Post-Occupancy Evaluation Studies in a recently Refurbished Office Building: Energy Performance and Employees' Satisfaction

Michelle Agha-Hossein[1], Sam El-Jouzi[2], Abbas Elmualim[3], Judi Ellis[4], Marylin Williams[5]

Abstract

Existing buildings contribute greatly to global energy use and greenhouse gas emissions. In the UK, about 18% of carbon emissions are generated by non-domestic buildings; sustainable building refurbishment can play an important role in reducing carbon emissions. This paper looks at the performance of a recently refurbished 5-storey office building in London, in terms of energy consumption as well as occupants' satisfaction.

Pre- and post-occupancy evaluation studies were conducted using online questionnaire surveys and energy consumption evaluation.

Results from pre-occupancy and post-occupancy evaluation studies showed that employees, in general, were more satisfied with their work environment at the refurbished building than with that of their previous office. Employees' self-reported productivity improved after the move to the new office. These surveys showed a positive relationship between employees' satisfaction with their work environment and their self-reported productivity, well-being and enjoyment at work. The factor that contributed to increasing employee satisfaction the most was: better use of interior space. Although the refurbishment was a success in terms of reducing energy consumption per m^2, the performance gap was almost 3 times greater than that estimated. Unregulated loads, problems with building control, ineffective use of space and occupants' behaviour are argued to be reasons for this gap.

Keywords: Post occupancy evaluation, Refurbishment, Energy-saving, Occupants' satisfaction, Space utilization

1. Introduction

In the UK, non-domestic buildings account for approximately 18% of the carbon emissions in the UK (Carbon Trust 2009). The majority of non-domestic buildings in the UK were built

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[1] Research Engineer; Halcrow (CH2M Hill); London, UK; AghahosseinM@Halcrow.com.
[2] Director Rail Civil Engineering; Halcrow (CH2M Hill); London, UK; El-JouziS@Halcrow.com.
[3] Senior lecturer; Construction management; University of Reading; Reading, UK; a.a.elmualim@reading.ac.uk.
[4] Professor, Psychology, University of Reading, Reading, UK, j.a.ellis@readimg.ac.uk.
[5] Registered Occupational Psychologist (HPC), m.j.williams@reading.ac.uk

before the 1980s, and more than half of all office space in the UK was built prior 1939 (Femenias and Fudge 2008). The age of the UK non-domestic stock indicates that for the country to meet its 80% CO_2 reduction target by 2050, refurbishment of existing buildings will play an important role.

Building refurbishment could also provide a more satisfactory work environment for the occupants, and, therefore, could improve productivity. This is explained in more detail in the following sections.

1.1 Work environment and employees' satisfaction

The 'habitability pyramid' developed by Vischer (2005) incorporates three groups of interrelated factors associated with employees' comfort in a workplace: physical, functional and psychological. According to Vischer (2005), all three groups need to be considered if a comfortable and productive workplace is to be provided. 'Physical comfort' includes the satisfaction of all basic human needs, which ensures one's health and safety; while 'functional comfort' concerns those features of the workplace that can help employees to perform their job well. 'Functional comfort' includes adequate lighting, flexible and adaptable furniture, designated spaces for different types of tasks, etc. 'Psychological comfort' involves feelings of ownership and control over one's environment.

It is usually assumed that employees who are more satisfied with the physical conditions of their workplace are happier and, therefore, are more productive than those who are less so (Leaman and Bordass 1999). Earlier studies indicate that there is a positive correlation between occupants' satisfaction and their perceived productivity (Leaman and Bordass 2001; J. C. Vischer 2007; Thomas 2010). These studies confirm the importance of improving physical features of workplaces, such as air quality, lighting, noise, and temperature and office layout. In a recent study, Thomas (2010) revealed that increasing daylight, glare control, noise management and access to the windows (views) increased occupants' satisfaction with their work environment.

1.2 Energy consumption assessment: Post-occupancy evaluation

The results from the PROBE (Post Occupancy Review of Buildings and their Engineering) studies, which reviewed post-occupancy of 23 buildings, showed that actual energy consumption in buildings is typically 2-5 times more than predicted at design stage (Menezes 2012). This is partly due to the fact that several sources of energy usage are not considered in the calculations of design targets. These sources are known as unregulated loads and include IT equipment, server rooms, external lighting and lifts. Unregulated loads accounted for more than 30% of the total energy consumption in an office building (Menezes 2012). In addition to unregulated loads, there are various other factors which can affect the accuracy of energy consumption predictions. Occupants' behaviour is one of these factors and, as this is often itself unpredictable, designers have to make assumptions about it (De Wit 1995).

This paper presents lessons learnt from a post-occupancy evaluation (POE) of Halcrow's recently refurbished HQ in London.

1.3 Background

Halcrow (a CH2M Hill company) delivers planning, design and management services for developing infrastructure and buildings worldwide.

In September 2010, Halcrow employees from the previous HQ, Vineyard House (VH) moved to the newly refurbished global headquarters (HQ), Elms House (EH). The poor environmental performance of VH, as well as its rigid and ineffective layout, generated the need for a new workplace. Halcrow decided to refurbish EH, which is located adjacent to VH (See Figure 1) and shares a common landlord with it, to be its new HQ building.

The main objectives of the refurbishment were to reflect a sustainable design and create a flexible and active work environment with appropriate spaces for different tasks. In this project, the design target for CO_2 emission was calculated to be 37 kg CO_2/m^2. This figure did not include unregulated loads. EH (marked with a circle in Figure 1) was completely stripped out and refurbished in 2010 and achieved a BREEAM rating of "Very Good" for its design. The key features of these two buildings are briefly described below.

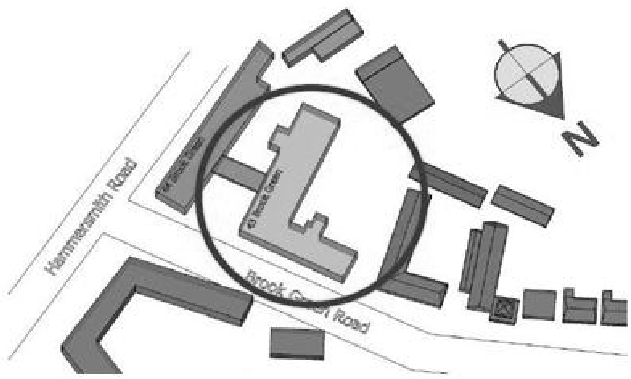

Figure 1: VH and EH locations

1.3.1 VH

VH is a 5-storey office building built in 1962, with a $5202.6m^2$ floor area. When Halcrow's HQ, it was mainly open-plan, with few cellular offices and few formal meeting rooms with video conferencing facilities. There was a high level of lighting available at VH from both daylight and artificial (mainly fluorescent tube) sources. Although mechanical ventilation was available, because of the poor performance of the system, employees had to open the windows to get fresh air and, therefore, due to the location of the building, many employees were affected by the noise from the street. VH was heated by gas fired boilers via radiators throughout the building. These were complemented by portable heaters supplied to individual members of staff. A small canteen was located on the ground floor. About 479 employees were working at VH in 2009.

1.3.2 EH

EH is a 5-storey office building which was built in the 1930's with a floor area of 11,725m^2. The offices are designed to be completely open plan with a number of small and large meeting rooms equipped with teleconferencing and video conferencing facilities. There are a number of designated areas for socialising and informal meetings as well as areas for concentration and contemplation; phone booths are available on each floor. A 60-seat restaurant is located on the ground floor, as well as kitchens on each floor. Facilities for cyclists are good, and include 6 showers. The office is mechanically air conditioned by use of fan-coils. A high level of lighting, from both natural and artificial sources, is available. The lighting system incorporates both daylight and PIR sensors to save energy. Half-hourly meters and electricity sub-meters are in use to monitor the energy consumption of the building accurately. Services at EH are mainly centrally controlled by a BMS system and the employees do not have control over their immediate environment. In 2011, 596 employees were working at EH.

2. Research approach

In this research, Post-Occupancy Evaluation (POE) was employed to evaluate the refurbishment project's success in terms of energy consumption, employees' satisfaction and employees' self-reported productivity. Surveys, observations, energy monitoring and benchmarking were used as research tools for this study. The actual performance of the building was compared to the UK's benchmark as well as to the design target. The results were used to identify areas for potential improvements.

There are different energy benchmarking tools available in the UK, such as CIBSE Guide F, ECON19 and CIBSE TM22. In this paper, ECON19 was used as a standard benchmark. For air-conditioned, prestige offices, the benchmarks are:

- Good practice:
  - fossil fuels: 114 kWh/m^2
  - electricity: 234 kWh/m^2
  - CO_2 emissions: 143.4 kg CO_2/m^2

- Typical:
  - fossil fuels: 210 kWh/m^2
  - electricity: 358 kWh/m^2
  - CO_2 emissions: 226.1 kg CO_2/m^2

The pre- and post-occupancy survey questionnaires used in this study were designed by the researcher to cover those workplace environmental factors identified as important influences in past studies (e.g., air quality, indoor temperature, noise level, outside view, personal control, visual privacy, auditory privacy, office layout, office appearance, cycling facilities, on-floor kitchen, recycling facilities). The questionnaire, which took under 15 minutes to complete, comprised three parts. There were 17 demographic items, 38 satisfaction items and 16 items concerned with sustainability awareness. In the "demographic" section, occupants were asked to indicate their age group, gender, the floor and building occupied, employment status, office type, frequency of visiting the in-house restaurant and frequency of using the shower facilities. There were 3 groups of 'satisfaction' items, pertaining to: physical environment, interior use of space and indoor facilities. In the "sustainability awareness" section, occupants were asked whether they knew about their company's environmental sustainability targets and whether they felt personally responsible for meeting these targets. They were also asked to indicate what they considered to be the best method of communication for raising sustainability awareness within the building. Responses to the "satisfaction" items were sought on a 5-point scale, where 2= Strongly Agree, 1= Agree, 0= Neither Agree nor Disagree, -1= Disagree and -2 = Strongly Disagree. Most questions were positively worded; scores were reversed for negatively worded items. Analysis of the responses yielded mean values (a positive score indicating agreement with a positive statement) which allowed comparison between pre-occupancy (benchmark) and post-occupancy values.

The pre-occupancy online survey was carried out at VH in June 2010. The link to the survey, which stayed open for two weeks, was sent out to all employees at VH. This benchmark survey was used as a tool to enable the employees to confidentially express how they felt about their work environment. A full year's (2009) electricity and gas consumption data were also collected at VH. These data were used as benchmarks against which to evaluate EH's performance.

The post-occupancy survey was conducted at EH in February 2011 to measure any changes in employees' level of satisfaction with their work environment 6 months after the move. At the same time, observations were carried out by the author to assess two areas: interior space usage and occupants' behaviour towards energy saving. A full year's (2011) energy data were collected at EH to evaluate the energy consumption of EH in comparison with that of VH and the benchmarks.

3. Results and Discussion

The data gathered from the pre- and post-occupancy surveys and the energy data provided useful pictures from VH and EH overall.

The mean value of each variable from the pre-occupancy survey was compared with the post-occupancy survey. Where a mean value is quoted in this paper, number of respondents (N), standard deviation (SD) and the percentage of dissatisfied respondents (DS) are also stated.

3.1 Pre- and Post-Occupancy Surveys

Having excluded data from ineligible participants, a total of 162 and 183 respondents completed the pre- and post-occupancy surveys respectively, generating a response rate of 32% and 31%, which were considered acceptable. In the post-occupancy survey, 66% of the respondents specified their previous workplace as VH; the other 34% indicated their previous workplace other than VH. In both surveys, the distribution of respondents across a number of demographic variables, including business group, employment status, and grade, mirrored well the actual distribution of all Halcrow's employees; the sample is considered to be adequately representative.

3.1.1 Work Environment Satisfaction

The scale reliability of responses to the 28 'satisfaction' questions (overall) was assessed for VH and EH; Cronbach's alpha was found to be 0.91 and 0.92 respectively, indicating excellent reliability.

The results confirmed that VH, with overall satisfaction mean score of -0.29 (N= 141, SD=0.50, 36%DS), had a poor workplace environment. Respondents at EH were statistically significantly more satisfied with their work environment, 0.39 (N=153, SD=0.52, 5.2%DS) than those in VH, t (292) =11.54, $p<0.001$.

With about 50% of respondents indicating their dissatisfaction, the physical condition of VH was identified as the main issue. The post-occupancy survey showed that EH was a more satisfactory environment, especially to those who had moved from VH. Although, the physical condition of EH was still not quite satisfactory, 0.12 (N=160, SD=0.65, 17.5% DS), it showed a significant improvement compared with VH, t (307) = -7.51, $p<0.001$. Interior use of space and indoor facilities, with the mean scores of 0.53 (N=174, SD=0.65, 7.5%DS) and 0.52 (N=181, SD=0.57, 3.9%DS), were satisfactory at EH but not at VH, -0.17 (N= 154, SD=0.60, 27%DS) and -0.24 (N= 157, SD=0.65, 29%DS) respectively.

In the following sections, the results of the surveys are discussed with regards to aspects of comfort, spaces and indoor facilities.

3.1.1.1 Physical environment

'Physical environment', overall, was the least satisfactory element of both VH (Cronbach's alpha =0.79) and EH (Cronbach's alpha =0.78). The main problematic areas at VH were indoor temperature in summer, -1.31(N=162, SD=0.95, 84.6%DS), the level of personal control, -0.83 (N=161, SD=1.11, 65.2% DS), indoor temperature in winter, -0.81 (N=161, SD=1.10, 62.1%DS), and the air quality, -0.67 (N=159, SD=1.11, 59.1%DS). The responses to open-ended questions indicated more concerns of feeling "freezing cold" in winter and "stuffy" in summer.

The HVAC system and lighting at EH were controlled centrally and the windows were non-openable. All these caused a lot of dissatisfaction with the level of personal control at EH, -1.19 (N= 178, SD=0.98, 78.1%DS). Open ended comments revealed that there was also no quick response to office environmental complaints. , in addition to level of personal control, the majority of the respondents at EH were dissatisfied with the temperature in winter, -0.70 (N=181, SD=1.22, 63%DS). The BMS system was set to maintain the temperature at EH at 23°C. Further investigation done by observations, informal chats with the employees and some open ended comments in the survey revealed that the main issue was the draughts from the air conditioning units and from the windows. About 20% (N=11) of the open ended comments described the workplace (EH) as draughty.

3.1.1.2 Interior use of space

The scale reliability of responses to the questions in this group was assessed in VH and EH; Cronbach's alpha was found to be 0.88 at VH and 0.90 at EH. VH was reported by the respondents to be, in general, a poor workplace in terms of space, -0.17(N= 154, SD=0.60, 27%DS), Whilst, in comparison, respondents at EH were statistically significantly more satisfied with their space, 0.52 (N=181, SD=0.57, 3.9%DS), t(326)=10.10, p<0.001. At VH, the two dissatisfactory elements with interior use of space were areas for contemplation, -0.66 (N=161, SD=1.0, 62.1%DS), and auditory privacy, -0.65 (N=162, SD=0.96, 58.6%DS). At EH, provision of a number of phone booths and informal meeting rooms on each floor improved employees' satisfactory in these areas, with mean scores for contemplation area and auditory privacy as 0.45 (N=182, SD=1.04, 17.6%DS) and -0.15 (N=183, SD=1.24, 38.8% DS) respectively.

3.1.1.3 Indoor facilities

In terms of indoor facilities, there was no unsatisfactory element in VH (Cronbach's alpha = 0.78) and EH (Cronbach's alpha = 0.75). However, at VH, shower facilities with mean score of -0.43 (N=160, SD= 0.92, 35% DS), and canteen facilities with mean score of -0.46 (N=159, SD=1.02, 48.4%DS), were close to unsatisfactory. Respondents in EH were statistically significantly more satisfied with the indoor facilities at their building than those at VH, t (333) =10.86, p<0.001. Respondents at EH were more satisfied with both their shower facilities, 0.14 (N=182, SD=0.71, 8.8%DS), and restaurant facilities, 1.10 (N=183, SD=0.77, 3.8%DS).

In answer to the question: "*How often, on average, do you visit the restaurant in your office building?"* it was found that about 50.0% of the respondents at VH visited the restaurant (canteen) at least one day a week. This figure increased to about 85% at EH.

With regard to the shower facilities, however, about 80% of the respondents at VH indicated that they never used the shower facilities at their building when answering the question: "*How often, on average, do you use the shower facilities in your office building?"* This figure increased to about 88% at EH. Responses explained that the showers were not maintained regularly and often broken.

3.1.2 Perceived productivity, well-being and enjoyment at work

Employees were asked to determine to what extent they agree that their current workplace had positive effects on their productivity, well-being and enjoyment at work. The respondents used the same 5-point scale as for the "satisfaction" questions. At VH, respondents did not believe that their work environment had a positive effect on their perceived productivity, -

0.02 (N=160, SD=0.90, 30.6% DS), well-being, -0.18 (N= 159, SD=0.88, 35.2%DS), and enjoyment at work, -0.10 (N= 160, SD=0.88, 30.6%DS). In comparison, EH environment had a statistically significantly more positive effect on respondents' perceived productivity, 0.31 (N=183, SD=0.94, 16.9%DS), t (341) = 3.24, p<0.001, well-being, 0.25 (N=183, SD=0.93, 20.2%DS), t (340) =4.34, p<0.001, and enjoyment at work, 0.37 (N=182, SD=0.92, 14.8%DS), t (340) =4.81, p<0.001.

3.1.3 Relationship between workplace environment and perceived productivity, well-being and enjoyment at work

As shown in Table 1, in both buildings the employees' perceived productivity, well-being and enjoyment at work were positively correlated with physical environment of the workplace, interior use of space and indoor facilities. This result is in agreement with those of the previous studies mentioned earlier in this paper, showing that, amongst other factors, the latter ones are important.

Table 1: Correlation between work environment and perceived productivity, well-being and enjoyment at work

		Correlation Coefficients (r)		
		Physical environment	Interior use of space	Indoor facilities
Productivity	VH	r=0.56, N=148, p<0.01	r=0.59, N=152, p<0.01	r=0.37, N=155, p<0.01
	EH	r=0.49, N=160, p<0.01	r=0.64, N=174, p<0.01	r=0.39, N=181, p<0.01
Well-being	VH	r=0.53, N=147, p<0.01	r=0.56, N=151, p<0.01	r=0.29, N=154, p<0.01
	EH	r=0.47, N=160, p<0.01	r=0.67, N=174, p<0.01	r=0.43, N=181, p<0.01
Enjoyment at work	VH	r=0.48, N=148, p<0.01	r=0.56, N=152, p<0.01	r=0.34, N=155, p<0.01
	EH	r=0.47, N=159, p<0.01	r=0.67, N=173, p<0.01	r=0.44, N=180, p<0.01

3.2 Energy performance EH vs. VH

The annual electricity consumption at EH was measured to be 144kWh/$m^{2,}$ which was 29.8% less than the total electricity consumption at VH in 2009 (205kWh/m^2). Gas consumption at EH in 2011 was found to be 98.4kWh/m^2, about 38% less than the 158.79kWh/m^2 gas consumption at VH in 2009. Figure 2 shows these results in more detail.

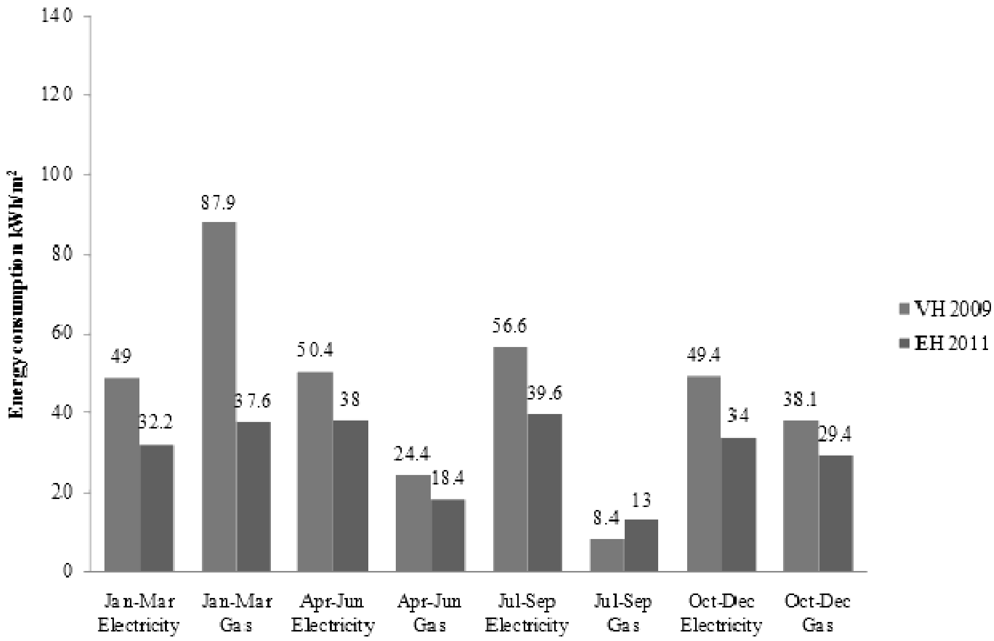

Figure 2: Electricity and gas consumption in VH and EH

The annual base-load for electricity (between 9.00pm and 7.00am) at EH was about 256,320kWh (21.9kWh/m^2) which accounted for 15% of the total electricity consumption. This figure, per m^2, was 65% less than the annual electricity base-load at VH which was measured to be 328,580kWh (63.16kWh/m^2), accounting for 31% of the total consumption. It was found that, during the study, the HVAC system at EH was in operation 24 hours a day, 7 days a week. So, the consumption at EH could be reduced further by reducing the hours of operation to 9 hours (e.g. between 8.00am to 5.00pm) on Saturdays and Sundays.

Figure 3, overleaf, shows the CO_2 emissions from electricity and gas consumption in VH (2009) and EH (2011). The total CO_2 emission at EH in 2011 was 93.6kgCO_2/m^2 which was 32% less than that measured at VH in 2009 (136.8kgCO_2/m^2). The design target at EH was predicted to be 30.5 kgCO_2/m^2. The actual emission, however, is about three times higher than what was predicted. This could be partly due to the unregulated loads (e.g. IT equipment, lifts and catering facilities) that were not considered in the design target. Compared to the benchmark (ECON 19), EH performance in 2011 was 23% better than 'good practice', while the performance of VH in 2009 was about 12% worse than 'good practice'.

Energy consumption per person, however, was higher at EH compared with VH. EH consumed 2831.11kWh/person electricity in 2011 which was 27% higher than that which was measured at VH in 2009 (2,229.59kWh/person). EH also consumed 12.3% more gas/person in 2011 compared with VH in 2009 (1936.51kWh/person at EH vs.1724.68kWh/person at VH). The main reason for this was ineffective use of space at EH. Observations showed that, at the time of the post-occupancy survey, on average, only 39% (263) of the workstations were in use. Observations also confirmed that, on the ground floor, contemplation and socialising areas (excluding the restaurant) were not being used effectively.

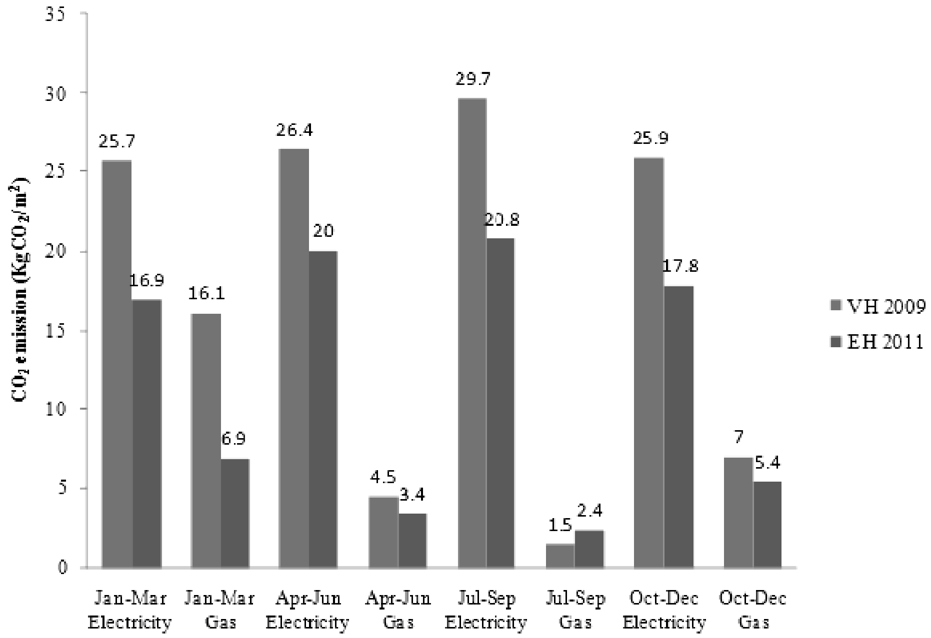

Figure 3: CO2 emission at EH and VH

4. Conclusion

Pre- and post-occupancy evaluation studies were carried out at Halcrow's previous headquarters and their newly refurbished headquarters adjacent to the site. The results showed that, after the move to the new headquarters, employees were more satisfied with their work environment (physical environment, interior use of space and indoor facilities). Employees' responses indicated that their perceived productivity also increased after they moved to the newly refurbished work environment.

EH showed better performance, in terms of electricity and gas consumption and CO_2 emissions per m^2, than VH. However, the CO_2 emissions at EH were more than 3 times higher than the design target. To reduce this gap, the facilities manager was advised to reduce the HVAC operation hours to 9 hours a day during the weekends. Occupants' behaviour and space utilisation should be also reviewed to detect further opportunities for more improvement.

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