energy saving over the virgin resource which is electricity produced from hydroelectric renewable resource<sup>79</sup>. The manufacture process of recycled aluminum uses energy for heating of primary bauxite and for creation of electrodes which are accrued during the process of aluminum and for final electrolytic reduction process. It should be mentioned that the final process of aluminum such as casting and rolling contained more energy to input. The electrolytic smelting of aluminum is the reaction of aluminum oxide and carbon to form the aluminum therefore it caused CO<sub>2</sub> emission and other green house gases, but globally is insignificant compare to the input from fossil fuel burning.

The other combination of Aeron chair is PVC, the production of the raw materials of PVC consumes more energy to manufacture, because use of oil or gas as the primary raw materials and rock salt used to provide chlorine for PVC which has significant impacts in increasing the embodied energy of this product, the initial embodied energy for Aeron

<sup>79</sup>Green building hand book volume 1

chair is about 88.75 MJ per m<sup>2</sup> of floor area with the total delivery energy of around 37.82 MJ per m<sup>2</sup> of floor area, as shown in table 15. In this study the Aeron chair has significant impacts due to the number of the items, compare to the meeting chairs and oasis chair.

Office chair	Density <sup>80</sup> kg/m <sup>3</sup>	Weight kg/ Item	Primary Energy MJ/kg <sup>81</sup>	Energy MJ/m <sup>2</sup>	Total Item	Total energy MJ	Total primary energy MJ per m <sup>2</sup> of floor area	Total delivery energy <sup>82</sup> - MJ per m <sup>2</sup> of floor area
Aluminum, recycled	2600	5.2	8.1	45.12	-	-	-	-
vinyl arm pods-PVC	1300	2.6	70	182	-	-	-	-
Carbon seat	80	0.16	10	1.6	-	-	-	-
<b>Total-Aeron chair</b>	<b>3980</b>	<b>7.96</b>	<b>88</b>	<b>704</b>	<b>132</b>	<b>92928</b>	<b>88.75</b>	<b>37.82</b>
Leather	945	1.9	60-90	142.5	-	-	-	-
Aluminum, recycled	2600	5.2	8.1	45.12	-	-	-	-
<b>Total- Meeting chair</b>	<b>3545</b>	<b>7.1</b>	<b>83</b>	<b>589</b>	<b>51</b>	<b>30039</b>	<b>28.69</b>	<b>14.12</b>
<b>PVC -Oasis chair</b>	<b>1300</b>	<b>2.6</b>	<b>70</b>	<b>182</b>	<b>8</b>	<b>1456</b>	<b>1.4</b>	<b>0.68</b>
<b>Total</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>191</b>	<b>124423</b>	<b>119</b>	<b>53</b>
<b>Total Embodied Energy = 172 MJ per m<sup>2</sup> of Floor area</b>								

Table 15 - The Embodied Energy of various type of chair in 50-60 years life times

<sup>80</sup> [http://www.simetric.co.uk/si\\_materials.htm](http://www.simetric.co.uk/si_materials.htm)

<sup>81</sup> <http://www.vum.ac.nz/cbpr/documents/pdfs>

<sup>82</sup> Assumption

As a result of global warming potential in 50-60 years time, the total GWP of Aeron chair has the greatest impact compare to the other options, which is around 4 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area, as shown in table 16.

Office chair	Total weight - kg	GWP kg CO <sub>2</sub> equiv./kg <sup>83</sup>	GWP kg CO <sub>2</sub> equiv.	GWP kg CO <sub>2</sub> equiv. per m <sup>2</sup> of floor area
Aluminum, recycled	-	1.0	-	-
vinyl arm pods-PVC	-	2.9	-	-
Carbon seat	-	-	-	-
<b>Total-Aeron chair</b>	<b>1056</b>	<b>3.9</b>	<b>4118</b>	<b>4</b>
Leather	-	3.0	-	-
Aluminum, recycled	-	1.0	-	-
<b>Total- Meeting chair</b>	<b>357</b>	<b>4.0</b>	<b>1428</b>	<b>1.36</b>
PVC -Oasis chair	21	3.0	63	0.06
<b>Total</b>	<b>1434</b>	<b>9.9</b>	<b>5609</b>	<b>5.3</b>

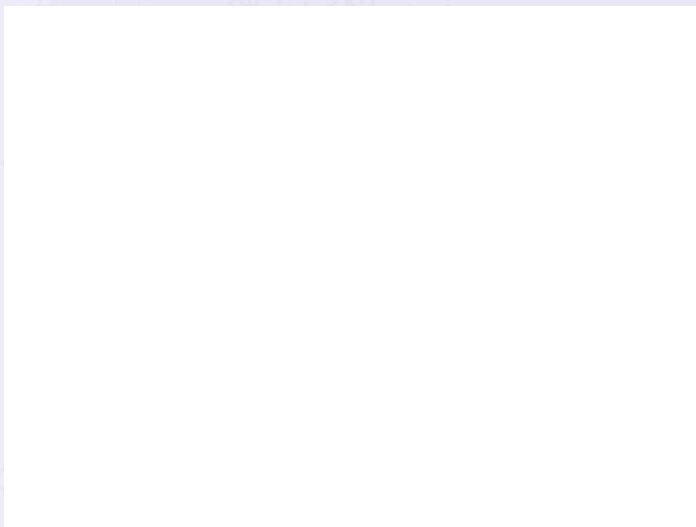
Table 16 - The global warming potential of various type of chair in 50-60 years time

<sup>83</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998



### 6.3.4 Office Partitioning

The P700 partition wall mainly used in the internal layout of the office as private areas to create completely transparent cellular meeting rooms, which consist of double glazed toughened glass panels combined with a total thickness of 100 mm<sup>84</sup>, structural elements based on an extruded aluminum profile and acoustic insulation materials, fixed to the floor and ceiling with expansion plugs as shown in figure 10. The components of the partitions in terms of height and width would be set up according to the design requirements which in this case partition walls have covered around 87 m<sup>2</sup> of the total floor area. Table 17 indicates the type and rating of different category of office partitions following the Green guide hand book, which is partially used all over the internal working spaces, Oasis location and servicing areas.



Product: Partition wall  
Company: Faram  
Designer: Daniele Del Missier  
Product: P700  
Category: dividing

Figure 10 – Partition wall by Faram. Source: Building Design Partnership consultant

<sup>84</sup> Source: [www.http://en.officebit.com/officebit/prodotti/scheda\\_prodotto.php?qua\\_prodotto=FARAMP700](http://en.officebit.com/officebit/prodotti/scheda_prodotto.php?qua_prodotto=FARAMP700)

Production				Use	
Office Partition	Energy use	Resource use	Global warming	Durability-Maintenance	Recycling-reuse-disposal
Glass, Toughened	C	C	C	A	A
Aluminum, extruded	C	B	C	A	A
Laminate	C	D	A	A	A
Stainless steel	A	A	A	A	A

Table 17- production and use procedure of different type of office chair after refurbishment

In general office partition walls combined with different kind of materials, that each component has its own environmental impacts, the P700 partition combined with the double glazed toughened glass and extruded aluminum. In this case the production of glass is extremely energy demanding, the extraction of minerals for creation of toughened glass has environmental impacts on local eco-systems and the extractions of raw materials for creation of glass all resulting from non-renewable resources. Moreover extruded aluminum has lower embodied energy compare to the other type of aluminum.

Office Partition	Density <sup>85</sup> kg/m <sup>3</sup>	Weight kg/ m <sup>2</sup>	Primary Energy MJ/kg <sup>86</sup>	Energy MJ/m <sup>2</sup>	Total m <sup>2</sup>	Total energy MJ	Total primary energy MJ per m <sup>2</sup> of floor area	Total delivery energy <sup>87</sup> - MJ per m <sup>2</sup> of floor area
Glass, Toughened	1600	16	26.2	419	-	-	-	-
Aluminum, extruded	2600	8.64	17.3	149	-	-	-	-
<b>Total Glass partition</b>	<b>4200</b>	<b>7</b>	<b>44</b>	<b>1084</b>	<b>292</b>	<b>316528</b>	<b>302</b>	<b>167</b>
Laminate	250	5	11	55	-	-	-	-
Stainless steel	7850	7.8	16.3	127	-	-	-	-
<b>Total Service partition</b>	<b>8113</b>	<b>13</b>	<b>27.3</b>	<b>355</b>	<b>78</b>	<b>27690</b>	<b>26</b>	<b>13</b>
Laminate	250	5	11	55	-	-	-	-
Stainless steel	7850	7.8	16.3	127	-	-	-	-
<b>Total Oasis location</b>	<b>8113</b>	<b>13</b>	<b>27.3</b>	<b>355</b>	<b>18</b>	<b>6390</b>	<b>6</b>	<b>3</b>
<b>Total</b>	-	-	-	-	<b>388</b>	<b>350608</b>	<b>334</b>	<b>183</b>
<b>Total Embodied Energy = 517 MJ per m<sup>2</sup> of Floor area</b>								

Table 18 - The Embodied Energy of various types of Office Partition in 50-60 years life times

<sup>85</sup> [http://www.simetric.co.uk/si\\_materials.htm](http://www.simetric.co.uk/si_materials.htm)

<sup>86</sup> <http://www.vum.ac.nz/cbpr/documents/pdfs>

<sup>87</sup> Assumption

The total primary energy for the P700 glass partition is 302 MJ per m<sup>2</sup> of floor area with the total delivery energy of around 167 MJ per m<sup>2</sup> of floor area. As shown in table 18. The laminate partition widely used in servicing areas and Oasis location, this type of partition combined with stainless steel that have longer service life span compare to the other type of steel, stainless steel is highly recyclable and is only produced by recycling in UK<sup>88</sup>. The total primary energy of laminate partitions all over the BSKyB is 32 MJ per m<sup>2</sup> of floor area with the delivery energy of 26 MJ per m<sup>2</sup> of floor area, as seen in table 18.

As a result of global warming potential in 50-60 years time, the P700 glass partition has the greatest impact of 15.8 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area in comparison to laminate partition, as shown in table 19.

Office Partition	Total weight - kg	GWP kg CO <sub>2</sub> equiv./kg <sup>89</sup>	GWP kg CO <sub>2</sub> equiv.	GWP kg CO <sub>2</sub> equiv. per m <sup>2</sup> of floor area
Glass, Toughened	-	1.3	-	-
Aluminum, extruded	-	1.0	-	-
<b>Total Glass partition</b>	<b>7195</b>	<b>2.3</b>	<b>16548</b>	<b>15.80</b>
Laminate	-	0.1	-	-
Stainless steel	-	1.2	-	-
<b>Total Service partition</b>	<b>1014</b>	<b>1.3</b>	<b>1318</b>	<b>1.2</b>
Laminate	-	0.1	-	-
Stainless steel	-	1.2	-	-
<b>Total Oasis location</b>	<b>234</b>	<b>1.3</b>	<b>304</b>	<b>0.3</b>
<b>Total</b>	<b>8443</b>	<b>4.9</b>	<b>18170</b>	<b>17.3</b>

Table 19 - The global warming potential of various types of Office Partition in 50-60 years time

<sup>88</sup> Green building hand book volume 1

<sup>89</sup> [www.umich.edu/~nppcpub/research/lcahome/homelca.PDF](http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF) - Life Cycle Analysis of residential in Michigan- September 1998

## 7. Results Overview

The previous chapter examined the total primary embodied energy, delivery energy per  $\text{m}^2$  of floor area and global warming potential of various types of office fit-outs and components over the 50-60 years entire life time of the BSKyB office building in the UK. Life cycle analysis was carried out, for specific locations such as wall coverings, floor coverings, office furniture and partitions; this included the environmental impacts of office fit-outs during the manufacturing process, use and disposal of all items. This section provides a summary of the previous section including the total life cycle mass of components used in office fit-outs; moreover it will cover the contribution to the overall embodied energy of the BSKyB office building of interior office fit-outs and also the overall global warming potential of office fit-outs.

### 7.1 Life cycle mass

The term life cycle mass is used to describe the total mass of various elements used for office fit-outs during the lifetime of an office building. Figure 11 indicates the total life cycle mass in  $\text{kg per m}^2$  of floor area broken down by individual items.

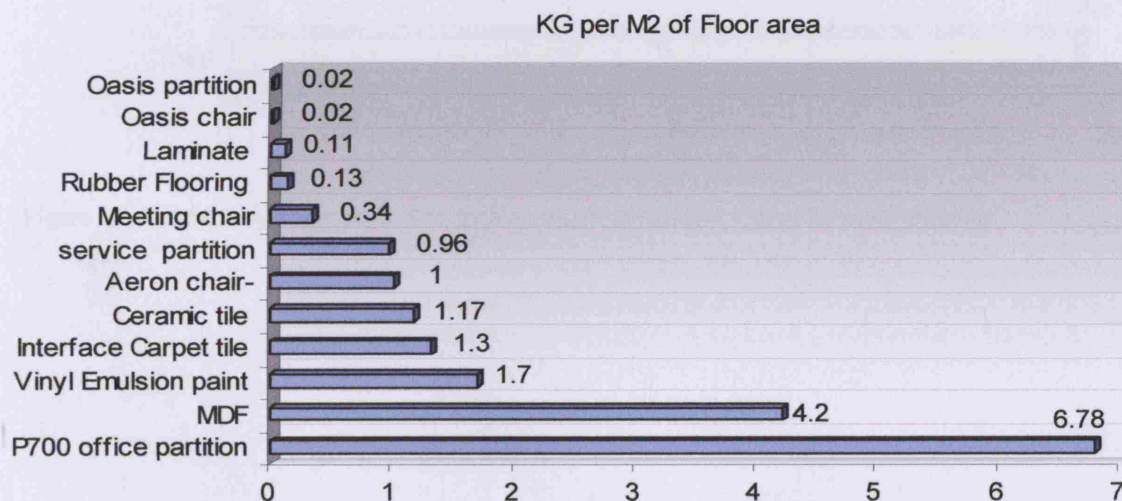


Figure 11 - Total life cycle Mass of material distribution-  $\text{kg per m}^2$  of floor area of different type of office fit-outs

The graph also shows the estimated overall mass of material used in office fit-outs in the BSKyB office building during the notional 50-60 years entire life time.

Figure 12 demonstrates the same information as shown in figure 12, total mass per m<sup>2</sup> of floor area but this time broken down into the main categories for the BSKyB office fit-out. The total life cycle mass of all the office fit-outs over their estimated 50-60 years life time is determined to be 19.02 kg per m<sup>2</sup> of floor area, the element, and office partition has the greatest impact compared to the other elements, and floor coverings have the lowest impact.

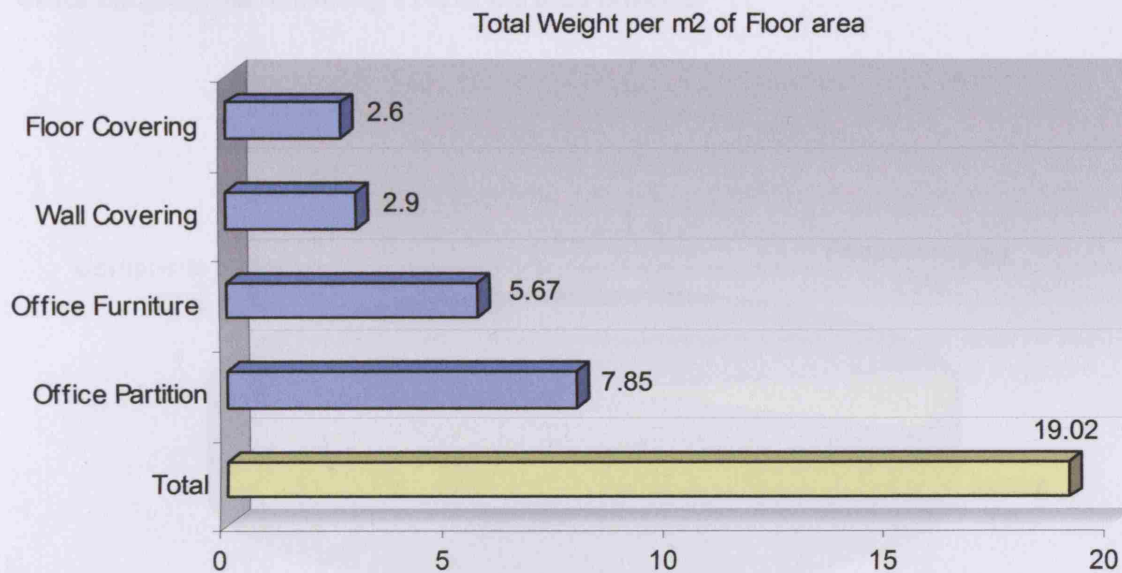


Figure 12 - Total life cycle elements distribution - kg per m<sup>2</sup> of floor area of the main elements

As defined in previous chapter, four material types identified in this case study as petrochemical (PVC, Solvent and nylon), minerals (gravel, gypsum and limestone all extracted from the ground and used without excessive manufacturing process), composite boards (MDF, laminate wood, etc) and metals (different type of aluminum and stainless steel). Figure 13 provides the percentage breakdown of all the materials used in relation to office fit-outs and components in BSKyB office building. It is found that 41% of the total mass can be considered mineral origin, which are generally recyclable, 27% of the total mass is due to composite board (office table and partitions with MDF and laminate wood), 21% of the total is due to petrochemicals, such as vinyl emulsion paint, PVC and interface carpet tile that widely used in different parts of the internal space in the BSKyB office building, the remaining 11% of the total is metal.

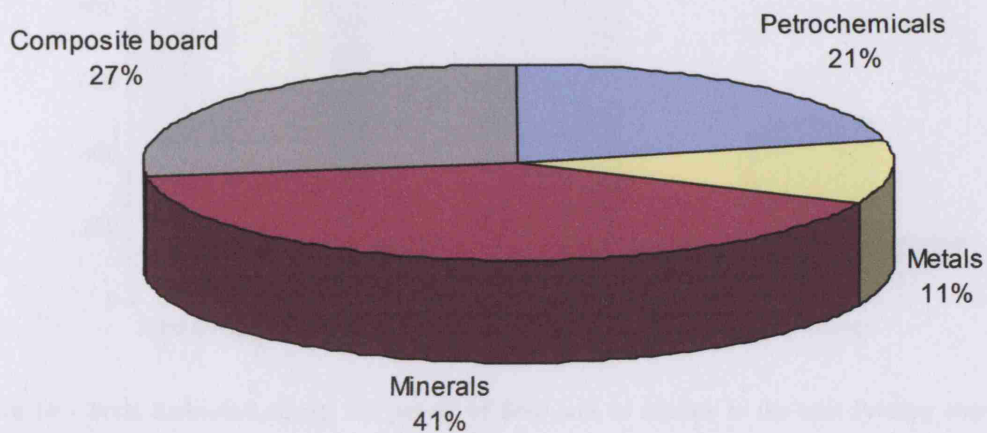


Figure 13 –BSkyB office building Mass Breakdown - kg per m<sup>2</sup> of floor area by different type of office fit-outs groups

## 7.2 Life cycle embodied energy consumption

The total life cycle embodied energy of all the office fit-outs including manufacture process, transportation to site, maintenance and improvement of office fit-outs over their estimated 50-60 years life time, is determined to be 1137 MJ per m<sup>2</sup> of floor area. This total includes total primary energy (pre-use phase) of 759 MJ per m<sup>2</sup> of floor area along with the total delivered energy of 377MJ per m<sup>2</sup> of floor area as shown in table 14. It should be mentioned that in this study the total energy for maintenance and improvements (use phase) and energy for final disposal (end of life) are assumed to be zero, future work could consider this issue in depth.

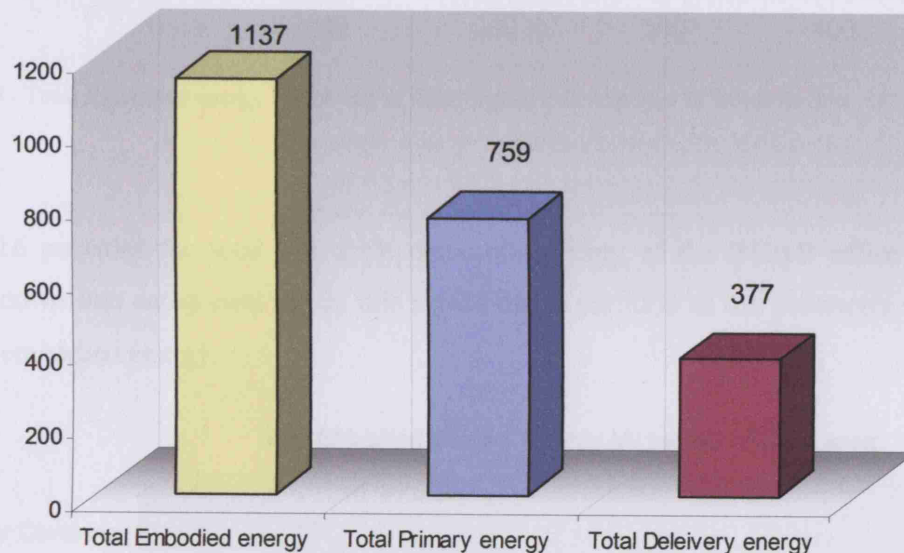


Figure 14 - Total Embodied energy MJ per m<sup>2</sup> of floor area in relation to the total Primary energy and Delivery energy in BSKyB office building

Table 15 shows the total life cycle embodied energy per m<sup>2</sup> of floor area broken down by the individual components used in the office fit-outs. The P700 glass office partition has the highest embodied energy, followed by vinyl emulsion paint, interface carpet tile and the Aeron chair. Appendix 12 indicates the primary energy and delivery energy per m<sup>2</sup> of floor area.

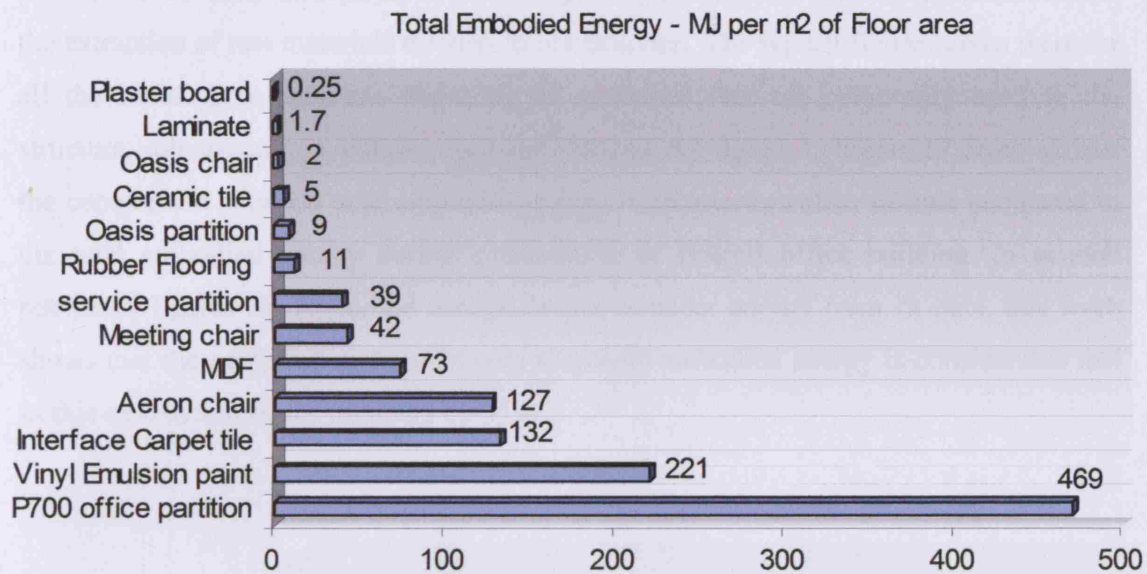


Figure 15 - Total Embodied energy MJ per m<sup>2</sup> of floor area of different type of office fit-outs

Figure 16 provides the total life cycle embodied energy of the BSKyB office fit-outs broken down into categories. Again this shows office partition as the parameter with the highest embodied energy.

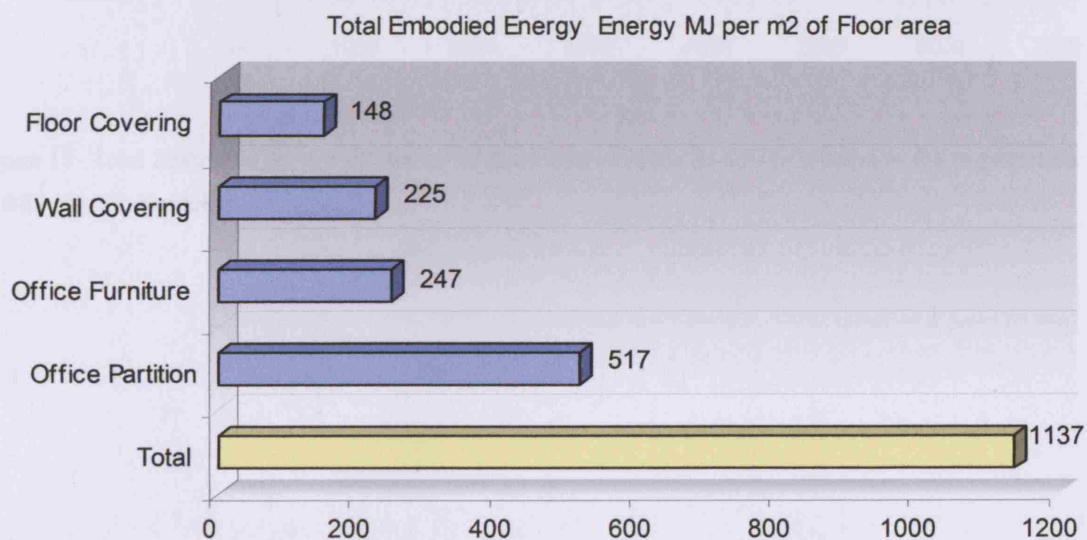


Figure 16 - Total Embodied energy MJ per m<sup>2</sup> of floor area of different type of office fit-outs



Section 3.2 covered the total embodied energy of typical offices including processes from the extraction of raw materials through to construction. The typical figures given were for all the building components including all materials that are commonly used in the structure, sub-structure, windows, roof and finishes, see figure 3. Figure 17 demonstrates the comparison between total embodied energy from interior office fit-outs compared to the total embodied energy during construction of BSKyB office building. In general published figures for embodied energy do not consider energy from fit-outs, this work shows that the contribution from fit-outs to overall embodied energy is considerable and in this case increases the numbers by 35%.

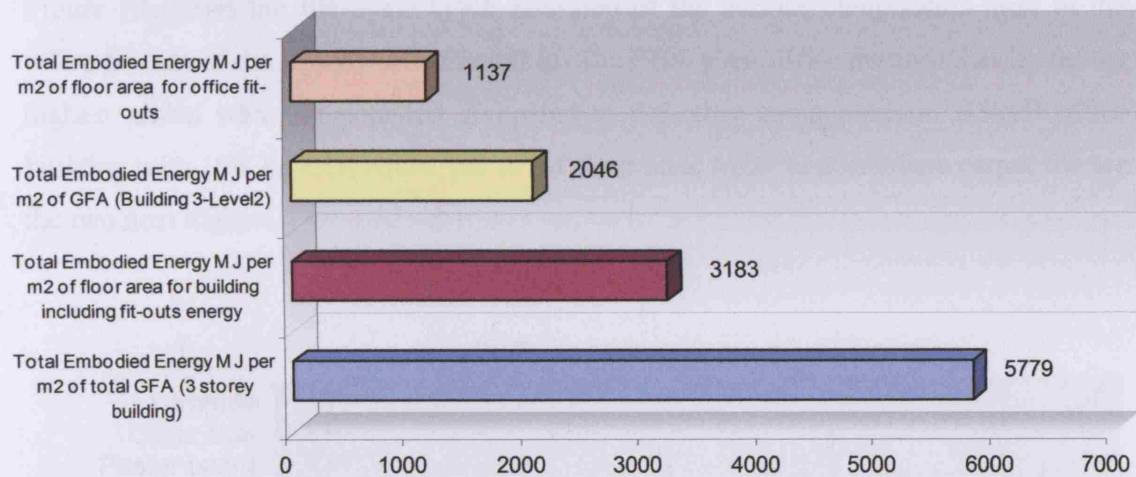


Figure 17- Total Embodied energy MJ per m² of floor area of office fit-outs in relation to the construction of BSKyB office building.

### 7.3 Life cycle global warming potential (GWP)

The total global warming potential for BSkyB office fit-outs and components is determined to be 39.54 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area over the 50-60 years life span, as seen in table 19, which includes all gases emitted to the atmosphere during:

- Extraction of raw materials and manufacturing processes
- Assembly of office fit-outs and components
- Transportation of all the office fit-outs from manufacture to the specific location
- use of materials over the 50-60 years life time
- End of life and disposal

Figure 18 shows the life cycle GWP emission of the various components used in the office fit-outs of the BSkyB office building. The P700 glass office partition has by far the highest global warming potential compared to the other components in BSkyB office building with 15.8 kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area, MDF and Interface carpet tile are the two next highest.

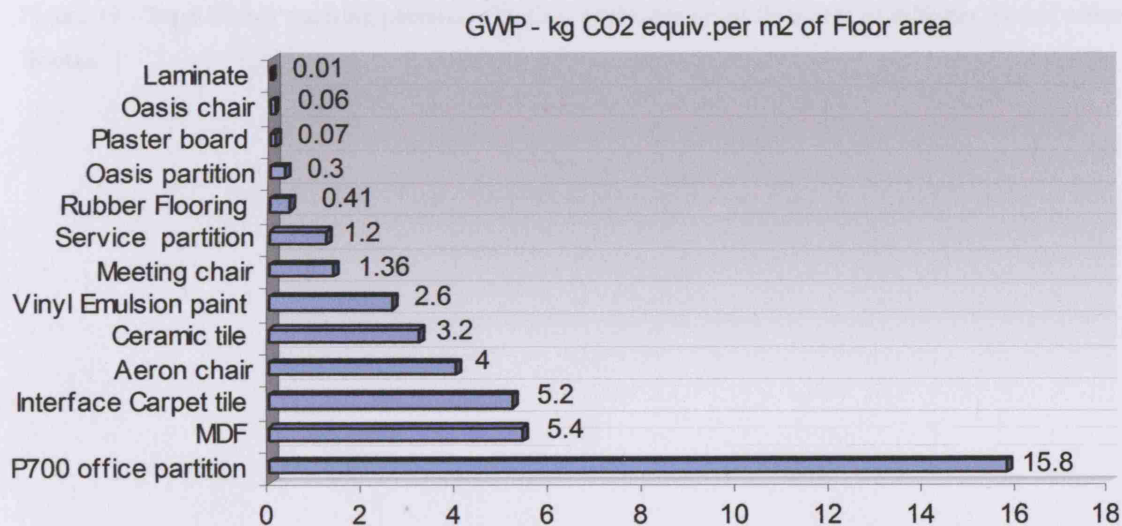


Figure 18 - Global warming potential - kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area of different type of office fit-outs

Figure 19 compares the total life cycle global warming potential for the four important elements of office fit-outs contributing to the total GWP, again the office partition has the highest impact; wall coverings have the lowest impact.

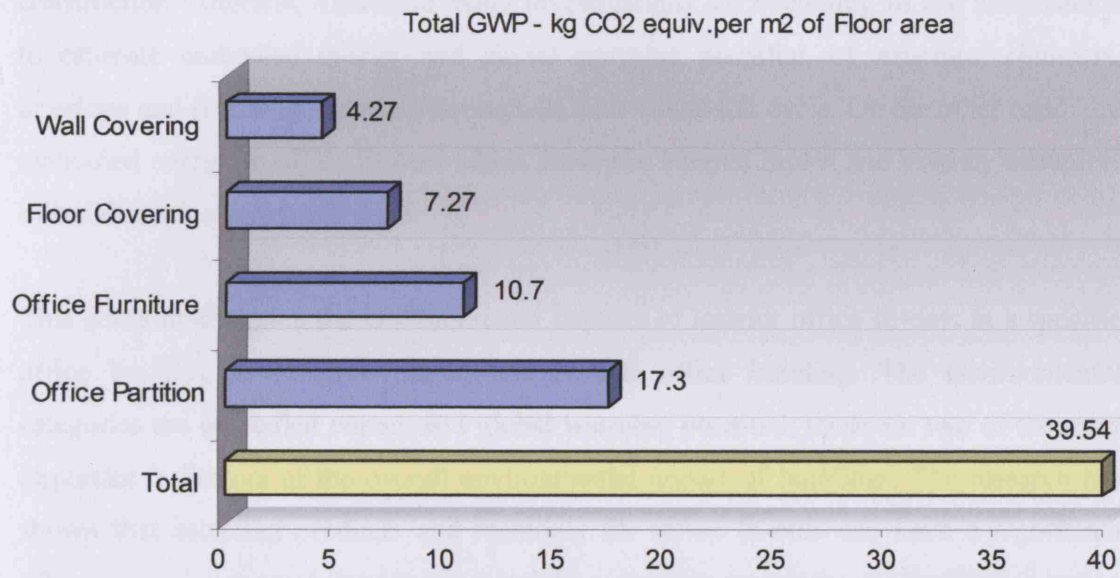


Figure 19 - Total Global warming potential - kg CO<sub>2</sub> equiv. per m<sup>2</sup> of floor area of different type of office fit-outs

## 8. Conclusion

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The energy required to operate office buildings has been the main concern during recent years in UK, while there have been limited attempts to quantify the embodied energy of construction materials. Therefore many investigations are beginning to use assessments to estimate embodied energy and global warming potential, of structural elements, envelope and finishing materials throughout their whole life cycle. On the other hand, the embodied energy in office fit-outs which cover the internal layout and used by occupiers of buildings is rarely mentioned.

This study investigated the environmental impacts of interior office fit-outs in a specific office building in London namely the BSKyB office building. The environmental categories are embodied energy and global warming potential; these are two of the most important indicators of the overall environmental impact of buildings. The research has shown that selecting products and materials for office fit-outs can have a significant effect on environmental impacts for a building. For this reason the most effective option should be selected for interior office fit-outs; as the energy efficiency of modern buildings has increased, consequently the importance of embodied energy of materials and components has also increased.

This project aims to estimate the environmental performance of interior office fit-outs by promoting life cycle assessment as a tool to examine their overall environmental impacts. The total embodied energy of the building production was determined using the energy intensity figures of a full range of office fit-outs. Furthermore the environmental impacts were calculated during their manufacturing process, use and final disposal according to Green guide hand book and BRE research. Office materials and components have been breakdown, in the context of Life cycle analysis in four specific elements in BSKyB office building as following:

- Wall covering
- Floor covering
- Office furniture
- Office partitions

According to the life cycle embodied energy of the BSKyB office fit-outs, office partitions have the greatest impact on overall embodied energy and global warming potential compare to the other office elements. Contemporary evaluations on overall embodied energy of office buildings are restricted to quantify the embodied energy of the structural skeleton, windows, roof and finishes, neglecting the contribution of the embodied energy of internal fit-outs. In fact, according to the findings of this study concerning BSKyB office building, the calculated embodied energy of office internal equipments could contribute to the increase of the total embodied energy of a building by 35%.

This research has also highlighted the potential to influence design decisions, while the main consideration in this study was to raise the awareness of owners, occupants, interior designers and architects to consider the overall life cycle embodied energy and global warming potential. With respect to environmental concerns and with proper information about environmental burden of office fit-outs, the architect is able to achieve more sustainable design decisions, either at design and refurbishment stages or in the case of existing buildings in operation, having on his disposal a wide range of potential alternatives.

With this study a further step is been made in order to alert consumers and engineers about the important impacts of internal equipments on the overall embodied energy of the building. With public concern and on environmental issues awareness and the conscious choice among the wide range of interior materials, to select the best choice with minimum environmental impacts, the contribution of internal fit-outs on the total embodied energy will be decreased following the principles of sustainable design. Furthermore construction industries and manufacturers should be able to provide with

**relative information about the environmental performance and the embodied energy values of their products to consumers. Consequently users and interior designers could be able to choose between similar materials, not only with aesthetic criteria but also by weighting their environmental impacts and choosing the most energy effective option.**

## 9. References

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- The Green Guide to housing specification – an environmental profiling system for building materials and components used in housing by Jane Anderson and Nigel Howard – BRE, Echo Homes- 2000
- Green building hand book volume 1 – a guide to building products and their impact on the environment – Tom Wooley 1997
- Green building hand book volume 2 – a guide to building products and their impact on the environment – Tom Wooley, Sam Kimmins, 1997
- BREEAM 98 for Offices, an environmental assessment method for office buildings – September 1998
- BRE methodology for environmental profiles of construction materials, components and buildings by Nigel Howard, Suzy Edwards and Jane Anderson – 1999
- BRE Information paper. The environmental impact of buildings. PB Bartlett, MA and Josephine J Prior – December 1991
- Sustainable homes – embodied energy in residential property development – a guide for registered social landlords
- Climate change and the indoor environment: impacts and adaptation – CBSE guide TM 36:2005
- Center for sustainable systems, university of Michigan. Life Cycle Analysis of a residential home in Michigan by Steven Blanchard and Peter Reppe. Report No. 1998-5- September 1998
- Building life cycle assessment: Residential case study by W.B Trusty and J.K Meil – ATHENA – Sustainable Materials Institute – Canada
- British council for offices- annual review 2003-2004, Roger Reeves BCO President
- Developing life cycle assessment tool for buildings in Hong Kong/ PDF
- Guinea JB(ed). Hand book on life cycle assessment – operation guide to the ISO standards, Dordrecht, Netherland, Kluwer Academic publishers, 2002

- **Determining the permissible degree of inaccuracy in life cycle assessment protocols by Raymond J Cole, university of British Columbia, paper No.96-WA78A.02**
- **A guide to sustainable office fit outs- published in December 2005 by Ministry for the environment – PO BOX 10-362, Wellington, New Zealand. ME number 703**
- **Plastic: surface and finish. (W.GordonSimpson, Ed.) Royal society of chemistry, Cambridge 1993**
- **Tall buildings and sustainability – The corporation of London – Author Will Pank (Maunsell Ltd), Herbert Giradet (Urban future) and Greg Cox, Oscar Faber Ltd – February 2002.**
- **Treloar, G.J. (1996) The Environmental Impact of Construction - A Case Study, Australia and New Zealand Architectural Science Association Monographs, No. 001, Australia and New Zealand Architectural Science Association, Sydney, November, 89.**
- **Treloar, G.J., McCoubrie, A., Love, P.E.D. and Iyer-Raniga, U. (1999) Embodied energy of fixtures, fittings and furniture in office buildings, Facilities, 17[11]. 403-409**
- **Hand book of Sustainable Building by Anink, Boonstra and Mak (James& James London, 1996)**
- **Building the future: a guide to building with out PVC (Green peace, London,1996)**



## Internet sources

<http://www.hadrianawards.com/shortlist.php>

<http://yosemite.epa.gov/oar/globalwarming.nsf/content/Emissions.html>

[http://www.est.org.uk/uploads/documents/housingbuildings/climate\\_change\\_strategy\\_bn.pdf](http://www.est.org.uk/uploads/documents/housingbuildings/climate_change_strategy_bn.pdf)

<http://www.emeraldinsight.com/Insight/ViewContentServlet?Filename=/published/emeraldfulltextarticle/pdf/0690171101.pdf>

[http://en.wikipedia.org/wiki/Global\\_warming\\_potential#Calculation\\_of\\_GWP](http://en.wikipedia.org/wiki/Global_warming_potential#Calculation_of_GWP)

[http://www.cfd.rmit.edu.au/programs/sustainable\\_materials](http://www.cfd.rmit.edu.au/programs/sustainable_materials) <http://auslcanet.rmit.edu.au/>

[http://www.architecture.ubc.ca/people/raycole/research/research\\_pdf\\_files](http://www.architecture.ubc.ca/people/raycole/research/research_pdf_files)

<http://www.areonchair.cco.uk>

<http://www.cambridge.gov.uk/ccm/content/building-control/office-fit-outs-guidance>

[http://www.simetric.co.uk/si\\_materials.htm](http://www.simetric.co.uk/si_materials.htm)

<http://www.vum.ac.nz/cbpr/documents/pdfs>

<http://www.en.officebit.com/officebit/prodotti>

<http://www.umich.edu/~nppcpub/research/lcahome/homelca.PDF>

<http://www.cf.ac.uk/archi/dfr/environmental%20benefits.htm>

<http://www.cmit.csiro.au/brochures/tech/embodied>

[http://www.sustainabilityworks.org.uk/guide/page.php?subsect=02\\_04\\_03#embodied](http://www.sustainabilityworks.org.uk/guide/page.php?subsect=02_04_03#embodied)

[http://www.cdnarchitect.com/asf/perspectives\\_sustainability/measures\\_of\\_sustainability/measures\\_of\\_sustainability\\_embodied.htm](http://www.cdnarchitect.com/asf/perspectives_sustainability/measures_of_sustainability/measures_of_sustainability_embodied.htm)

<http://strategies.ic.gc.ca/epio/internet/insid-tour.nsf/en/qq00054e.html>

<http://www.greenhouse.gov.au/yourhome/technical/fs31.htm>

<http://www.built.qld.gov.au/aps/ApsDocs/fitout.pdf> Office fit outs guidelines – July 2001

<http://buildlca.rmit.edu.au/casestud/Ee/EEmain.html#OVERVIEWCommerci>

<http://www.epa.gov/energystar/> Building energy use

[http://www.cityoflondon.gov.uk/NR/rdonlyres/.../0/BC\\_RS\\_tallbuild\\_0202\\_FR](http://www.cityoflondon.gov.uk/NR/rdonlyres/.../0/BC_RS_tallbuild_0202_FR)

<http://www.pca.state.mn.us/greenhouse.html>

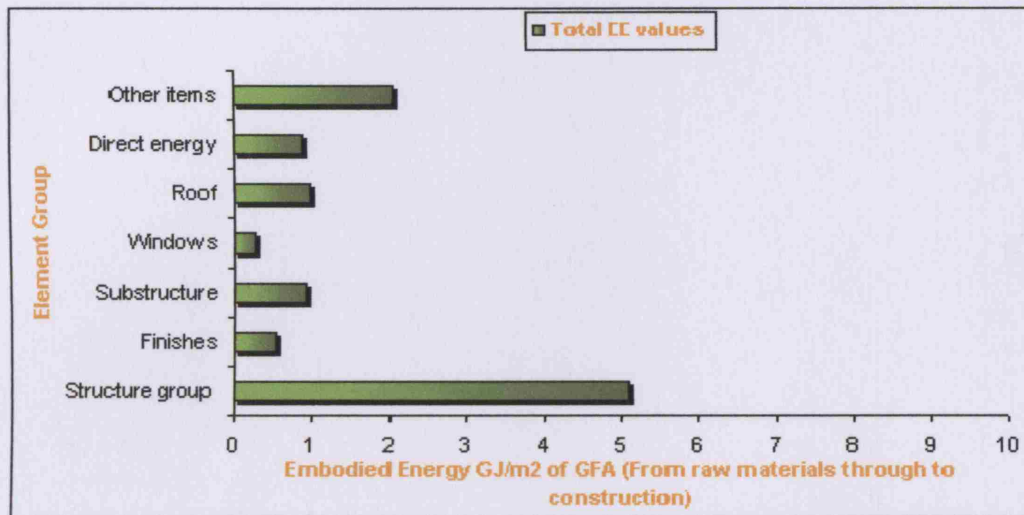
<http://www.sustainablehomes.co.uk/> Sustainable homes – Embodied Energy in residential property

## 10. Appendices

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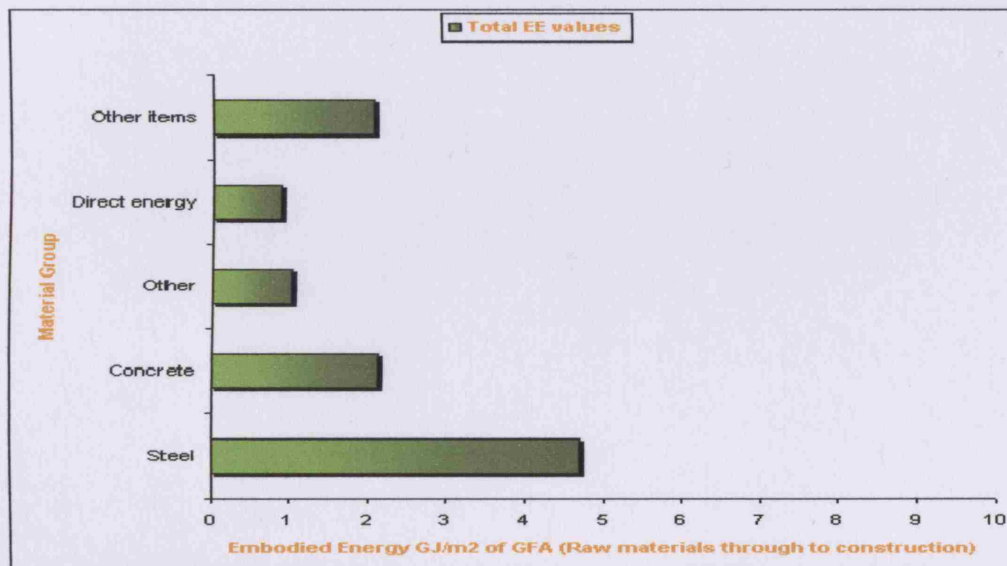


## Small office 1



**Element Breakdown** – small office 1 -Includes only Structure, Enclosure and Finishes elements.

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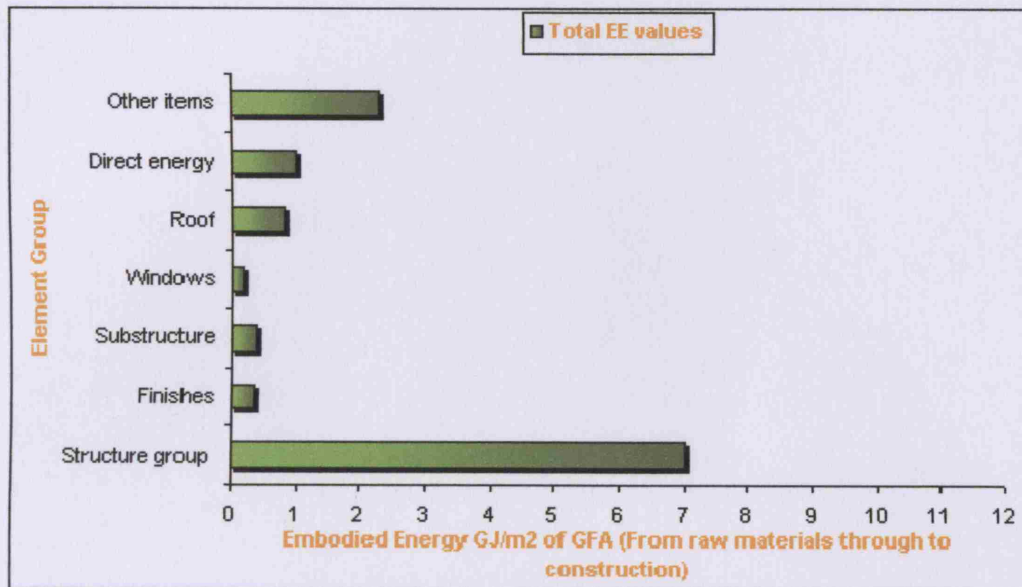


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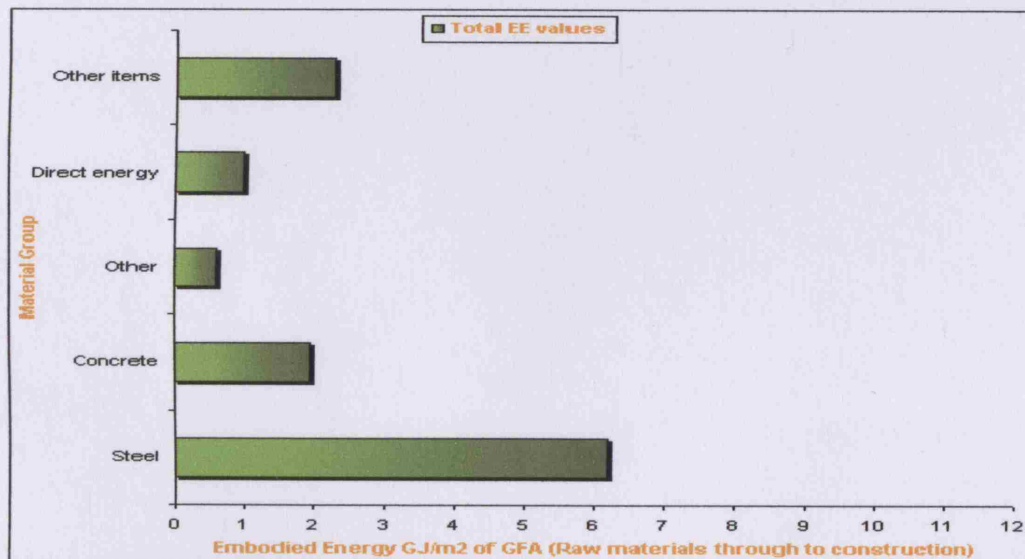


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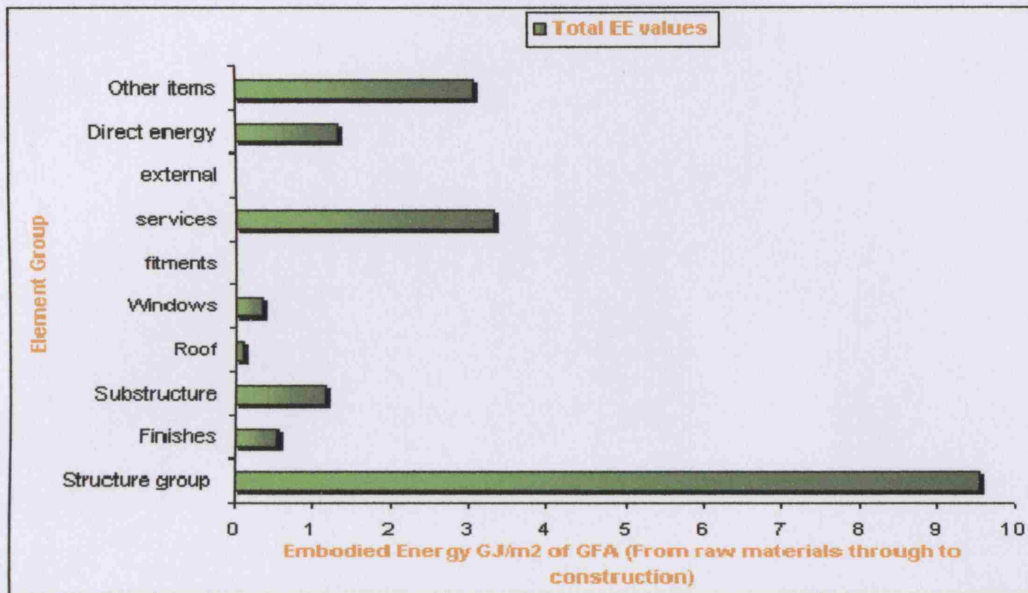


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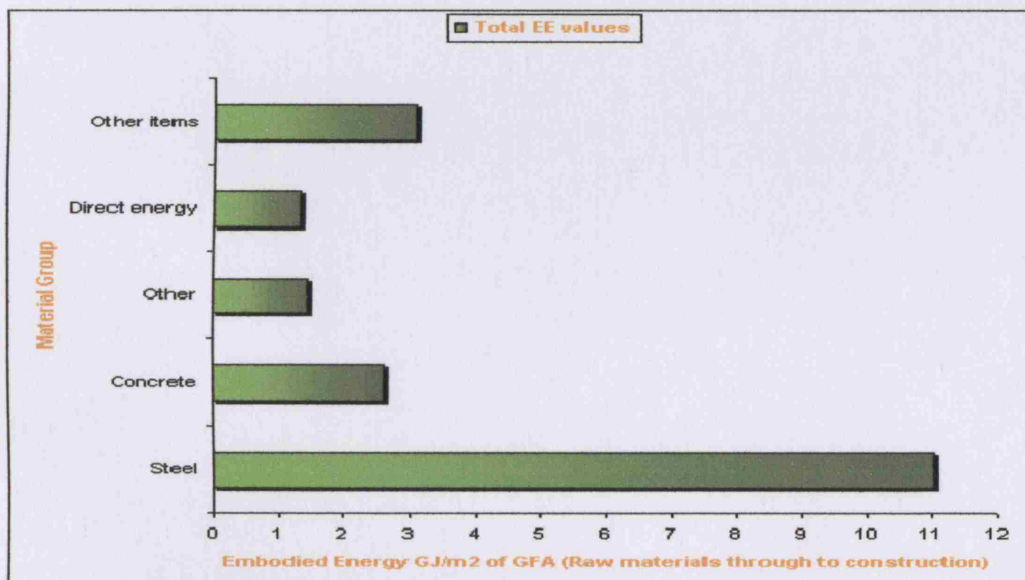


## Medium office



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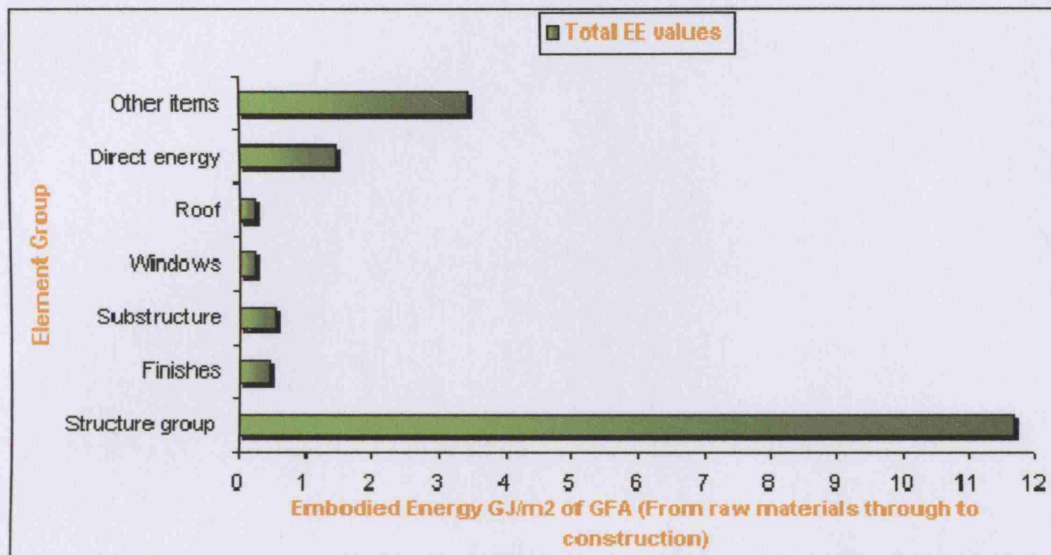
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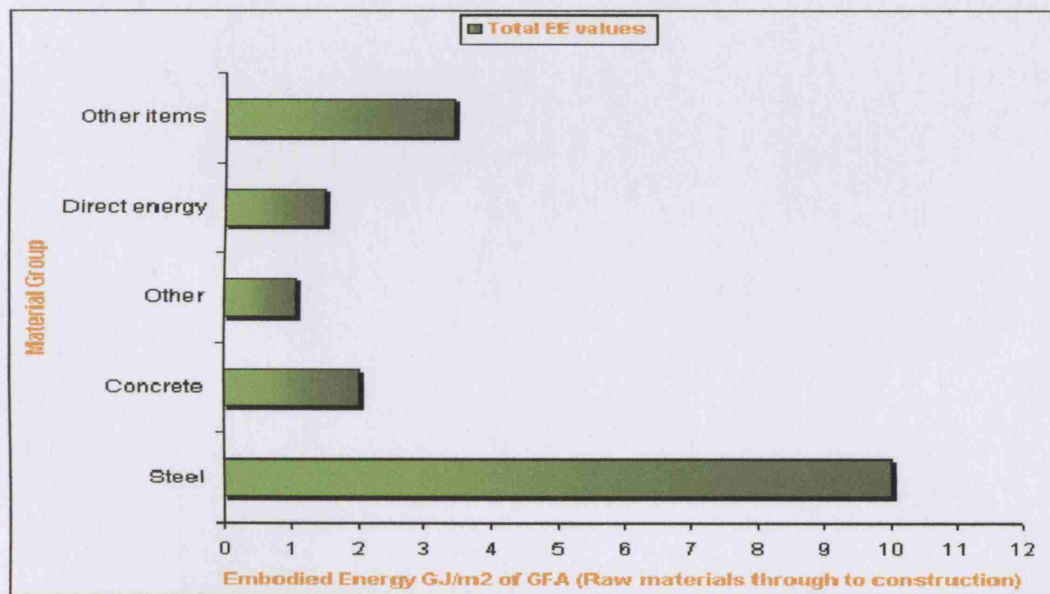


## Large office 1



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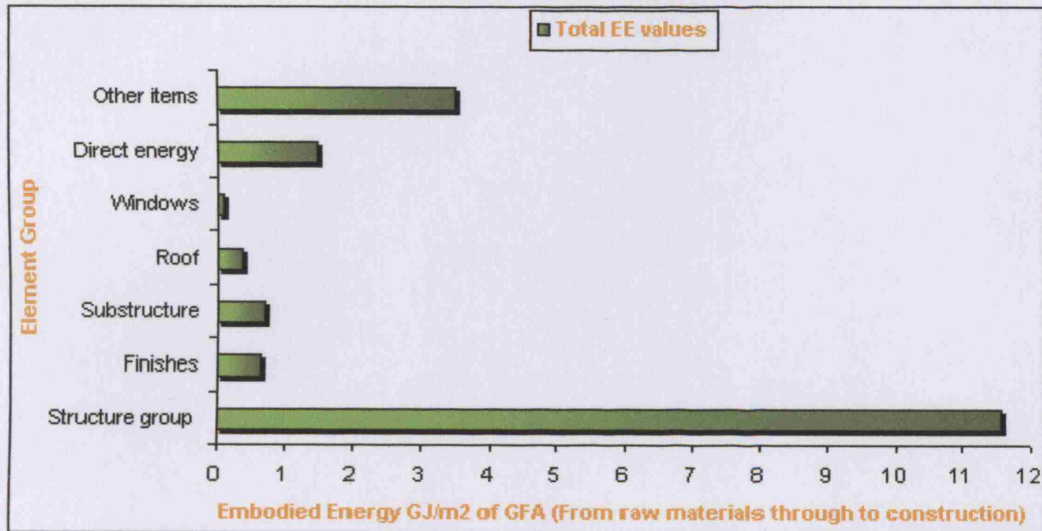


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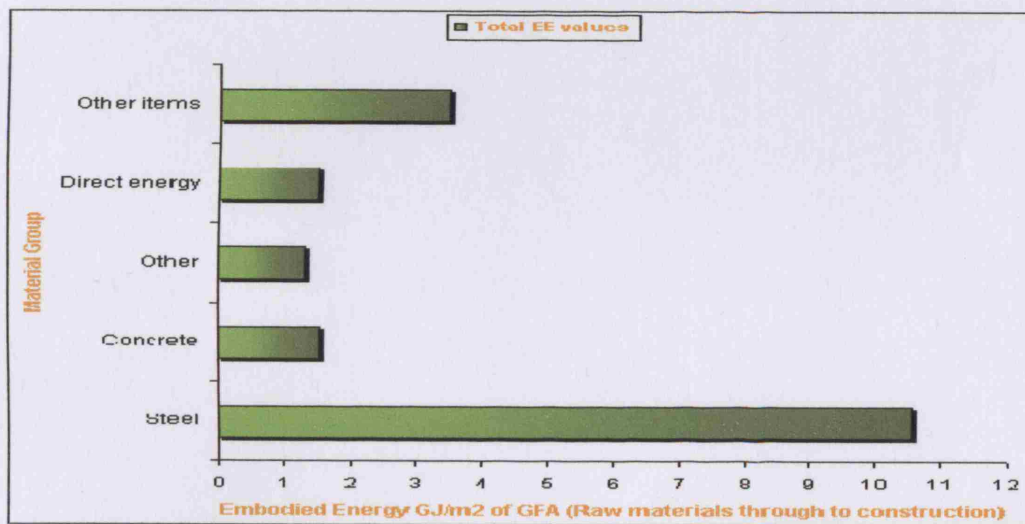
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## Location Aerial



Top view of B Sky B office building. Source: Building Design Partnership consultant



## Site plan



Site plan-scale: 1/1000. Source: Building Design Partnership consultant







Effectiveness and performance of design B Sky B after refurbishment. Source: Building Design Partnership consultant



Building		NIA	GIA	Net: Gross	Staff population	Net area/ person(m2)
Building 1	Ground	1.206	1.573	77%	77	15.66
	First	1.448	1.635	88%	140	10.34
	Second	1.12	1.295	86%	77	14.55
	Third	941	1.137	83%	20	47.05
	Subtotal	4.715		86%	314	15.02
Building 2	Ground	955	1.123	85%	88	10.85
	First	964	1.111	87%	104	9.27
	Second	1.106		89%	90	12.29
	Subtotal	3.025	3.469	87%	282	10.73
Building 3	Ground	906	1.134	80%	83	10.92
	First	944	1.123	84%	117	8.07
	Second	1.047	1.237	85%	107	9.79
	Subtotal	2.897	3.494	83%	307	9.44
Building 4	Ground	457	578	79%	Occupational health suite	
	First	875	990	88%	Meeting / conference	
	Second	950	1.078	88%	Restaurant	
	Subtotal	2.282	2.616	87%	N/A	
<b>TOTAL</b>		<b>12.919</b>	<b>15.219</b>	<b>85%</b>		

Net/Gross internal area of the four B SkyB office building. Source: Building Design Partnership consultant

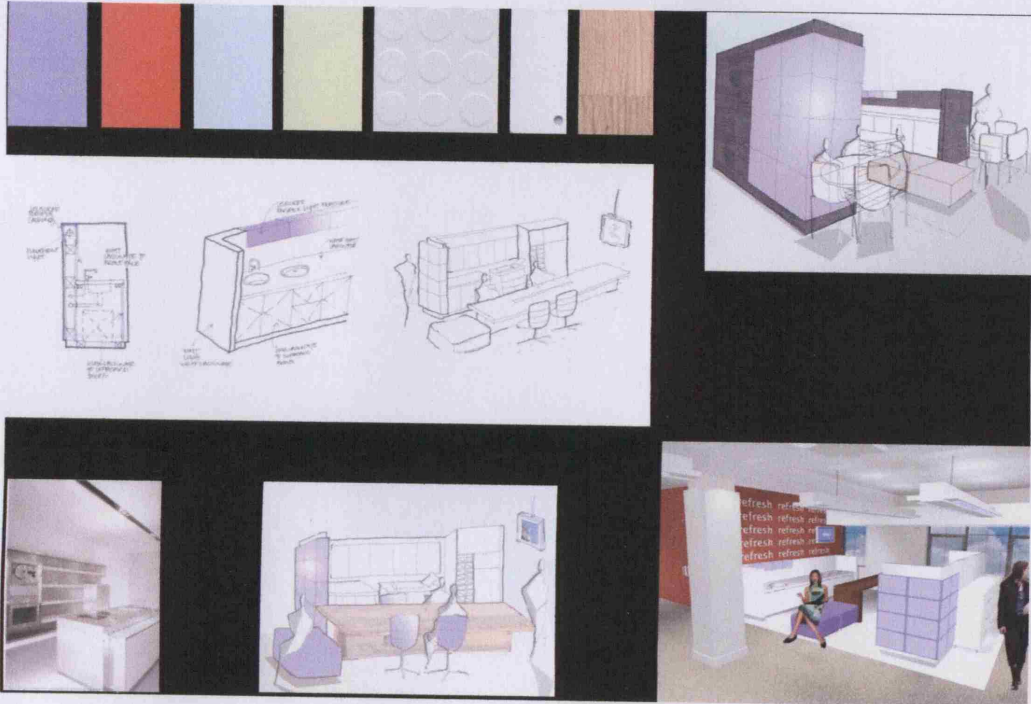




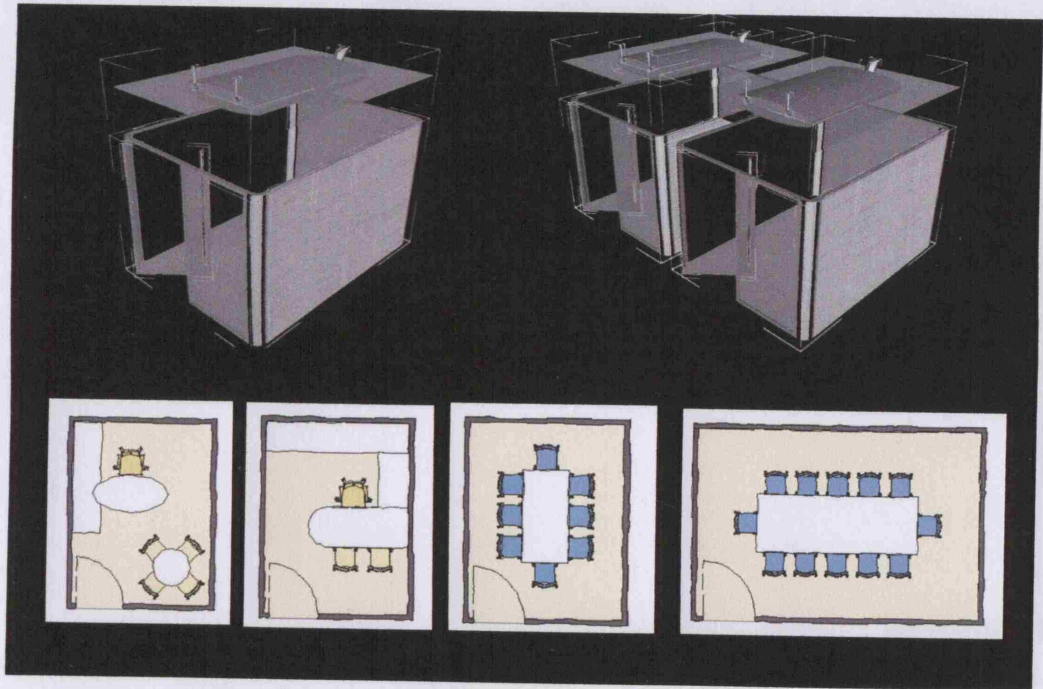
Performance of new office fit-outs arrangement of the four BskyB office building Scale 1/500. Source:  
Building Design Partnership consultant



**Oasis location**



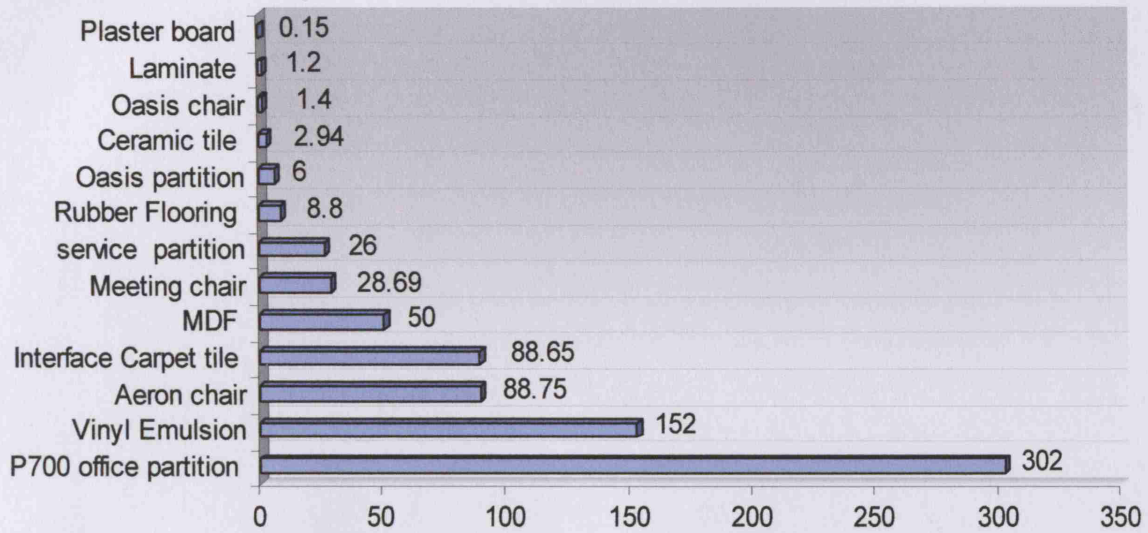
**Pod concept - Meeting Rooms**





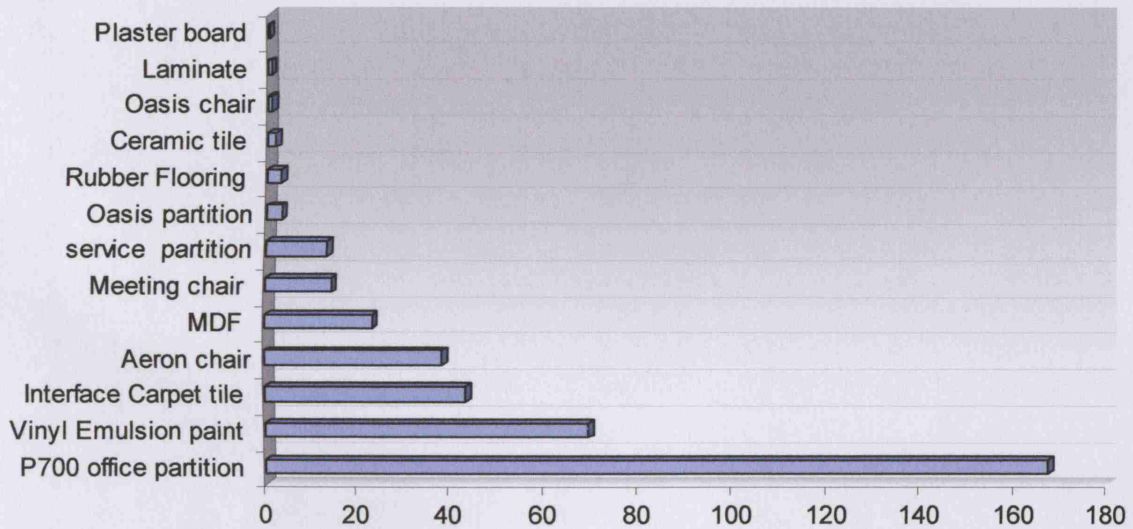


Primary Energy MJ per m2 of Floor area



Primary energy MJ per m<sup>2</sup> of floor area of different type of office fit-outs

Delivery Energy MJ per m2 of Floor area



Delivery energy MJ per m<sup>2</sup> of floor area of different type of office fit-outs