SUSTAINABLE REFURBISHMENT OF OFFICES IN THE UK

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ABSTRACT

With the passing of the 2008 Climate Change Act the UK Government set ambitious targets of reducing carbon emissions by at least 80% by 2050 compared to a 1990 baseline. 44% of UK emission comes from the built environment, 18% of this from the non-domestic sector. Within the non-domestic sector offices after retail are the second highest energy user. The refurbishment of office buildings presents a great opportunity to reduce energy consumption and carbon emissions, ultimately working towards the 2050 target. This research utilised interviews, case studies and current literature to investigate the UK office stock typologies, the main causes of energy consumption and carbon emissions in office buildings, and refurbishment solutions that improve energy efficiency, reduce carbon emissions and improve end-user satisfaction. The results show that the main causes of energy consumption and carbon emissions as the buildings services and main central plant. The extent to which these are the main consumer and cause of carbon emission is ultimately dependent on the individual building. Many measures were identified to improve occupant satisfaction. Two examples are; the provision of personal control and providing a connection to the exterior environment. Enhancing the natural elements of a building is a key solution that improves energy/carbon performance and end-user satisfaction.

Keywords: ***S****ustainable refurbishment****,*** *energy, occupants' behavior, satisfaction and productivity.*

1 INTRODUCTION

In 2008 the UK Government's Climate Change Act was passed; the act set a target of reducing UK carbon emissions by at least 80% by the year 2050 compared with a 1990 baseline [1]. The built environment accounts for around 44% of UK CO_2 emissions, 26% being produced from domestic buildings and 18% being produced by non-domestic buildings [2].

It is predicted that around 60% of non-domestic building stock in 2050 will have been built prior to 2010 [3]. The successful refurbishment of current stock will therefore play a key role in the achievement of the 80% reduction target for 2050. The achievement of this will be challenging as currently around 41% of non-domestic building stock has a DEC (Display Energy Certificate) rating of below E. An average improvement of around four ratings of existing stock will be required in order for non-domestic building stock to play its part in achieving the carbon reduction targets of 2050 [2]. It is clear that successful refurbishment of current non-domestic building stock is of vital importance. Large scale refurbishment must be achieved if the 2050 targets are to be met and the threat of climate change is to be tackled.

Refurbishment of office buildings presents a great opportunity to reduce energy consumption and carbon emissions. Office buildings have a high level of energy consumption compared to other building sectors. The annual consumption varies between 100 and 1000 kWh per square meter, dependent on location, type and use of equipment, envelope type, type of lighting etc. [4]. Currently approximately half of all energy consumed by the non-domestic sector is for space heating, the vast majority of this is consumed within commercial offices, education, retail, hotel and catering facilities. Out of these built facilities offices along with retail, have the biggest energy consumption and carbon emissions accounting for over 50% of total energy consumed. Offices account for 17% of energy. Offices have a higher than average energy consumption for heating compared to the rest of the non-domestic sector and approximately double the average for ventilation and cooling [2].

2 UK OFFICE BUILDINGS TYPOLOGIES

To be able to gain an understanding of the issues surrounding energy consumption and carbon emissions in office buildings and present plausible measures to ensure reductions it is necessary to consider the typology of office buildings. This can be done via identifying built forms that can be generalised to similar buildings. The diversity of office buildings does however hinder this approach. The approach presented is to develop a number of archetypal buildings that represent the typical built form of an office. Additionally the design, construction and activity features in a building that have a bearing on energy consumption will be parameterised, thus customisable, to represent buildings' individually. In general, UK offices can be categorised into four types:

A. Naturally ventilated, cellular (estimated 68% of England and Wales office stock).
B. Naturally ventilated, open-plan (estimated 9% of England and Wales office stock).
C. Air-conditioned, standard (estimated 14% of England and Wales office stock)
D. Air-conditioned, prestige (estimated 9% of England and Wales stock)

Dascalaki & Santamouris, (2002) [5] conducted a thorough investigation of ten buildings and their energy relating behaviours, the buildings were located throughout Europe and are examples of offices requiring retrofit. As part of the study the buildings were categorised by four main criteria: degree of exposure, thermal mass, skin dependence and internal structure. There are five key building characteristics that will have a significant bearing on energy consumption: (1) Built form, (2) Glazing ratio, (3) Envelope construction, (4) Solar shading and heat gain control measures, and (5) Indoor environment.

3 SUSTAINABLE REFURBISHMENT

The terms 'sustainable' and 'sustainable development' are common terms, however they have many different [6]. This broad array of meanings is ultimately linked to the vast number of definitions, Shah, (2012) [7] states that there are over 500 definitions of sustainable and sustainable development. The commonly used and accepted definition is;

"Development that meets the needs of the present without compromising the ability of future generations to meet their own." [8].

Mansfield (2002) [9] identified that there are currently more than twenty terms used to describe the attempts to rectify the depreciation of a building, refurbishment being one of them. Therefore refurbishment encompasses a suit of terms such as adaptation, retrofit, upgrade, conversion, renovation etc. Combining the terms sustainable and sustainable development with refurbishment, enables readers to answer the question of what is sustainable refurbishment? It is the process of adapting, upgrading, converting a building in a way that mitigates the buildings environmental impact, in an economical way mitigating the use of resources and creating a building that enhances society.

There are a large number of technologies that could be incorporated into a refurbishment to make a building sustainable. There are a number of studies identifying refurbishment strategies, such studies categorising different levels of refurbishment that can be implemented. Such as passive strategies, mechanical services and control, efficient equipment and lighting and renewable energy options [4, 10]. Dascalaki &

Santamouris, (2002) [5] identified a number of retrofitting interventions. The interventions vary from an individual action or a number of actions. The refurbishment strategies use a combination of passive refurbishment and mechanical services and controls upgrade. The interventions focus specific areas of a building that affect energy performance.

Improvement of the building envelope: the aim is to reduce the impact of the external environment on thermal performance. Minimise heat losses, maximise solar gains for heating and day lighting, reduce cooling demand by effective solar control. Use of passive systems and techniques: the aim is to reduce the heating and cooling demands by optimising solar gains in winter and mitigating solar gains in summer. Measures will consist of use of thermal mass and passive cooling techniques. Installation of energy saving lighting and use of daylight: the aim is to reduce the power consumption of lighting by the implementation of energy-efficient lighting and a reduction in operation hours. Improvement of heating, cooling and ventilation system: the aim is to reduce the energy consumption for heating and cooling by maximising the efficiency of the building services and the utilisation of heat recovery systems.

4 ENERGY CONSUMPATION IN OFFICES

Van de Wetering & Wyatt, (2010) [11] identified that since the 1980s UK office space has been increasing in specification, resulting in energy intensive air-conditioning and electrical systems being increasingly incorporated into offices, these offices are predominantly located in areas only accessible via vehicular transport. From these findings it was concluded that there are two main causes of CO_2 emissions: (1) highly specified office space with air-conditioning and fully integrated technologies and (2) out-of-town vehicular-based transport. These two causes of CO_2 emissions were also identified by Agha-hossein *et al*., (2014) [10]. Over half of new offices built during the 1990s had air-conditioning compared to 36% during the 1970s and 43% during the 1980s. Also from the period of 1988 to 2001 the UK sales of air-conditioning units tripled, the vast majority of these units were sold to the commercial sector, approximately 45% of these were installed into commercial offices. Office space in the period of 1970 to 1994 almost doubled and it is consistent with out-of-town growth [10].

Findings Agha-hossein *et al*., (2014) [10] further support the above. The authors found that in office buildings the amount of lighting, IT equipment and air-conditioning has steadily increased. Also that there has been a large increase in office floor area; between 2000 and 2005 office floor area within the UK has risen by around 4%. Many of these office developments have been in major city outskirts.

5 END-USERS AND SUSTAINBLE REFUIRBISHMENT

Whilst a key aim of a sustainable refurbishment is to deliver a building with improved physical attributes and asset value, a key aim should be to provide an environment that satisfies the end-users [7]. It is important to consider the social implications of a refurbishment, analysing the effects of the physical environment on the end user and identifying refurbishment solutions that enhance the end-users ’ satisfaction whilst still improving energy efficiency. It is key that end-users are engaged with these refurbishment solutions. Cole *et al*., (2008) [12] states that without their active engagement, improved environmental performance will not be achieved. To achieve this there must be a shift from conceptualising the end-user as a passive recipient of indoor conditions, to an active inhabitant [12]. Simple measure of adjusting end-users’ behaviour will enhance energy efficiency. Behavioural changes, such as ensuring when not in use equipment is turned off and fine tuning temperature levels.

From the perspective of organisational science the physical features of a workplace has minimal implications on working life and organisational success. In contrast, from the perspective of designers and consultants the physical environment has significant implications [13].

The argument that the physical environment has minimal implications is supported by three factors: (1) a strong perceptual bias favouring the social environment; (2) the Hawthorne experiments; (3) the view that the physical environment is a low-level need or hygiene factor [13].

In contrast, the organisational science view is that there is a strong correlation between the physical environment and working life. The quality of the indoor environment has large implications on health, well-being, quality of life and social or personal relationships [14]. Social behaviours such as collaboration and communication are all affected by the physical environment. It is strongly argued that those employees who are satisfied with their working environment are happier and thus more productive [15]. Shah, (2012) [7] states that good office design can increase productivity by nearly 20% and that it is a key factor in job satisfaction, recruitment and retention. Four out of five (79%) professionals believe that the quality of their working environment is an important factor in job satisfaction. Leaman & Bordass, (1999) [15] stated that the productivity of 20% of US office workers increased by improving air quality. The PROBE studies indicate a difference of 25% in productivity between comfortable and uncomfortable staff [15].

There are numerous studies supporting the view that there is a strong correlation between the physical environment and enhanced end-user satisfaction and productivity. A survey conducted by the American Society of Interior Design in the late 1990s of 200 business decision makers found that 90% of respondents believed that employee productivity would increase with improved office design. A study conducted in the United States documented 16% productivity gains of individuals having been relocated to a new building. Kampschroer & Heerwagen, (2005) [13] from their study found a strong link between the working environment and organisations effectiveness. One of their workplace consultancy teams identified a number of problems with the workplace in question. These problems hindered the ability for groups to work effectively together. The findings from studies by Agha-hossein *et al*., (2014) [10] further support the assumption that there is a correlation between end-user satisfaction and productivity. This correlation between end-user satisfaction and productivity means there is a strong case for the incorporation of green technologies and design strategies such as advanced ventilation systems and high quality energy efficient lighting. Such technologies and design strategies will enhance the internal environment therefore in turn enhancing human health, satisfaction and productivity [10].

Incorporating such measures of improved management, design and use characteristics not only improve individuals' welfare but also contribute to enhanced energy efficiency. For example daylighting levels have implications on energy efficiency, health and productivity [14].

Having identified that there is a strong correlation between the physical environment and end-user satisfaction and productivity, the question that should be asked is; what are the key factors in a building that influence end-user satisfaction and productivity?

Vischer, (2005) [16] 'habitability pyramid' identifies three related categories influencing environmental comfort: physical, functional, and psychological. All three categories need to be considered to ensure a comfortable and productive environment. Physical comfort is ensuring an acceptable workplace in regards to basic human needs (safety, hygiene). Functional comfort refers to environmental elements that support or hinder work, such as lighting, noise level, temperature and layout. Psychological comfort is the feeling of empowerment over environmental conditions.

Leaman & Bordass, (1999) [15] identified offices will work best for human productivity when there are:

1. Opportunities for personal control; enabling adaptive comfort providing a healthy, comfortable and safe operation.

2. A rapid response environment; environments that will meet people's needs rapidly, either in anticipation or as they arise, for example the ability of personal control, to adapt space and reconfigure furniture. Failing this, a positive and productive response from the buildings facilities management team.

3. Shallow plan forms; end-users are generally more satisfied in buildings of a shallow depth. Shallow plans allow the use of natural ventilation, which is generally favoured by end-users over mechanical ventilation.

4. Workgroups; in offices productivity is perceived to be higher in small more integrated workgroups. Thus offices that accommodate small workgroups that are well integrated create a more productive environment.

Agha-hossein *et al*., (2014)) [10] identified the following parameters that influence productivity:

1. Interior ambient quality;

2. The thermal environment (temperature, humidity, ventilation), air quality and lighting;

3. Personal control over ambient conditions especially temperature and ventilation, this is important to reduce discomfort and to create an environment to personal preferences and task needs.

Independent research conducted of middle and senior managers in the legal, media and financial service sectors found that personal space (39%); climate control (24%) and daylight (21%) are the key parameters influencing satisfaction in a working environment. Similar research; an employee survey conducted by Arup of 2,000 full-time UK office workers during spring 2013, found that the key factors affecting productivity are: Outside views (23%), private rooms where people can work (19%), and breakout areas (18%). Other factors employees consider important are: Natural lighting (85%), effective heating and cooling (90%), having surrounding windows (77%), the ability to open windows (71%), clean toilets (93%), the ability to personalise workspace (60%) and a variety of work spaces (68%) [17].

6 RESULTS AND DISCUSSION

An in-depth interviews were conducted followed by various case studies.

6.1 Case study

The building is a 1958 office building close to Oxford Circus. The building has a narrow floorplate with windows running along the length of two sides and along part of the third side facing into a large rear light well. This built form allowed for workstations to be positioned next to windows (Figure 1).

The data on this case study consists of:

- The refurbishment solutions adopted for the building to improve energy performance and end-user satisfaction.
- An energy performance assessment against benchmark figures.
- End-user satisfaction post refurbishment.

The refurbishment took place late 2001 and early 2002. Works consisted of removing existing services, internal partitions, and suspended ceilings, the strip out of existing toilets and installation of new toilets. The existing single-storey entrance lobby was demolished and a new glazed entrance tower was constructed containing a lift for access to the fourth floor and to other floors across access bridges. The existing stairways and lifts were retained and reused. New double-glazed aluminium windows with opening lights replaced the existing single-glazed steel windows.

Figure 1: West End House: external view (Edwards & Naboni, 2013)

The refurbishment incorporated three main sustainable strategies to reduce energy consumption whilst maintaining comfortable internal conditions.

- The use of architectural passive solutions
- The specification of energy-efficient plant and equipment
- The provision of adaptive opportunities for end-users to intervene in controlling the environment

The passive solutions consisted of:

1. Natural ventilation to provide cooling.
2. Exposing floor soffits to enable thermal mass to provide cooling.
3. Fitting external shading to reduce solar gains during the summer, the design permitted solar gains during the winter, reducing heating demand.

The energy-efficient plant and equipment consisted of:

1. Specification of new high-efficiency condensing, low nitrous oxide-burning gas boiler providing space heating.
2. Energy efficient lighting; T5 fluorescent lamps in offices and compact fluorescent bulbs in other areas. (3)
3. Use of chilled beams to provide low energy radiant cooling.
4. Optimising building services by linking the Building Energy Management Systems (BEMS), the system incorporates self-learning capabilities, to the operation of the natural ventilation strategy whilst monitoring the external environmental conditions.

The BEMS controls the natural ventilation via motorised grilles under each window, additional natural ventilation is provided via the openable windows. Grilles also link each office to the entrance tower. Internal comfort is maintained via the design creating pressure stack differentials generating air movement by discharging air from roof level offices. The narrow floorplate allows for wind driven natural ventilation. Stack and wind driven ventilation is provided on the fourth floor via roof mounted ventilation enclosures and grilles in the walls. The grilles are designed to temper the incoming air if required by drawing the air over radiators. Outside normal working hours when cooling demand is detected, BEMS will open the grilles to provide cooling, only when the external temperature is lower than the internal temperature.

The period of time that natural ventilation could provide a comfortable internal environment was increased by reducing solar gains.

The reduction in solar gains is achieved by BEMS monitoring solar irradiation, when this is excessive BEMS automatically opening external fabric awnings fitted over the windows on the south-east and south-west elevations. The awnings close when the solar irradiation decreases.

The adaptive opportunities for end-users to control the environment consisted of; openable windows, to provide localised air movement and cooling and controllable internal blinds and manual override to external shading to avoid glare and improve daylighting.

Other strategies incorporated to improve energy efficiency consisted of:

- Water efficiency measures; low-volume dual-flush WCs, waterless urinals and self-closing taps to reduce consumption.
- Adequate storage to encourage collection and recycling of waste paper and plastics.
- Efficient transport; easy access to public transportation and local amenities, and cycle storage and showers to encourage cycling to work.

The building energy performance was assessed against the benchmark figures for naturally ventilated offices in the ECON 19 – Energy Use in Offices. More tailored energy targets were identified using ECON 19 Good Practice and Typical Energy Consumption Levels. These consumption levels were then adjusted using Energy Assessment & reporting Methodology, described in CIBSE Technical Manual 22. The targets from ECON 19 and the tailored targets are shown in table 1. The results showed that gas consumption was just below the typical mixed-mode building benchmark, however well above the good practice benchmark. Electrical consumption was recorded 1% above the good practice mixed-mode benchmark.

Table 1: Energy consumption for West End House with benchmark

Benchmark	Gas Consumption	Electrical Consumption
ECON 19	97 kWh/m^2/yr	123 kWh/m^2/yr
West End House	Between 88 to 123 kWh/m^2/yr	Between 103 to 171 kWh/m^2/yr

A post-occupancy evaluation was conducted to assess end-user satisfaction; a Building Use Study (BUS) Occupancy Survey questionnaire was used. Results showed that end-users overall comfort exceeded the BUS benchmark and that a significant improvement was made on the previous office. Satisfaction with winter and summer temperatures, air-quality, lighting and noise levels all exceeded the BUS benchmarks. Perceived productivity increased by 9.4% from the move to West End House.

6.2 Interview results

The interview results showed that the array of classification of office building typologies presents a problem for pinpointing the typologies of UK offices. From collating the findings from the literature review and that of the interviews the main causes of energy consumption and carbon emissions can be clearly identified. Mechanical/building services and central/main plant (heating, cooling and lighting) can be identified as the main causes of energy consumption and carbon emissions. The results highlighted the need to adopt passive refurbishment solutions as well upgrading mechanical systems to improve energy efficiency in offices. The findings show that while sustainable refurbishment have positive implications on energy abatement and end-users' satisfaction, both these areas do seem to underperform, with set targets and expectation not being fully met.

7 CONCLUSIONS

To meet carbon emissions target sets by the UK Government, it vital to adopt sustainable refurbishment of office. The results from the case study presented indicated the need for greater levels of insulation and reduced air leakages. To ensure local controls are possible, sufficient thermostatic sensors and variable speed pumps must be specified. Including more adaptive opportunities for end-users can increase the buildings capacity to maintain comfort levels whilst using less energy. Better BEMS interfaces should be provided to allow for easier control and alteration of setting by end-users.

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