

OVERNIGHT LIGHTING IN LONDON'S NON-DOMESTIC BUILDING STOCK: AN EXAMINATION OF HUMAN INTERACTIONS WITH TECHNOLOGY

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Carbon Reduction in Buildings

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Abstract

Global warming has become a prime focus on the world scene. It has led to worldwide initiatives to reduce greenhouse gas emissions. London has set ambitious emissions reduction goals. Carbon Reduction in Buildings (CaRB) is a research project aimed at discovering ways of reducing carbon emissions in London's non-domestic building stock. The goal of this project is to begin initial research into reasons for overnight lighting use. The information will help CaRB determine where further research should be conducted, as well as begin to develop methods for reduction of overnight lighting use.

Executive Summary

Increasing rates of greenhouse gas emissions into the atmosphere, especially carbon dioxide, have become a major global concern. Once emitted, greenhouse gasses, created by the burning of fossil fuels, absorb infrared radiation from the planet and release it as heat into the atmosphere (EPA, 2008). The heat produced by these gases is required for life on Earth, but in excess, it can cause natural disasters such as the meltdown of polar ice caps (IRIN,2009). Carbon dioxide, the most common greenhouse gas, is currently being emitted into the atmosphere in uncontrollably large amounts. Approximately 6.8 billion tons of carbon dioxide were emitted into the atmosphere in 2003, more than four times the carbon emissions of 1950 which were around 1.6 billion tons.

Various non-profit entities have been created to help control this global issue. Carbon Vision Buildings (CVB), a partnership in London focused on funding carbon related studies, created Carbon Reduction in Buildings program (CaRB). Its mission is to develop a model of carbon emissions of the United Kingdom's non-domestic building stock comprised mainly of office buildings (ESPRC, 2009). Our goal with CaRB was to uncover reasons for overnight lighting in London's office buildings.

We began our project by examining the data on lighting usage obtained by a previous WPI research team that had worked with CaRB in 2007. This data included estimates of overnight lighting usage and floor space in 140 office buildings. To generalize our study, we selected buildings with both low and high lighting usage from this sample and began collecting information on building and office managers for possible interviews. We did this by visiting the buildings during the day and speaking with receptionists and security personnel whom provided us with information about the tenants occupying the building and contact information for both building and office managers. We managed to conduct interviews with 8 building managers and 7 office managers. During the interviews, we asked for permission to distribute surveys in their respective work spaces to receive responses from the employees themselves.

During our search for contacts, we noticed most buildings had undergone several changes since 2007; different tenants moved in and out of the buildings, some buildings had been demolished and other buildings underwent major refurbishments, including lighting systems. Having observed these changes, we questioned whether or not the data obtained by the previous group was still reliable. Therefore, we replicated the first research group's methodology of counting illuminated windows at night to estimate overnight lighting usage. As a result, we observed and took pictures of 19 buildings during each week night, Monday through Friday between 10PM and midnight. Overnight lighting

usage in these buildings had reduced by 20.3 percent overall, a significant decrease.

Though the data collected through overnight observations was useful, it did not provide reasons for overnight lighting or why energy consumptions had dropped substantially. Therefore, we developed three research questions that helped us understand the technical and motivational factors behind this issue: 1) How might lighting systems layout and structure influence user behavior? For example, we asked about the presence of automated sensors to our interviewees, and we asked how much lighting does a light switch control to our survey respondents. Additionally, when allowed by our interviewees, we performed building inspections which helped us see for ourselves if the light switches were easily accessible, for instance. 2) Are there any policies or efforts in place to reduce overnight lighting usage? We addressed this question mainly through our interviews by asking, for example, if there were any policies regarding lighting usage in the building. 3) What are employee attitudes and knowledge about energy conservation? These results, although not many, were obtained through surveys.

When reviewing our data, some interesting results were immediately noticed. The level of technology present throughout the buildings was surprising; with eleven out of our fifteen interviewees saying that they use motion sensors in their spaces. In addition, managers seem to be more than aware about energy consumption issues since they task cleaning and security staff with turning off any unused lights. Managers also keep their employees aware of energy consumption and its consequences. Overall, there seems to be an improvement in buildings with regards to overnight lighting.

Having finalized our research, we noticed many flaws in our procedures. Survey distribution was not very effective since we received very few answers. Additionally, there was much background research that should have been done with regards to this distribution process as well as with interviewing. Therefore, we decided to develop a methodology for future research groups. In it, we discuss the methods that helped us the most and which ones should be avoided.

Although we managed to conduct 15 interviews, we were not able to clearly discern any conclusions with regards to the reasons for overnight lighting. The data acquired from these interviews was not supported with enough information. However, we noticed a substantial decrease of overnight lighting in our target buildings over the past two years. Additionally, we encountered more buildings with motion sensors than expected. Concluding our analysis, we suggested possible ideas for determining the presence of motion sensors in buildings and the functionality of them, by observations.

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1. Introduction

Recent human history has been comprised of major technological advances, most of which utilize energy in some way. This energy consumption has lead human beings to find ways of producing energy, the most prominent method being the burning of fossil fuels. This combustion produces emissions of greenhouse gases into the atmosphere. Global carbon emissions, which consist of approximately 75% of global greenhouse gases (EPA, 2008), exceeded 6.8 billion metric tons in 2003, more than four times the emissions of 1950 which consisted of 1.6 billion metric tons (Earth Policy Institute, 2003). The scientific community has identified this practice as a cause of recent global temperature rise, approximately .4 degrees Celsius (EPA, 2008), an effect that could cause the bringing of another ice age. Immediately, this would affect London through greater seasonal variations and general temperature increase. These seasonal variations could cause droughts in summer time and flooding in the winter time. Droughts will likely cause London's water supply to ebb, and flooding could potentially cause major structural problems for buildings by increasing soil shift. However, this global threat also presents opportunities for London. The city can become the center for the development of "green" technologies and methodology, which will spur job creation (LCCP, 2009).

Recognizing the enormous impact climate change would have, the city of London, released a Climate Change Action Plan (CCAP) that discusses possible approaches to reduce carbon emissions in London. The CCAP mentions the Better Buildings Partnership which focuses on offering incentives for landlords to upgrade their buildings to become "greener." Under this scheme buildings are given different "badges" based upon their "greenness" which provides an incentive for the building's owners to reduce carbon emissions (CCAP, 2007). Through initiatives such as CCAP, the United Kingdom has decreased its emissions by 15.6 percent since 1990 (UNFCCC, 2005), and plans to further decrease carbon emissions by 23.6 percent by 2010 (DEFRA, 2005).

Lighting represents a large portion of the overall energy consumption in buildings. According to the Greater London Authority, lighting in the non-domestic building stock contributes approximately 26 percent of total energy consumption (Greater London Authority, 2006). This percentage clearly

indicates that lighting is a significant contributor to the carbon emissions from the non-domestic building stock. One of the major areas of waste with respect to lighting in the non-domestic building stock is the usage of lights throughout the night. According to previous work done on quantifying energy usage through overnight lighting, approximately 25.23 percent of lights are left on in buildings during weekdays between the hours 10PM-3AM and 16.58 percent during weekends (Levine et al, 2008).

The Carbon Reduction in Buildings (CaRB) project was created to establish an accurate model of building energy consumption levels. CaRB's previous efforts have included quantifying overnight energy consumption through lighting in commercial buildings of the London area. However, there is little information about why people leave lights on in buildings at night, or how the lighting designs/circuits in buildings influence people's behavior. Our project team investigated the reasons why people leave lights on in buildings after working hours. To do so we conducted interviews with building managers and office managers, and surveyed tenant employees. Our pilot will help CaRB hypothesize about the interaction between lighting systems and human beings to reduce energy use and will provide them with a methodology and initial findings that they can build upon with further research throughout their larger building sample.

2. Background

In this chapter we first describe the possible impacts of climate change on London; we then examine the strategies in place to reduce carbon emissions both at the national and regional level. Next, we focus on energy use in buildings as a source of carbon emissions, and pay particular attention to the problem of leaving lights on in buildings at night after work hours. We conclude by highlighting possible reasons from the environmental psychology literature as to why people may fail to turn lights off at night.

2.1 Climate Change Overview

Over the past years, the large emissions of greenhouse gases have become a major global concern. These gases, produced mainly by the burning of fossil fuels, absorb infrared radiation emitted by the planet, and release it as heat into the atmosphere (EPA, 2008). Although this constant greenhouse effect is required for life on Earth, it can also become excessive and cause natural disasters. Most models predict that the polar ice caps could end up melting, which would result in another Ice Age and global flooding. Similar studies have also demonstrated that weather conditions would also change with uncontrollable fluctuations, resulting in higher levels of precipitation during the winter and lower levels during the summer (IRIN, 2009). Figure 1 represents the effect of greenhouse gases on the atmospheric temperature over the past two centuries:

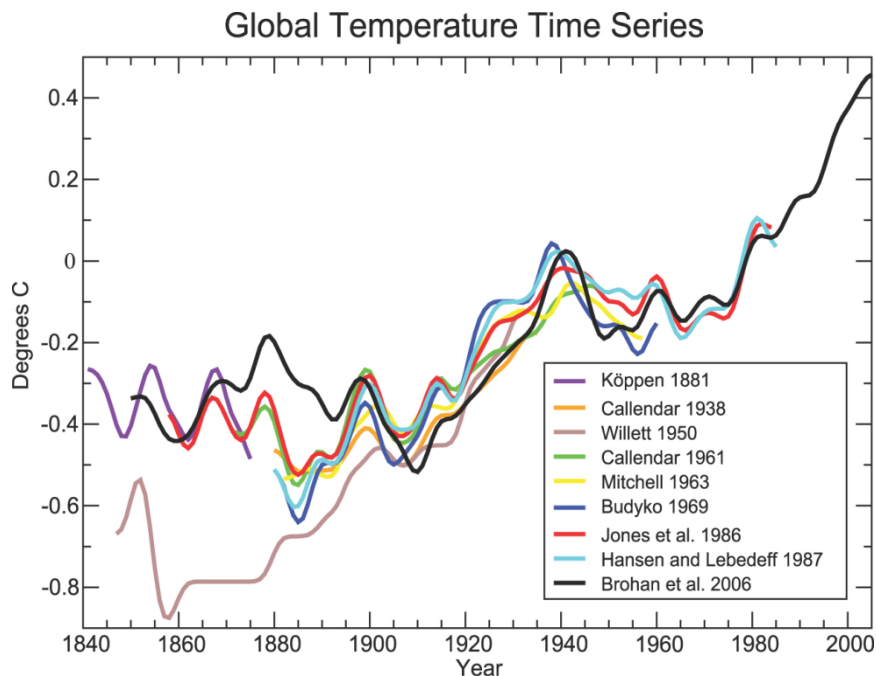


Figure 1: IPCC Climate Change 2007 Synthesis Report

Recent studies have shown that approximately 6.8 billion tons of carbon were released into the atmosphere in the year 2003. This number quadruples the amounts of carbon emissions in 1950 which were around 1.6 billion tons (Earth Policy Institute, 2003). Atmospheric concentrations of carbon dioxide reached 370.89 parts per million, approximately 94.17 parts per million more than when the Industrial Revolution took place (Earth Policy Institute, 2003). Furthermore, according to the Environmental Protection Agency (EPA, 2008), the average atmospheric temperature is estimated to increase around 3.2 to 7.2 degrees Fahrenheit (1.8-4 degrees Celsius) at the end of the 21st Century.

These temperature rises have had a profound effect throughout the world. In London specifically, there has been an increase in winter time precipitation. The increase in precipitation during the winter has been linked to increased flood risk. London, however, was at high risk for flooding prior to the raised temperatures; the increased precipitation due to this temperature change has exacerbated this. The flooding can cause sediment displacement, which could shift building foundations, roadbeds and other structural entities common in urbanized areas like London. The temperature changes have also caused a decrease in summer precipitation throughout London, which has been causing recent water shortages and necessitating the storage of water from the winter months (LCCP, 2007). Figures 2 and 3 below illustrate the precipitation levels and their changes over the past centuries:

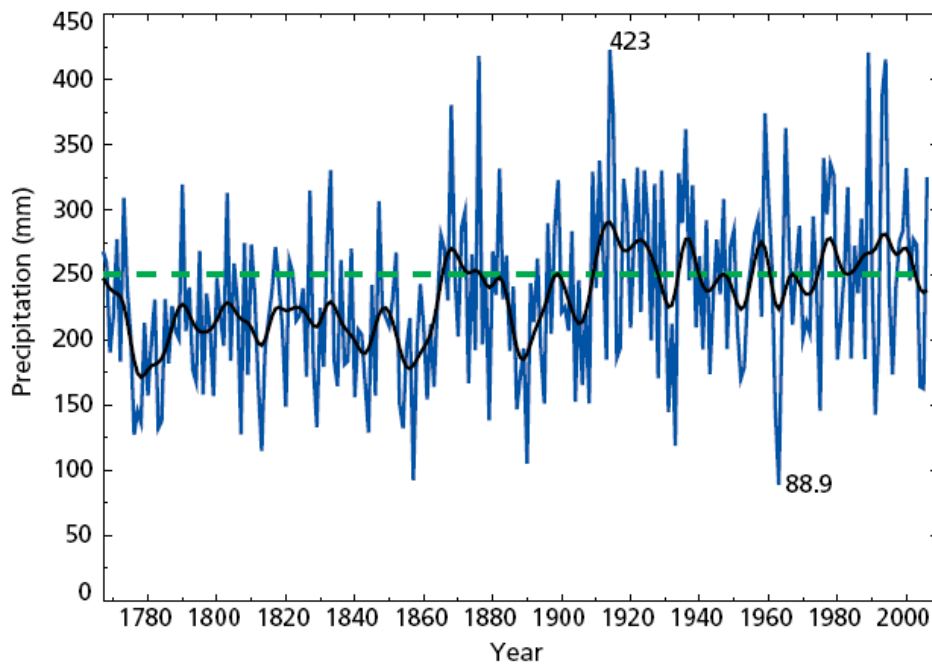


Figure 2: England and Wales Precipitation 1766-2006 (Met Office Hadley Centre)

The above table is averaged over the three winter months (Dec-Feb), and below over the three summer months (Jun-Aug). Individual winters are shown by the blue line; the black line emphasizes decadal variations. Highest and lowest seasonal totals (mm) are indicated. The winter is shown by the year of its December. The 1961-90 average seasonal precipitation is shown by the green dotted line (Met Office Hadley Centre).

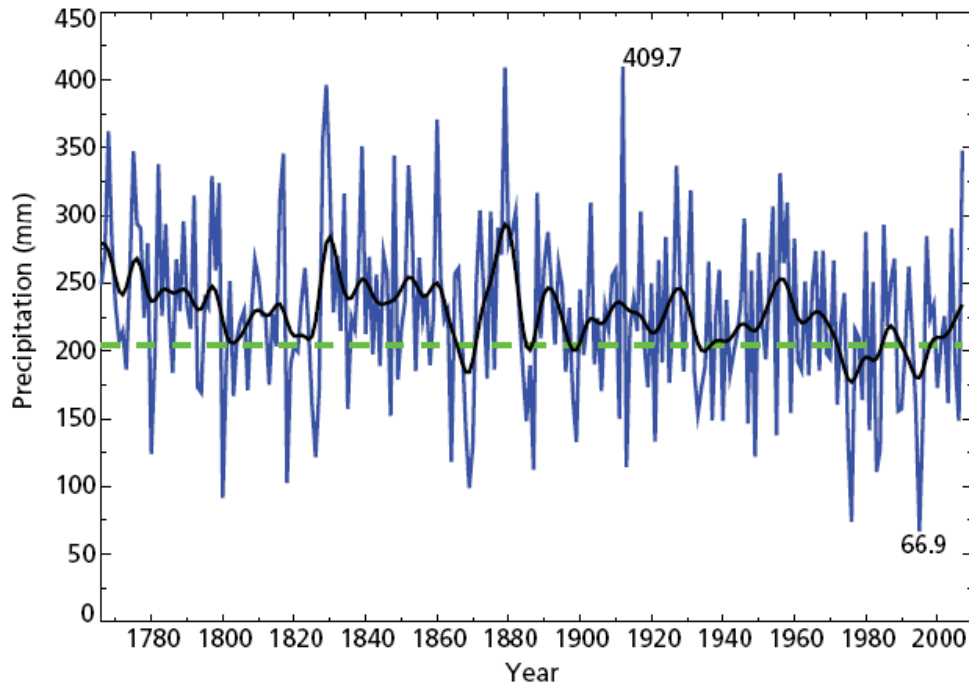


Figure 3: England and Wales Precipitation 1766-2006 (Met Office Hadley Centre)

2.2 Global and National Initiatives

These figures have put the issue of global warming center stage on the world scene. This has led to the creation of The United Nations Framework Convention on Climate Change (UNFCCC), who created the Kyoto Protocol. Officially adopted in December of 1997, the protocol has created a required level of greenhouse gas emission reduction for 37 of the participant nations. The amount of reduction is based upon the nation's original amount of emissions in 1990 and will yield a worldwide reduction of approximately 5 percent of original emission levels by the 2008-2012 time gap (UNFCCC, 2005). However, The Kyoto Protocol is often criticized for its lack of effectiveness, with its goals being called "politically palatable" (Adam, 2009); even the United Kingdom's Committee on Climate Change has outlined a 42 percent drop by 2020 from 1990 levels for its own nation (CCC, 2009). In addition, The United Kingdom has already reached, and surpassed, its outlined percentage decrease by dropping its emissions approximately 15.6 percent since 1990 (UNFCCC, 2005), and plans on having

them decreased to 23.6 percent by 2010; that is 11.1 percent below the 12.5 percent outlined by the Kyoto Protocol (DEFRA, 2005). This clearly shows that more drastic emissions cuts can be, and should be, implemented at the next UNFCCC meeting in Copenhagen.

2.3 London Initiatives

The greater London authority, in its Climate Change Action Plan, has created a “vision [...] to develop London as an exemplary sustainable world city” (Green, 2004) and has taken on a very ambitious goal which outlines a CO₂ emissions rate drop of 60 percent, from the 1990 figure, by 2025 (Green, 2004). This could have a significant effect on the United Kingdom’s overall CO₂ emissions. As illustrated in Figure 4 below, London’s emissions conservatively comprise approximately 8 percent of the total United Kingdom emissions, excluding contributions from London’s airports (LEP, 2004). Figure 4, in addition, shows why the non-domestic building stock is such a prime target for carbon emissions reduction efforts, as it sits as the second largest contributor to London’s total emissions.

2006 carbon dioxide emissions from London

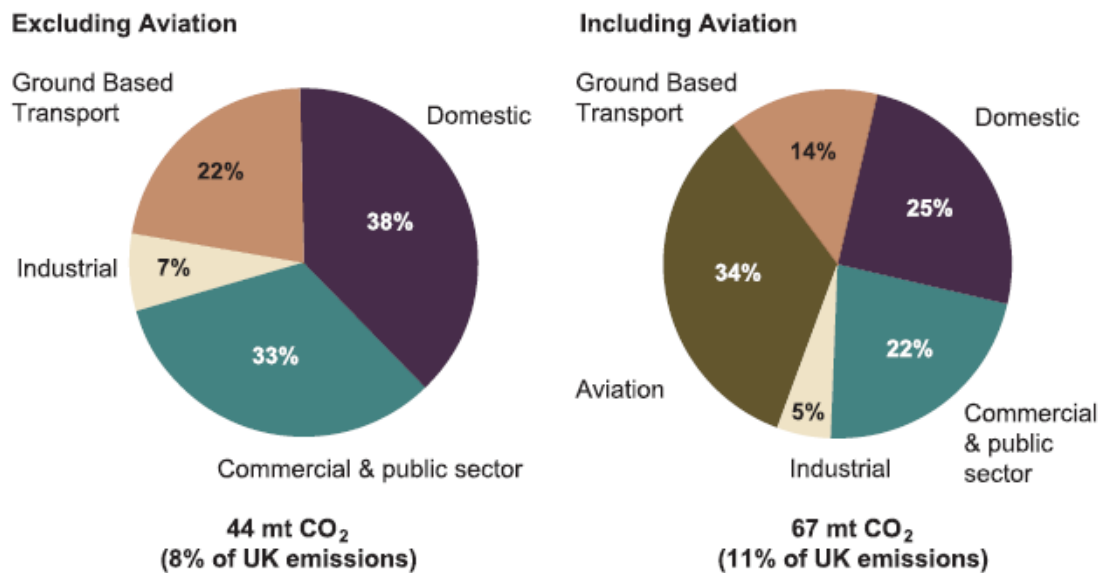


Figure 4: 2006 Carbon Dioxide Emissions from London (CCAP, 2007)

The greater London authority, has released a Climate Change Action Plan. It discusses solution methods for all aspects of London carbon emission causes; however, we will concentrate on the non-domestic building stock efforts here. The plan mentions a Better Buildings Partnership, which will focus on offering incentives for landlords to upgrade their buildings to become greener,

specifically when they are performing maintenance. It will also introduce a green “badging” system, as a way of rating the “greenness” of a building. This will serve as an incentive for tenants to reduce energy waste through employee behavioral changes and better building management. In order for this method to be successful, research must be done to figure out how to influence employee opinion. These campaigns are to be backed by a thorough lobbying campaign that will inform people of these programs so that they are fully utilized (CCAP, 2007).

These efforts are expected to lead to a 39 percent reduction in carbon emission by 2025. The illustration below shows a breakdown of how each aspect is to contribute to the reductions.

Commercial and public sectors’ contribution to CO₂ savings by 2025

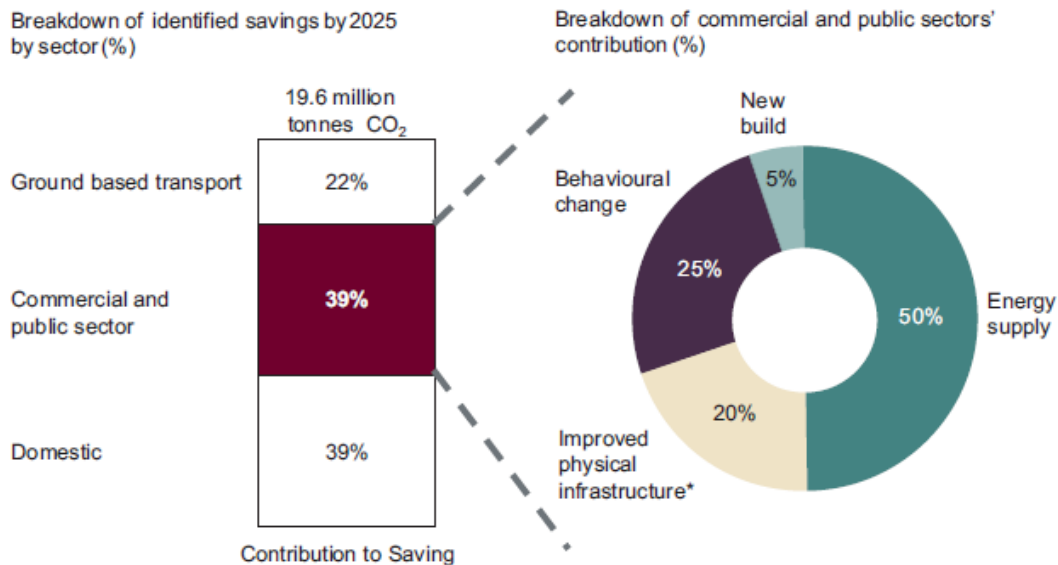


Figure 5: Commercial and Public Sectors’ Contribution to CO₂ Savings by 2025 (CCAP, 2007)

Based on the data of Figures 4 and 5 and the aspirations of London and the United Kingdom, The Carbon Trust and The Engineering and Physical Sciences Research Council (EPSRC) created the Carbon Vision Partnership, a cooperative effort of both of these groups. The Carbon Trust is an independent company created by the government in 2001 with the purpose of accelerating carbon emission reductions. The EPSRC was created in 1994 as the United Kingdom’s government agency responsible for providing funding for research in the engineering and physical sciences fields. The two organizations work together to provide a main research body with an immediate source of funding and to help to facilitate research efforts. The Carbon Vision Partnership’s largest initiative is the Carbon Vision Buildings (CVB) research program, which was created in 2004 with the purpose of

concentrating on the non-domestic and domestic building stock (ESPRC, 2008). In turn, the Carbon Reduction in Buildings (CaRB) research group was created by the CVB with the purpose of producing a model of carbon emissions. The model is intended to be effective for anything from regional to national applications, and will be able to accurately predict the effect of introduced efficiency measures. CaRB is focused on researching possible non-technical solutions to wasted energy consumption within London's non-domestic building stock (CaRB, 2009), which is where our is derived.

2.4 Previous IQP Findings for Lighting Afterhours

Previous WPI project groups have focused their attentions on quantifying overnight lighting usage in the non-domestic building stock throughout London by establishing a database (Di Cesare et al. 2008). Their plans to achieve this consisted of acquiring data on lighting in the non-domestic building stock from the hours of 8PM to 5AM (Di Cesare et al. 2008). They determined that previous expectations of carbon emissions through overnight lighting in these buildings had been underestimated. Prior research had estimated that .8 mega tons of carbon emissions were emitted each year because due to overnight lighting. However, results from the WPI project groups provided figures that said otherwise. The levels of carbon emissions were much higher than 0.8 mega tons just through overnight lighting (Di Cesare et al., 2008). As a suggested area of research, the project group recommended that future project groups place their attention on the reasons for why lights are left on overnight.

2.5 Background Research Conducted in United States

In order to apply more accurate and effective data acquisition techniques in London, in the United States we conducted a series of interviews with some local companies and asked them about their lighting policies after work hours, and distributed a survey to the WPI faculty via email. We included questions regarding the reasons people believe that lights are left on during these hours. We characterized the type of answers and used these to hypothesize possible reasons that we could later study in depth.

2.5.1 Survey of Worcester Polytechnic Institute Faculty

Our first observations took place on the WPI campus, where we sent a survey to the faculty. We asked a set of five closed-ended questions about lighting usage in academic buildings and provided a

series of answers to be chosen from. After two weeks, we received a total of thirty two completed surveys (See Appendix B.2). The survey helped us develop a better survey for distribution once in London. First, we learned that we should make our questions more open-ended, so as to obtain as much data as is possible. This would influence the survey taker to think more about the questions and provide more detailed information. For instance, we asked if there were any lights in their buildings that remained on all night, twelve people said yes. They could have also been asked if they knew why the lights were left on and where the lights were located. We also asked how long they used lighting after hours, to which the average response was three hours. Though this survey was conducted in Worcester and not amongst the same buildings as the first WPI project groups observations, this survey would suggest that there is very minimal reason for overnight lighting, as anyone using lighting for three hours at night would be out of the office by 9pm, and the observations were conducted between the hours of 10pm and 2am.

2.5.2. Interviews with the WPI Green Committee Chair and the Corporate Headquarters for a Multinational Retailer

While in Worcester, we conducted two interviews, one with the WPI Green Committee Chair, and a second with the office managers of a corporate headquarters of a multinational retailer known for their cutting-edge initiatives in the area. We learned from our interviews (see Appendix C) that our college leaves some lights on overnight, however the company we interviewed made a specific point of turning all lights, except emergency lighting, off at night. At our college, lights tend to be left on depending on the type of building. For instance, the academic buildings have janitors turn the lights off after cleaning. In office buildings, whether or not lights are turned off is dependent upon those using them; whereas, in the residence halls, the hallway lights and common room lights are always left on. The newer buildings on campus have motion sensors that will turn lights off after a set amount of time should the room remain empty. Currently, the Green Committee provides information on ways to reduce carbon emissions to students and faculty on a regular basis. However, the WPI Green Committee chair has hypothesized that the reason for leaving lights on was mainly due the mentality of older generations. In the past, people did not worry about carbon emissions or turning off lights. Their wasteful patterns as children became engrained into their lifestyle as adults. We found no research to support this, although it could be true.

This contrasts drastically to the company interviewed, whose lighting systems are timed and specifically designed for the departments using them. They have also applied motion/heat sensors,

however, in a much more effective fashion. The sensors are in every bathroom and all individual offices and conference rooms. All lights, including hallway lights, are controlled by a timed grid system that has no user interaction at all. If someone needs the lights turned on for a grid, they must provide their specific key and the hours that they need the lights activated for. This is a purely technical approach, which the company claims has reduced their lighting usage by 33 percent.

The interview with the WPI Green Committee chair suggested a minimal effort existed to motivate and inform those who use the facilities on campus. However, the company uses various programs to inform their employees. In one such program, they have asked their workers to bring in any incandescent bulbs, either from home or work, which would be exchanged for newer high energy efficient fluorescent bulbs. Additionally, if people committed to reducing energy by a number of hours then they got a free fluorescent bulb. In a recent event, fact cards about energy usage were handed out at the door. These programs try to reinforce green behavior such as powering down computer monitors whenever someone leaves their desk for five minutes or longer and convert technical information into terms people can understand.

Generally, these interviews brought to our attention the variability of concern and consideration that existed amongst our target buildings. On one hand, the corporation considers every aspect of energy use in their office buildings and is very committed to reducing their energy waste; whereas, the WPI Green Committee Chair indicated that there was a lesser interest in this concept at the college. They also brought to our knowledge the existence of timed grid systems and daylight harvesting sensors. Because of this, we included questions in our interviews asking if either of these types of systems were employed on the premises.

2.6 Reasons for Lighting Usage After Hours

There have been few studies focusing on the reasons why people leave office lights on after hours. In the remainder of this section, we examine literature that suggests several different possible causes: diffusion of responsibility, simple laziness, and forgetfulness due to stress. Additionally, we will examine why people choose to not recycle, because a lack of motivation to recycle could possibly be linked to a lack of motivation to conserve energy. Ultimately, these reasons contributed to the questions we asked on our survey and throughout our interviews.

2.6.1 Reason One: People Attribute Responsibility to Authorities

Many of the problems associated with the wasted energy use resulting from the human factor may stem from the belief that it is businesses' or the government's responsibility to fix (Farhar, 1994).

In general, public support for energy conservation and overall “greenness” is high. However, when asked which methods would be more effective for reducing or offsetting GHG emissions, people favored those methods that have to be instituted by government or business authorities. To illustrate: in a poll discussing the development of “smart” houses, which would give homeowners the ability to closely watch and control the use of energy consuming devices throughout their household, 55% thought this was very important; whereas, 78% thought that planting more trees to help filter the carbon dioxide out of the air was very important, or 73% for phasing out the use of CFC’s. These figures obviously suggest that the public believes the problems mostly remain outside of their own hands (Farhar, 1994). There seems to be an overwhelming sentiment towards energy waste that it is not public responsibility, that it is the fault – and responsibility to fix – of the government and businesses. As this case study shows, people may believe that they are not personally responsible.

Because of this data, we included several questions in our survey (appendix B.3) asking if people believed that lighting in office buildings was a significant portion of total consumption. Because, as was shown by these studies, if people do not believe that it is their use that is affecting the environment, they may not make any effort to change their consumption. This would directly link their knowledge about energy consumption and whether or not they turn off lights.

2.6.2 Reason Two: Diffusion of Responsibility

A case study done by Freeman et al. shows that, in regards to tipping, people give less as the number of people increases. Their hypothesis stated that the size of the tip decreased as the group size increased. In the study, individuals dining alone tipped an average of 19% while groups with four to six people tipped 13.5% (Freeman et al., 1975). This study shows that individuals will take more responsibility when alone, but as group size increases it is assumed that someone else will take responsibility. If we translate this study to reducing carbon emissions in the workplace, we can infer that a possible reason for lights being left on overnight is because employees assume someone else will turn them off.

This discussion lead us to ask questions in our interviews and survey regarding whether or not people knew whose responsibility it was to turn off the lights. We included questions in our interviews that asked specifically if it was the security personnel and/or the cleaning staff’s responsibility to turn off any lights they find that are not in use. In our survey we added a question that asked if there were any policies about turning the lights off as they leave.

2.6.3 Reason Three: People Forget to Turn Lights Off because They Are Stressed

People may often leave lights on at night by accident, out of sheer laziness, or because they get stressed and forget. In his work, The Myth of Laziness, Dr. Melvin Levine hypothesizes a link between stress and laziness. He discusses that when a person fails to do something important, it may be stress rather than laziness. Levine states “laziness is not an innate trait.” He believes that at some point people lose the momentum that keeps them producing due to a frustration from their inadequacy, which results in less work and their being labeled as lazy (Levine, 2003). He cites a specific case with one man who is incredibly brilliant and motivated, but is unable to write or type. As a result of his inability, he becomes stressed and his motivation dissipates and eventually disappears, as well as his attempts. Just as he became unmotivated from his stress, employees may become unmotivated from theirs and not care about conserving energy, and in turn, switching off lights.

Since there is no way to quantify stress levels at work, and we assumed that employers would not like us asking if their employees were stressed at work, we attempted to observe the busyness levels of the offices we visited. This provided a rough idea as to whether or not people were often running into deadlines and stressed about keeping them.

2.6.4 Reason Four: Lack of Motivation

There is a direct correlation between why people do not recycle and why people do not turn lights off after hours. In regards to knowledge about recycling, there is an ample amount of information about it on the internet, on television, and in newspapers, so why don't people recycle? Many researchers have given monetary incentives in order to make it worthwhile for people to recycle, but their studies have shown that though monetary incentives work in the short-term, they have negative effects in the long-term (Pelletier et al., 2006). Studies have shown that those who have an internal motivation to help the environment will continue to help the environment in the long-term. “Results of [De Young’s] studies indicate that intrinsic and self-determined motives such as personal satisfaction (i.e., feeling good about doing something for the environment), being frugal (i.e. avoiding wasteful practices), being self-sufficient, and participating in a program where one’s actions can be seen to make a difference were significant incentives for recycling,” (Pelletier et al., 2006). This information shows that in order to convince people to save energy, we will need to be able to clearly illustrate to them that global warming is a serious threat, and that their actions can have a profound effect on overall emissions.

As a result of this research, we decided to make notes of any presence of recycling bins or

recycling reminders, as this reflects an effort to motivate people to think “green” in general. And also to ask employers if they attempted to keep their employees informed of the ecological effects of their energy usage so as to instill an ongoing effect of energy conserving habits.

3. Methodology

Our goal was to explore the reasons for out of hours lighting use in selected buildings in London and to develop recommendations to reduce this consumption, and for future research. Our research will focus on three related questions: 1) why do people leave lights on in buildings after hours, 2) do they believe it is important to turn them off, 3) do they have access to light controls. To address these questions we inspected buildings ourselves, conducted in depth interviews with building and office managers and surveyed building employees. Achieving the objectives below through the listed methods helped us answer these questions.

3.1 Project Objective One: Determining the Reasons for Overnight Lighting in London’s Non-Domestic Building Stock

Our first task was to organize the first WPI research teams 140 building sample in a way that would clearly illustrate which buildings should be a priority for us to study. This would save us time, and make sure that we spoke with both ends of the spectrum; “good” and “bad”.

3.1.1 Determining Priority Targets Within the Given Building Sample

Once in London, we were given the previous 2007 IQP report’s database created by the Levin et al group that contained their inspection information. Their database included the size and location of the buildings, some businesses in the buildings, and the percent of lights illuminated in the building at night (two nights worth of inspections for each building). We sorted the buildings by the percent of lights on at night and then averaged the numbers from both nights together to get the average overnight lighting use. Next we sorted their sheets according to lighting percent used from the smallest amount to the largest amount which were 0 percent and 100 percent respectively.

After sorting the data we determined that the 6 worst buildings were over 65 percent usage, with the closest behind those being about 50 percent and under. There were a significant number with 0 percent usage (about 35), so we did not worry about good buildings. Additionally, we wanted a good cross-section of sizes, to determine if there were differences between larger and smaller buildings. We classified the big sized buildings to be any building between 10,000, and small to be below 10,000 (No units were given on any datasheet). This was an arbitrary classification only made to make the presentation of any obtained data more clear. Due to a lack of cooperation from building staff or the

physical absence of some buildings present in 2007, we were required to select the next best or worst buildings.

After seeing some of the drastic changes in the building occupancy from 2007 to 2009, as well as the lack of data points, we decided it would be useful to repeat the first group's inspection of lighting usage at night. We observed the buildings for five nights, one for each business day of the week, starting at 10pm and finishing around midnight.

The previous group's methodology for measuring overnight lighting use consisted of comparing the number of lit windows at night to the total number of windows on a building's façade. Levin, et al. defined a window unit as a window pane or group of panes bounded by building structuring (framework). To illustrate their methodology they provided the below figure:

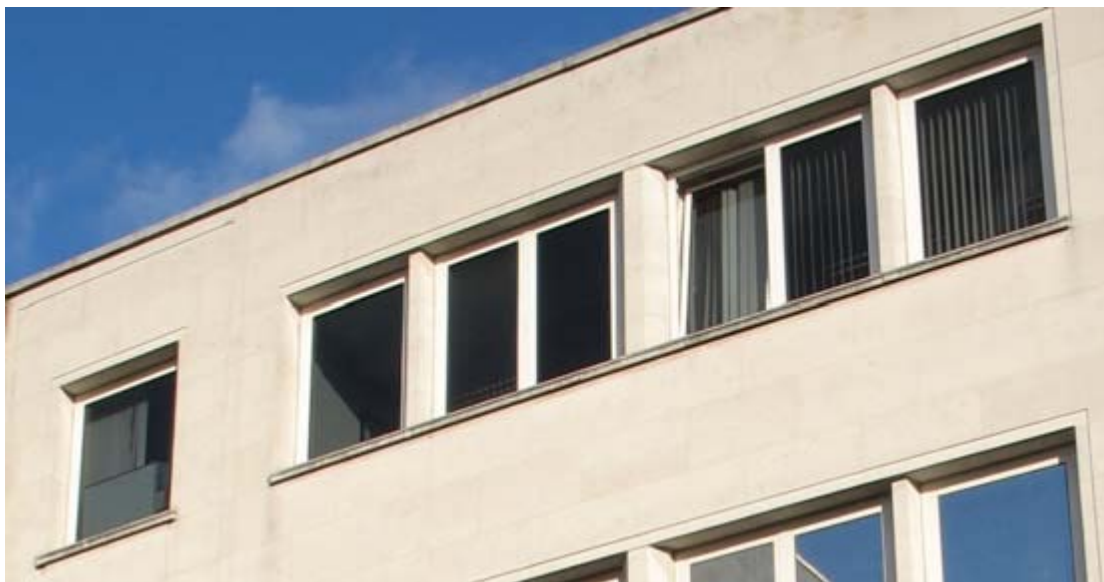


Figure 6: Example Building Façade (Levin, et al., 2007)

In figure 6 above, there are five total windows. On the far left, there is one pane completely surrounded by building framework; this is one window. On the right there are six panes, however four windows. If one looks closely, they can see three pieces of framework dividing the panes and making it four windows. It is very important to define the size of one window, because if you do not, it is very simple to have values not indicative of the actual buildings overnight lighting usage.

Levin, et al. also considered “light spillage”. This occurs when a window is illuminated by a light from directly behind it, however the adjacent windows are not illuminated by lighting directly behind them. The adjacent windows are illuminated by the light that is directly behind the first window. In order to keep from overcompensating for the individual light that was illuminating all of these

windows, only the first window would be counted as illuminated.

In most occasions when we observed the buildings, areas such as lobbies, stairs, and attached living spaces were illuminated. Stair lights, for instance, are considered emergency lights and in some cases must remain on all night during the week. Lobby lights provide a sense of security and, in some cases, publicity for the building. The living spaces were often situated above the actual office spaces in the same building. Since none of these were reflective of which lights are left on overnight due to human interaction with the lighting systems, they were not included as lit windows or total windows. However, we noted if the lobby or the stairs were lit for any possible future reference. Figure 7 below shows an example of a building with both the lobby and stair lights on. The lights on the bottom are an example of what we classified as lobby lighting, and the windows on the right are an example of stair lighting.



Figure 7: Example Lobby and Stair Lighting Picture

3.1.2 Determining Lighting Systems, Layout, and Access in Sample Occupants

We determined lighting systems, layout, and access through two main methods: interviews and inspections. In order to obtain interviews, we needed to get in touch with building and office

managers. We began to acquire the necessary contact information by visiting the buildings. At our target buildings, we spoke with receptionists and some office managers about obtaining the contact information for the building managers. We introduced ourselves as “students working with University College London on a research project concerning office building lighting habits”, and most people greeted us warmly and supplied us with a company name. Upon asking, we were also sometimes given a person’s name and phone number or email address. Additionally, we obtained complete lists of most of the buildings’ tenants by taking pictures of the directories in the lobbies or on the building outside. Once the photos were analyzed and company names obtained from the directory information we then put the information into the database and sorted it with the buildings information. Next, we searched the internet for contact information not already obtained for individual office managers. The information was obtained via company websites and personnel lists that were found using various search engines. The contact information was then put into our database of the buildings’ information.

ID	Street	St. No.	Company	Name	Phone	E-mail
2	Example St.	13-22	Building Managers Ltd.	Reception	0207-555-5555	
				John Doe	0207-555-5555	j.d@bmltd.co.uk
			Company A	Reception	0207-555-5555	
				Jane Doe	0207-555-5555	j.d@companya.co.uk
3	Example St.	107-113	Management Services Inc.	Reception	0207-555-5555	
				John Smith	0207-555-5555	j.s@msinc.co.uk
			Company B	Reception	0207-555-5555	
				Jane Smith	0207-555-5555	j.s@companyb.co.uk
			Company C	Reception	0207-555-5555	
	George Smith	0207-555-5555	g.s@companyc.co.uk			

- Strikethrough = Nonexistent/Uncooperative
- Black = Pending Information/Not contacted
- Purple = Interviewed
- Red = Priority Target

Figure 8: Example Contact Sheet

The contact information was added to a secondary datasheet, like the example above (figure 8), to help organize it and prevent the accidental error that occurred in the Levin, et al. study. This also facilitated our efforts to obtain interviews by creating an ordered list of information. We could quickly refer to this database to determine who we had already interviewed and who we still needed to, which building they were associated with, and whether it was a priority or not. This database helped us use time efficiently. Additionally, a contact log database was created, which contained information on how many interviews we had done, who they were with, at what exact time and day they were, what calls

needed to be made, and what emails needed to be sent. We also included some side notes for each call, email, or visit done to keep track of what information was obtained from each interaction. An example of the contact log is given below as figure 9.

ID	Date	Time Contacted	Type	Company	Name	Position	Method	Call
35	Monday, May 18 th	10:45:00 AM	Email	Company A	J. Doe	OM	020-7555-5555	Later
7	Monday, May 18 th	11:00:00 AM	Call	Company B	L. Doe	BM	020-7555-5555	No
9	Thursday, May 28 th	11:12:00 AM	Visit	Company C	Max Doe	OM	md@cc.cp.uk	No

Green----- Conducted interview
 Red----- Declined

Figure 9: Example Contact Log

We inspected the inside of the buildings with the consent of the interviewee. This procedure helped us clarify factors such as the general size of the building, estimated number of employees, light switch accessibility, types of light switches and lighting layouts. This procedure determined whether lights were left on due to inaccessibility or forgetfulness. If the building had working daylight harvesting and motion sensors then this would determine that the system was autonomous which does not require human effort to be turned off. Additionally by investigating and observing the interior of the buildings, we were given a sense of the working atmosphere, what levels of stress people were feeling and whether or not there were reminders to conserve energy posted. These procedures aided us in performing an effective comparative case study.

In addition to observing the workplace, we asked several questions in our interviews to gain a better understanding of the layout of the buildings. In order to obtain an interview with a building manager, we used the contacts found during our updating process. The questions we asked that are related to this objective were:

1. Do you use automatic switches of any kind?
2. Do you have a timed grid system?
3. How many lights does one switch control?
4. Is there often a master switch provided for an entire suite?
5. Are the light switches throughout the office easily accessible?

In our interviews we first asked questions one and two from above, which provided us with information about the level of human dependence that the building or offices lighting relied upon. If a better performing building seemed to have a trend of using motion and/or heat sensors or timed grids, it could be considered a valid lighting overnight reduction tool. In addition, the rooms and areas in which these technologies are applied could be assessed for effectiveness by comparing one building’s data to another.

Secondly, questions three and four told us something about the level of control available. If both switches are provided, there is less likelihood of wasted lighting usage, as there is a wider range of control. This eliminates the problem of people leaving lights on by accident or out of sheer irresponsibility and allows for individual access to lighting for one person. Also, question five told us whether or not any office lighting policy and strategies are failing because people do not know where the switches are.

3.1.3 Identifying Efforts and Policies Implemented to Reduce Overnight Lighting Usage

There were two main methods for determining the efforts and policies in place. The first of these methods was through our interviews of both building and office managers. Several questions were directed at uncovering any policies or general efforts towards conserving lighting energy.

1. How long do you allow lighting use after hours? Any policies or rules?
2. Is anyone responsible for turning all the lights off at the end of the work day?
3. Is the cleaning or security staff asked to turn off lights that are not in use?
4. Do you try to inform the tenants/workers of the ecological effects of energy use?

Asking, “How long do you allow lighting use after hours? Any policies or rules?” provided us with any direct policies the offices or buildings might have in place. The two questions, “is anyone responsible for turning all the lights off at the end of the work day?” and “Is the cleaning or security staff asked to turn off lights that are not in use?” told us whether or not the offices or buildings had considered that lights may often be left on overnight. “Do you inform your tenants/workers of the ecological effects of energy use” told us if the target was trying to motivate their tenants or workers to conserve energy through behavioral influences, as well as if they considered it a viable method to reducing lighting usage.

The second method that we used to determine the buildings efforts and policies was our inspections of the offices themselves. After or during our interviews we looked around to see if there were signs reminding people to turn off lights or encouraging energy conservation through lighting in general. Our checklist consisted of four things related to this:

1. Kinds of switches present
2. Signage about lighting present
3. Messages supporting “greenness”
4. Recycling bins present

The presence of these items gave us an overall indication of the building or offices commitment to being “green” in general. The “signage about lighting present” told us specifically if our targets are conscious of the lighting issue and its contribution to energy use. “Messages supporting “greenness” showed us whether our targets considered employee or tenant opinion a contributor to lighting use and worth attention. The “kinds of switches present” showed us if the landlords and employers considered lighting usage a significant enough contributor to energy wastage to spend money addressing it.

3.1.4 Identifying Employee Attitudes and Behaviors Toward After hours Lighting Usage

Our main method for uncovering these reasons was a survey. Our initial survey to understand how people use lighting at WPI is included in Appendix B. The interviews we conducted helped us revise the survey distributed in London (listed below) and make it more effective:

Thank you for your time, feel free to leave comments anywhere on the survey. If this survey is being completed digitally, please e-mail it as an attachment to carbreduce@googlemail.com.

Date: _____

1. If you are using lighting after hours, how many hours a night do you use them for typically?

2. Do you use lighting in your office after hours?

- a. 7 nights a week
- b. 6 nights a week
- c. 5 nights a week
- d. 4 nights a week
- e. 3 nights a week
- f. 2 nights a week
- g. 1 night a week

3. Why do you use lighting after hours? Select all that apply, if any

- a. Work late
- b. To deter crime
- c. Comfort
- d. Inconvenient to turn off
- e. Forget
- f. Other: _____



4. How much lighting does one switch or sensor often control?
 - a. Enough for 3 or less people
 - b. Enough for 4 to 10 people
 - c. Enough for more than 10 people
 - d. Other: _____
5. Are you aware of any policies in your office concerning lighting usage?
 - a. Yes
 - b. No
6. If your office does have a lighting policy, is it enforced?
 - a. Yes, always
 - b. Yes, most of the time
 - c. Yes, some of the time
 - d. No
7. Are you concerned with energy conservation in general?
 - a. Very Concerned
 - b. Concerned
 - c. Somewhat Concerned
 - d. Not Concerned
8. Do you think turning lights off that are not in use is important?
 - a. Very Important
 - b. Important
 - c. Somewhat Important
 - d. Not Important
9. Do you think lighting is a significant portion of energy use in office buildings?
 - a. Very Significant
 - b. Significant
 - c. Somewhat Significant

Only applicable if your office has non-timer or sensor controlled lighting (regular switches):

10. When leaving the office at the end of the day, do you notice lights left on with no one using them?
 - a. 1 night a week
 - b. 2 or 3 nights a week

- c. 4 or more nights a week
 - d. No, never
11. Do you know if there are switches controlling your entire suite or floor?
- a. Yes, there are
 - b. No, there are none
 - c. Don't know
12. Do you know where switches controlling your entire suite or floor are?
- a. Yes
 - b. No
 - c. There are none/Don't know
13. Do you check before you leave and turn off any extra lights not in use?
- a. Yes, always
 - b. Yes, sometimes
 - c. No, never

The survey attempted to determine how employees use lighting and if they apply the policies set forth by their managers. We tailored the survey to make the process as easy on the respondent as possible. We used as few questions as possible in order that the person taking the survey could complete it quickly. Our questions considered if people leave lights on afterhours because of safety concerns, lack of knowledge about where the light switches are, and if there is a lack of concern.

At the end of every one of our interviews, we asked specifically if we were allowed to distribute a survey on the premises. We distributed the survey in a few ways in accordance with building or office manager's restrictions.

1. Active distribution – the survey was distributed and collected by one of the team members in the lobby of the target building or entrance-way of the target office.
2. Passive distribution – the survey was left in the lobby of the target building or entrance-way of the target office with a collection bin.
3. Managerial distribution – the survey was provided to the manager of the building or office and was distributed and collected by them. They were then either picked up or returned to us via mail or email.

The surveys themselves attempted to cover each aspect of out of hours lighting use. These

aspects included 1) Why are lights used after hours, 2) Are switch layouts conducive with the goal of conserving energy, 3) Do people consider responsible lighting use important, and 4) Are current afterhours lighting practices in this office efficient?

The first question of the survey supplied us with a percentage of employees that use lighting after hours by asking, “Do you use lighting after hours in your office?” Then, to address the first aspect, our survey asked, “Why do you use lighting in your office after hours?” and gave a set of choices including an “other” selection to encompass a wide variety of options. This question had been left open-ended to allow us to receive a wide array of answers that we did not originally expect. The answers to this question can inform the development of future surveys with regard to specific reasons for overnight lighting use. Addressing the second aspect, we asked, “Do you know where switches controlling your entire suite or floor are?” which determined whether the lights were easy to access and if the lack of access to them was a factor. The third aspect was addressed with: “Do you check before you leave and turn off any extra lights not in use?” which determined whether there was a lack of concern for wasting energy and helped us understand if people are knowingly not turning off lights.

For our analysis, we looked for patterns in the interview responses and for unexpected responses, and we attempted to compare the “good” and “bad” buildings, with respect to their lighting usage, lighting systems, policies, and patterns and differences in individual behaviors and attitudes as indicated by the survey.

3.2 Project Objective Two: Develop a Methodology for Future Research

Throughout the project, we continually refined our interview questions and how we spoke to people. We made a practice of noting when we supplied too much information, and when we supplied too little. To do this, we tried to gauge receptionists’ reactions to our statements; whether they were happy to help, confused, or very defensive. No official log was kept of the reactions; however, we noted days during which we had more success than others, and matched them to our applied method for the day. A clear description of the effective and ineffective methods is supplied in the Results section of this report. In addition, we gauged the effect of tonality on those we spoke with. We compared more professional tones with more friendly tones. This illustrated to us the best way to present ourselves to receptionists or managers.

As stated above, we began our research by visiting the buildings and introducing ourselves to receptionists in one of two ways: 1) “Hello, we are students working with University College London on a research project concerning office building lighting habits. We were wondering if you had the

building managers name and phone number” or by just asking 2) “Do you have the building managers phone number?”. This showed us clearly if identifying ourselves was helpful or if it was better to just ask to speak with the necessary individual. The same methods were used when contacting office managers, except this was done by phone. Attempting one by phone and the other in person gave a way to compare the different types of interactions and their effectiveness.

4. Results

4.1 Factors That Might Contribute to Overnight Lighting in London’s Non-Domestic Building Stock:

This section presents results uncovered by our research that are relevant to our first project objective: determining reasons why lights may be left on overnight. It discusses 1) the system layouts present in the buildings, 2) efforts and policies implemented throughout the sample, and 3) employee opinions concerning after hours lighting usage. Before discussing our findings on these three issues, we briefly describe the final buildings sample we studied, and we summarize what types of data we were able to collect for each of these buildings.

Of the 140 buildings within our study’s scope, we observed and analyzed nineteen of them. We initially chose these buildings as either “good” or “bad” representations of the stock according to the 2007 data. We observed each building on five separate nights, as described in the methodology. This allowed us to compare light usage in the past two years, and it enabled us to re-categorize the buildings as “good” or “bad”, using more current data. Table 1 categorizes each of the nineteen buildings by percentage of light use in 2007 and now (2009). It also indicates building size and the type of data we were able to collect: direct observation of interior lighting, interviews with Building Managers (BM) and interviews with Office Managers (OM), and whether and how many surveys were distributed and collected in each building:

Building ID	Good or Bad (2009)	Overnight Lighting (2009)	Good or Bad (2007)	Overnight Lighting (2007)	Size	BM Interview	OM Interview	Survey Notes	Surveys Received
28	Bad	78.38	Bad	43.33	B		Yes	Scan	
58	Bad	47.94	Bad	51.11	S	Yes	Yes	Copies	
32	Bad	41.67	Good	24.44	S		Yes	Email	4
35	Good	38.57	Bad	66.67	S	Yes		Denied	/
22	Good	33.33	Bad	40.48	S			Denied	/
42	Good	30.77	Bad	65.83	B	Yes		Email	
115	Good	18.61	Good	37.50	B	Yes *	Yes	Email	
5	Good	15.80	Bad	50.81	B	Yes *		Copies	
7	Good	14.27	Good	12.40	B	Yes		Copies	
102	Good	11.11	Bad	47.97	B	Yes		Email	
116	Good	8.79	Good	18.32	B			Denied	/
86	Good	6.67	Bad	87.50	S			Denied	/
51	Good	5.57	Good	1.11	B	Yes		Email	
3	Good	5.29	Bad	100.00	S			Copies	1
108	Good	1.67	Bad	72.73	S			Denied	/
8	Good	0	Good	0.00	S		Yes	Denied	/
9	Good	0	Good	0.00	S		Yes	Denied	/
39	Good	0	Good	23.08	S		Yes	Copies	
57	Good	0	Good	1.33	B	Yes		Email	1
Total	16 Good, 3 Bad	18.93	9 Good, 10 Bad	39.19	10 – S 9 – B	8	7		6

Table 1: Data Collected on Sample Buildings

As shown in the table, far fewer buildings were categorized as “bad” than in 2007. These categorizations depended on their average overnight lighting usage. Overall fifteen buildings had improved or maintained zero percent usage. The “good” category was defined for buildings which had 40 percent average lighting or less; “bad” buildings had more than 40 percent average lighting. From the 2007 results, we categorized nine buildings as “good” and ten as “bad”. However, for our 2009 results, sixteen were “good” and three were “bad”.

As for our interviews, we pursued thirty-two different building and office managers, and ended up conducting eight interviews with building managers and seven with office managers. There were two buildings where we conducted interviews with both building and office managers (58 & 115). None of the buildings allowed us to distribute the survey manually. Most asked us to send it to them via email or to deliver a copy for them to scan and distribute via email (passive distribution). We distributed the survey through email to nine buildings, left multiple copies for six (three of which were also previously emailed) and provided a copy for scanning to one. A week prior to our final report and

presentation, we collected six surveys. Of these six surveys, four were received by emails and two from filled copies. Four were from one building, and two from two others.

We were able to assemble complete sets of data for none of the buildings. Despite having interviews for the majority of some buildings office space, we received no survey results from these buildings. As a result, our data is merely suggestive. However, the data obtained from the night observations, which had to be performed to update the 2007 data, has shown some interesting results.

4.1.1 Priority Targets Within the Building Sample

Data for the 140 buildings included in the original CaRB was incomplete in several ways for the purpose of our study. The previous group’s research topic was not concerned with the building names or company names, since they did not need to speak with people in the buildings, so they did not obtain very many. Those that they had obtained were out of date and had mostly changed. This illustrates the time sensitivity of this type of data. Whether it is the percentage of night lighting use or building names, the information obtained throughout our time in London may or may not reflect the previous groups’ data, and will need to be obtained again for future studies. Additionally, the previous group only did overnight observations two times for each building. Due to the observed time sensitivity as well as the minimal number of observations performed, we decided it would be useful to repeat the first group’s procedure on a smaller selection of buildings that we had received some cooperation with for five nights, one for each business day of the week since usage may vary from day to day

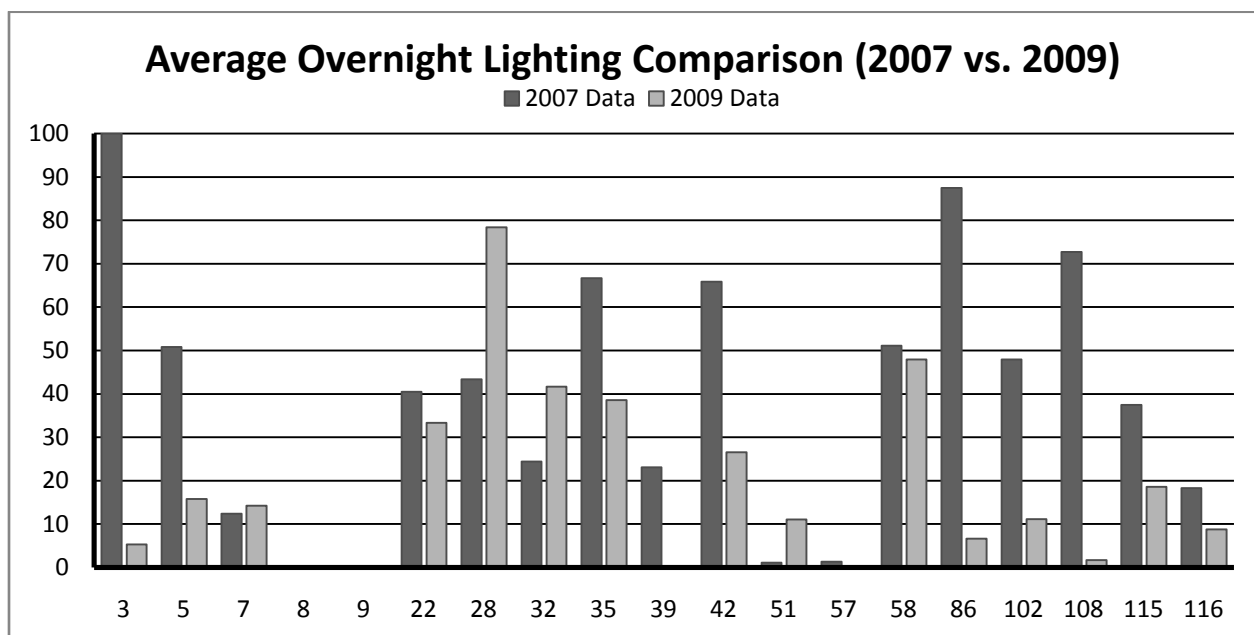


Figure 10: Average Overnight Lighting Comparison (2007 vs. 2009)

As shown by figure 10 above, the overnight lighting usage drastically changed from 2007 to 2009. The general average usage from these nineteen buildings went down from 39.2 percent in 2007 to 18.9 percent in 2009; a change of 20.3 percent. Building 3 improved from having one hundred percent overnight lighting use in 2007, to an average 5.3 percent overnight lighting use in 2009. This could show that recent measures taken, such as the legislative measures outlined in our background section, have had some effect on both consciousness about energy waste and use in general. However, four of the buildings in the sample increased their overnight lighting usage; buildings 7, 28, 32, and 51. Building 7 went up only 1.9 percent, which could be considered mere fluctuation and not be representative of any changes at all. Conversely, buildings 28 and 32 increased their usage by 35.1 and 17.2 percent respectively – clearly illustrating changes of some kind and not mere fluctuation. These are 80.9 and 70.5 percent increases in usage respectively.

In our interview with an office manager of the major tenant in building 32, it was explained that there were motion and daylight harvesting sensors installed throughout the office spaces in a recent renovation. However, the contractor hired to do the installation of the new system made an error, and many of the daylight harvesting sensors did not function correctly and the lights, as the manager stated, would have “schizophrenic fits”, turning on and off constantly. Additionally, during our observation of the office space, we noted an effective layout, in that the lights farther from the windows were on separate switches. Yet, they were supplying light for too many people, and at night we saw entirely lit rooms for one or two people working in them. In our interview with the office manager of the only tenant in building 28, we were told that the lights were left on all night because there were employees constantly working in the building. This seems careless, as we observed far less employees working at night than during the day; those working at night could not possibly have needed all of the office spaces lighting.

Another interesting finding from our data is that the size of the buildings did not have an effect on the average usage, as big buildings had an average overnight lighting use percentage of 20.5, whereas small buildings had a percentage of 17.5. However, as figure 10 below illustrates, the big buildings all but one seemed to cluster around the average, whereas the small buildings seemed to lie on the extremities of the plot. This phenomenon is something that should be further researched. It may be due to the differences in applied technologies, or maybe the differences in applied strategies to raise awareness; either way, the cause should be uncovered.

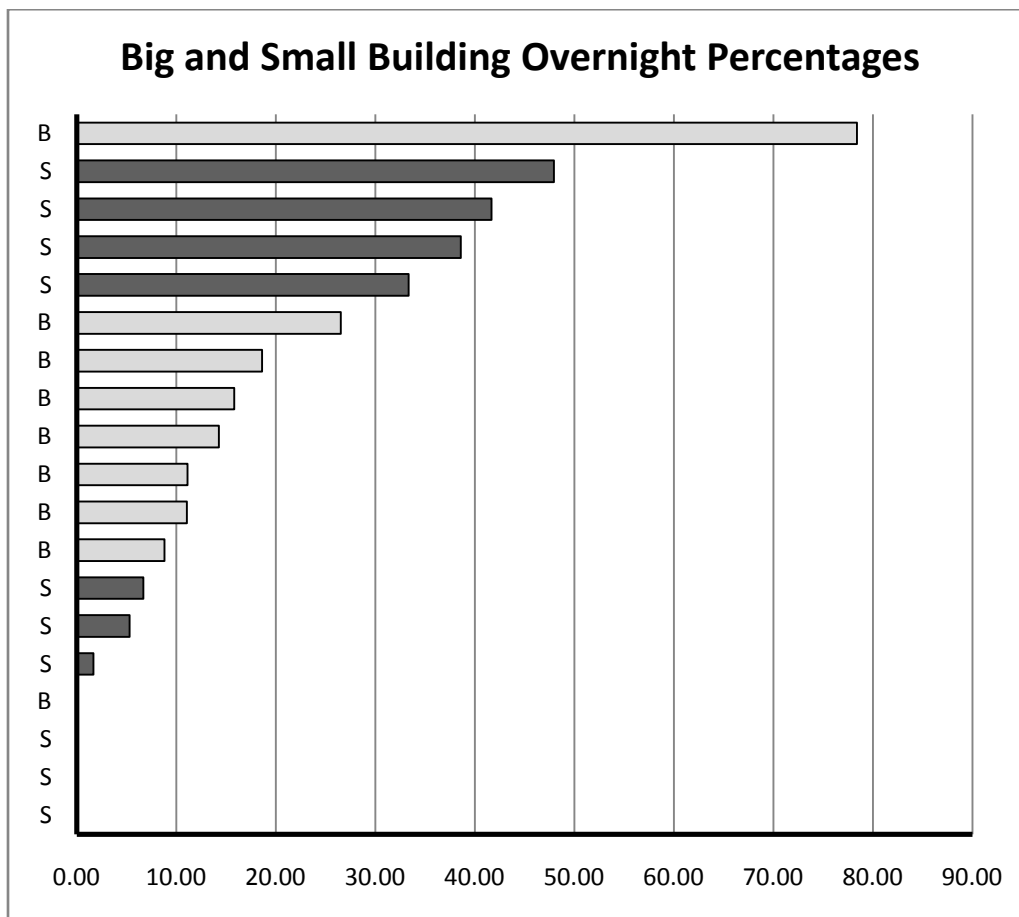


Figure 11: Big and Small Building Overnight Percentages

4.1.2 Lighting Systems, Layout, and Access in Sample Occupants

Through our interviews with building and office managers we determined what types of switches, sensors, and layouts were present in the buildings. Table 2 below illustrates the results obtained from building and office managers respectively with regards to these aspects:

Interview Questions	# of Building Managers who said yes	# of Office Managers who said yes	Total Yes Responses
Are there any timed lighting systems in the building/office?	1 out of 8	0 out of 7	1 out of 15 (6.66%)
Are there any motion sensors employed in the building/office?	6 out of 8	5 out of 7	11 out of 15 (73.33%)
Is there a master switch controlling an entire floor or section in the building/office?	3 out of 8	1 out of 7	4 out of 15 (26.67%)
Do tenants/employees have access to the building after hours?	8 out of 8	5 out of 7 office	13 out of 15 (86.66%)

Table 2: Interview Responses Regarding Lighting Systems

A total of twelve of our fifteen respondents have applied autonomous systems in at least some areas of their managed spaces. Eleven out of fifteen of the respondents said that motion sensors are employed in their spaces. Building 7 employs a timed lighting system, which was also one of the buildings that did not employ motion sensors or require security and cleaning staff to turn off unused lights. They are almost always present in the common areas, bathrooms, and halls, as six of the eight building managers stated. They are also present in four of the seven offices whom we spoke with. In addition, two other buildings said they had their external lighting on a timer, but no internal timed lighting. There were two building managers who said Master switches – switches that control an entire section or floor – are present in four of fifteen of the buildings; however, none of these buildings provide access to these master switches for anyone other than maintenance personnel.

4.1.3 Efforts and Policies to Reduce Overnight Lighting Usage

In addition to determining the technical aspects of the buildings, we tried to identify currently employed efforts and policies to reduce energy consumption in buildings, specifically with respect to lighting. Again, we asked both building and office managers about their awareness of lighting issues and whether they attempt to reduce energy consumption in general. Table 3 below shows the answers from our interviews:

Interview Questions	# of Building Managers who said yes	# of Office Managers who said yes	Total Responses
Are there any signs present in the building/office to remind workers to turn off the lights?	1 out of 8	2 out of 7	3 out of 15 (20.0%)
Is the cleaning or security staff responsible for turning the lights off after hours?	7 out of 8	7 out of 7	14 out of 15 (93,33%)
Are any lights purposefully left on overnight in the building/office?	6 out of 8	1 out of 7	7 out of 15 (46.67%)
Do you attempt to keep your employees/tenants informed about the consequences of energy consumption?	6 out of 8	7 out of 7	13 out of 15 (86.67%)

Table 3: Interview Responses Regarding Policy

As shown, there is a lot of commitment in buildings and offices with regard to keeping employees conscious of keeping “green” habits. In attempting to inform their employees about greenness, the respondents said on three occasions that it was still a work in progress and that it was a weak aspect, and that it only helps to some extent. In other words, though they provide influence and incentive, it is ultimately the individual’s responsibility to practice “green” habits. In one specific building, number 28, an office manager said there is always at least one worker in the building after hours, so the managing staff does not bother turning any lights off for the night. This clearly is not a good habit, as an entire floor may be lit for one or two employees working after hours. In another case, number 51, a building manager stated workers come in overnight, turn on the lights, and rush out sometimes forgetting to turn them off.

Often, when asked about their attempts to inform their employees or tenants many of the respondents said they use signs, bins for recycling, or reminders of sorts about being “green”. The employees in all the buildings were responsible for their own lights. However, there were buildings where employees had no control over the lights. As in the aforementioned case of building 28, employees did not have control of the lights after hours since it was a policy to just leave the lights on all night. However, this is only one case, as fourteen of the fifteen respondents said that it was policy for the security or cleaning staff to circulate their building or office and turn off any unused lights.

No.	Question	Responses
5	Are you aware of any policies in your office concerning lighting usage?	4-No 2-Yes
6	If your office does have a lighting policy, is it enforced?	3-N/a 2-Yes,most of the time

Table 4: Employee Survey Responses Regarding Policy

Several questions were also asked on the employee survey pertaining to policy. As shown in table 4 above, we asked employees if they knew about any lighting policies in the building, and whether or not they were enforced. Only two of the respondents were aware of lighting policies in their buildings. On the other hand, the remaining four employees did not know of any lighting policies in their offices. These responses were consistent with the interview data obtained where applicable. The two employees that knew about the existing lighting policies said that they are enforced most of the time. However, the other remaining employees of that company do not even know these policies exist. This implies that, at least in this building, methods used to keep employees aware of office policies concerning lighting may not be effective.

4.1.4 Employee Attitudes and Behaviors Toward After hours Lighting Usage

The main purpose of the survey was to find out how and why office employees use lighting after hours. We have received surveys from only six employees and three companies. Our results cannot be generalized across all the sample buildings. But, from the surveys gathered, four from one company and two from two others, we discovered people use their office after working hours 3.8 nights a week for an average of 3.625 hours per night. Table 5 shows the results of our survey:

No.	Question	Responses
3	Why do you use lighting after hours? Select all that apply, if any	4-Work Late 1-Comfort 1-To deter crime 0-Inconvenient to turn off 1-None of the above
4	How much lighting does one switch or sensor often control?	5-Enough for 4-10 people 1-Enough for more than 10 people
7	Are you concerned with energy conservation in general?	4-Concerned 1-Very Concerned 1-Somewhat Concerned
8	Do you think turning lights off that are not in use is important?	4-Very important 2-Important
9	Do you think lighting is a significant portion of energy use in office buildings?	1-Very Significant 4-Significant 1-Somewhat Significant
13	Do you check before you leave and turn off any extra lights not in use?	2-Sometimes 1-Always 1-No never 2-N/a

Table 5: Survey Responses Regarding Attitude

Regarding the employees' opinions on energy conservation and how concerned they were about it (question 7), Only one respondent said they were very concerned, four said that they were concerned, and another, somewhat concerned. Also, four employees stated that turning off lights that are not in use is very important; while two employees answered it was important. These results suggest that there is a general concern and awareness. However, when asked how significant a portion of energy usage lighting was, only one employee stated it was very significant, three said it was significant and another, that it was somewhat significant. This suggests that those surveyed may not understand how much of an effect changing their lighting habits might have on overall energy consumption. Some still reported that they make the effort, as two said they sometimes, and one always, check before they leave to turn off lights not in use.

Working late (four votes) was the most common reason employees gave for their usage. Lighting comfort was the reason that one employee gave and another employee specifically said he uses overnight lighting for reasons not given in our survey. Four employees said their lights illuminate enough space for four to ten people to work and one other employee said their lights illuminate enough for more than ten people. This implies that if one person is working late, they will need to use lighting for at least four people if they aren't using a desk light.

4.2 Recommended Future Research Methodology

Several flaws in our original methodology became apparent throughout the course of our project. Firstly, to begin an effective and reliable study of the overnight lighting usage in London’s non-domestic building stock, we discovered that a relatively close time frame (no more than four months) must exist between the observationally determined overnight lighting usage and any information obtained about efforts being employed within the buildings. This became obvious once we began our overnight observations. To illustrate, building 3 went from 100 percent overnight lighting usage in 2007, to 5.8 percent in 2009, which would have effectively reversed its status in our study had we had this data previously. Figure 12 shows the timeline that we think we should have followed, and would suggest to future teams:

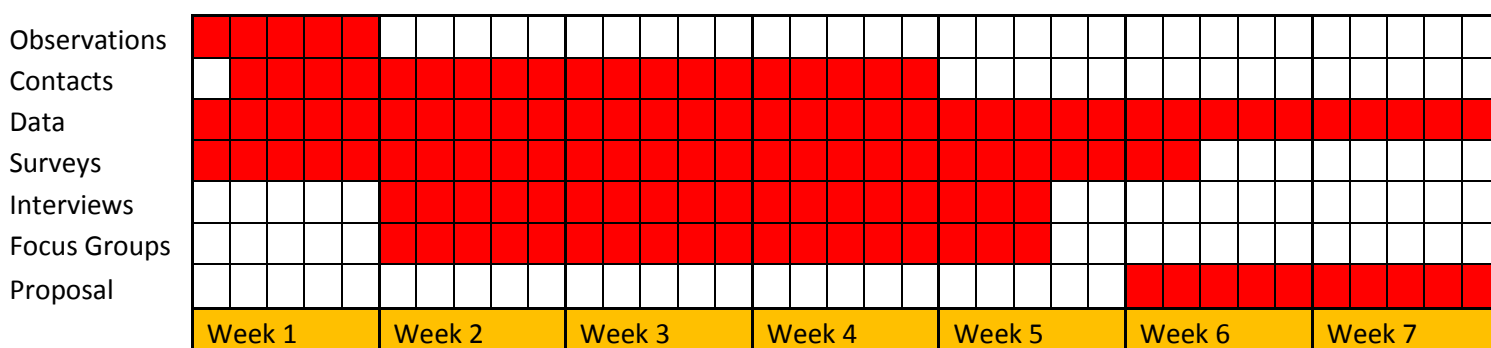


Figure 12: Suggested Timeline for Future Research Teams

4.2.1 Determining a Suitable Building Sample

In general the sample should be about thirty buildings. Ours was nineteen and was more than manageable for the night observations, but lacking in terms of obtained information. So perhaps with a larger sample, we could have tried for more interviews, and certainly more survey results. The building sample should be determined by means of 1) overnight lighting usage, 2) general size, and 3) age. The second two categories are relatively simple to determine.

The general size of the building should not be quantified, but instead classified as either large or small. This will make it much easier to see size trends when examining any obtained data. A small building in Camden is most often attached to adjacent structures on either side, and often is taller than it is wide. A large building would be one that most often is not attached to other buildings and may be as tall as a smaller office, but much wider, and often faced with far more windows. As seen in our results, the building size seems to have some effect on its percentage of overnight lighting usage.

The age of a building or office most often actually means the last time it was refitted. Many of the office spaces had changed hands since the 2007 group performed their study, and as a result, many

of the managers had said they had refurbished their suites when they moved in, and in doing so, changed the lighting systems. Since this will not be available information until interviews have been conducted, the group should make rough estimates when visiting the buildings.

Throughout our project we determined better ways of performing the overnight lighting observations. Firstly, we discovered that to conserve time to a group member should map out the team's path prior to the nights study. Our first night took us from 10pm until approximately 1:30am to complete. We had only outlined which buildings to go to, no order was made ahead of time, and this caused some confusion throughout the night. The second night we went out, one person had used an atlas to look up all of the streets, and had ordered the buildings we would go to, and we finished around 12:30am.

Initially, we were somewhat disorganized. We did not assign tasks, and as a result, there was some confusion. However, by the third night we had more efficiently divided the work; one person took pictures as soon as we arrived, a second began counting, the third noted the second's dictations. It went very efficiently and sped up our process. By the third night we finished our observations by about midnight.

Determining a building sample is a vital step to complete early on, preferably by the end of the first week. The results from these observations should then be used to prioritize which buildings will be visited first, as in our original methodology. This data can then be related to the interview and survey findings later to measure the effectiveness of any efforts (or lack thereof) to reduce overnight lighting usage and develop conclusions and further suggestions.

4.2.2 Developing Contacts

As shown in the suggested timeline (figure 12) this should begin once the initial overnight observation data is taken, as most of the data we obtained did not fluctuate significantly from night to night. When we were visiting buildings we had chosen via our original method of building selection, we discovered that the best method of developing contacts was to go into building foyers and lobbies and introduce ourselves as stated in our methodology. This routine most often prompted a polite and cooperative response. We did try an alternative method, which was simply asking for the building managers or office managers contact information, which most often caused a more guarded response that was not helpful, but instead inquisitive. They usually dismissed us when we tried this method; however, sometimes they asked who we were first and then dismissed us.

When actually speaking with the respondent, we found it best to first introduce ourselves as

“...students working with University College London on a research project concerning lighting habits and systems in office buildings;” as it also prompted a welcoming response more often than did simply asking if they would answer a few questions. It was also in our data collections interest to emphasize that our questions would take five or ten minutes to answer; however, this is only if they were hesitant to speak with us.

Possibly the most notable discovery of our research would be the effectiveness of face to face interactions, as opposed to over the phone. The majority of our attempts to obtain building manager information were made via face to face contact and resulted in a 53.3 percent response rate with just less than a week and a half worth of effort. Our office managers were mostly contacted through phone conversations after researching their company’s information online. The office managers had a 41.2 percent response rate with over two and a half weeks of effort. The effectiveness of the face to face interactions clearly signifies an important difference between the two methods.

4.2.3 Conducting Interviews

Several observations were made pertaining to this which should be noted for future research. Firstly, it is very important to have someone who can keep an accurate summary of the interview in their head, so that when the respondent answers multiple questions at once (something that happens very often) the interview can quickly be readjusted accordingly. For instance, sometimes when asking if a system employed timed lights, the respondent discussed their motion sensor systems, which was another of our questions. This question also needed to be followed by one asking where they were employed, so it was important to ask that immediately after their discussion about the motion sensors, rather than coming back to it later.

Additionally, this person should be able to facilitate the respondents answer. This is something that must be done throughout the course of the interview. When a respondent stumbles on a question, the interviewer must determine a better way of wording this question so the respondent better understands what the group is looking to receive as a response. For example, sometimes when the group would ask “How long do you allow lighting use after hours?” the respondent seemed confused. To clarify, we began to add “Do you have any policies or rules?” which usually helped lead them to a relevant response.

It is also important to have a good note taker. This person needs to be able to distinguish relevant information from irrelevant as the respondent supplies it. For example, many times when asking about policies and rules, many respondents began to discuss recycling policies and computer use

policies which were irrelevant to our topic, and something that should not overshadow the pertinent data in the notes. It would be advisable to have a sheet to be filled out by the note taker with some general information required from each respondent. Factors like the number of employees/tenants in the given office space/building, company name, date, building ID number; and even for some things like the presence of motion sensors and where they are located. A proposed idea is listed below as Figure 12:

ID#	No. Tenants	Company		
	Motion Sensors	Timed System	Policies	Reminders
Y/N				
Applied to				

Figure 13: Proposed Note Sheet

Despite our actual acquisition of contact information being done mainly in person, the majority of our interviews have been conducted over the phone. This is because it is the easiest method for the respondent. However, our face to face interviews have proved more valuable, because we have gained a personal observance of the facility and its systems. One such respondent walked us through his entire office, flipping switches as we went to show us the banking layouts (which were very effectively laid out in this case). Face to face interviews should be a goal, future researchers should do their best to obtain them as opposed to phone interviews.

4.2.4 Survey Distribution

Our interviews concluded with a question asking if we were allowed to distribute a survey throughout the building or office. Once we were given permission, we asked how we could distribute the survey throughout the building or office. Managers mostly wanted this to be done by email, a method we would not suggest. It is easy for the survey to be forgotten or dismissed for spam when distributing via email. If this is insisted upon, one should make a confirmation call and speak to the individual responsible for distributing the survey throughout the office and see if they received the email. We would suggest getting permission to distribute the surveys in the main lobby of the building or just outside the doors, leaving a collection bin with the receptionist. Though we were unable to get permission to apply this method, it would seem the best way to distribute them, because this gives the respondent more of a sense of responsibility to complete the survey. You have given them a physical

piece of paper, whereas an email can be deleted, or likely dismissed for spam.

We would not suggest leaving copies with any receptionists, as our results from this method were worse than dismal. We received one filled copy from a receptionist, and two more from another building that had been randomly checked. We determined this by looking at some questions, like number eleven, which asked if a master switch existed for their office or floor, which they responded no to, and then responded yes to question twelve, asking if they knew where the master switch was.

5. Conclusions

We only have a complete set of interview data for six office buildings, which limits the conclusions that can be drawn from it. The data limitation also makes it impossible to make a comparison between the “good” and “bad” buildings. As a matter of fact, two of our small buildings, 35 and 42, had nearly the same lighting usage figures despite the fact that one used motion sensors throughout the building, and the other did not. Building 35 has no motion sensors throughout the building and has a 38.6 percent usage, and building 42 has them everywhere, yet still has a 30.8 percent usage. Two of our buildings with motion sensors in the office common areas, 28 and 102, have 78.4 and 11.1 percent usage respectively. These two cases summarize the inconclusiveness of our study. We believe that this could be due to the lack of cooperation seen throughout the buildings. Perhaps if there were more results, trends could be observed from them.

In summary, our research indicated a surprising substantial decrease of overnight lighting usage in our target buildings from 2007 to 2009. The nineteen buildings we observed reduced their overnight lighting consumptions by an average 20.3 percent over the course of two years. During our interviews and in our documentation of building locations, we found that some of the issues that could have caused these reductions include the refurbishment or reconstruction of buildings, varying tenant occupancies within the buildings, and the incorporation of new lighting or energy consumption policies. Additional research might uncover more reasons as to why overnight lighting has decreased in these specific buildings over the past two years.

We also learned that the presence of the motion and daylight harvester sensor systems does not guarantee their effectiveness. For example, an office manager in building 32 mentioned that they had installed motion sensors and daylight harvesting switches throughout the entire office. However, as described in our Results section, the contractor hired to perform the installation of the system made an error, and as a result, none of the sensors work properly. Though we found this to only have happened in this one instance, the problem with technology maintenance should be further investigated.

Additionally, the results obtained from our interviews show that a large portion of the buildings employ motion sensors. Although a more expensive method for reducing lighting costs, these sensors remove human interactions with lighting switches and thus remove the chance for human error. In other words, there should not be any lights accidentally left on all night in buildings with motion sensors. However, this claim requires further analysis since our data proved inconclusive in this aspect.

For further analysis, a study pertaining to this specific case should be attempted and refined to further test the reliability of this claim.

Prior to arrival on site, we did not have time to conduct sufficient background research into the areas of interview procedures, survey development and distribution, and focus group methodologies. This kind of background research will be critical for other researchers conducting studies on reasons for overnight lighting in office buildings. Our group found its most prominent method of data collection to be interviews, despite not having studied any of the methods of this while in Worcester. If we had reviewed proper interview procedures, we might not have made as many errors in our note taking procedures that could have caused us to misplace vital data. For example, our note taker was often rushed because the interviewee would sometimes speak quickly. If we had researched these methods, we may have uncovered a way to avoid this problem.

One of our groups main issues was a lack of survey results. We now realize that face to face distribution or collection of surveys is the best method for getting responses, however we did not see the need for this at the time of our interviews. None of our interviewees gave us permission to distribute the survey from building lobbies or office lobbies. Surveys should not be left with receptionists, for we found that they did not have either time or motivation to follow through and collect them for us. Wherever possible, keep them uninvolved wholly, as they have a tendency to throw the surveys away.

Focus groups should certainly be conducted wherever possible, as a survey can be distributed during them which will provide a few survey results at least. They will also provide insight into additional questions that could be asked in the survey that did not immediately occur to us. Our group was considering conducting some of these, but found ourselves a little pressed for time, so we would suggest conducting them as soon as permission is obtained. We would have asked some of the interviewees who were eager to help and very cooperative, if they would invite a few of their employees to sit down and discuss the topic with us.

Something also brought to light by our interviews is that many of the large development firms contract out their lighting system design. These lighting system designers may have done similar research to that being done by CaRB. It would be helpful to contact any companies involved in design in this way, both in the states, and in London, wherever the opportunity arises. They may be able to provide information that could answer some of the more technical questions proposed by CaRB and its researchers. For instance, we found out how many of our respondents employed motion sensors in their buildings and offices, but one question this raises is how long do the sensors turn the lights on for

if someone just walks past the light and isn't actually working under it? Or even, are these times user adjustable, can the office managers set them? Are there standards for how the motion sensors are employed, how many lights do they often control? They could also be asked if they employ daylight harvesting switches, and how they determined the proper level of sensitivity for these switches. Are they employed throughout buildings, or just in certain spaces? They could also be asked about the research they have conducted with relation to their timer and sensor systems. Perhaps they have researched how long a motion sensor should leave a light on, or how sensitive a daylight harvesting switch should be.

Additionally, a methodology for detecting the presence of motion sensors in a building should be drafted. It is relatively simple to go to the buildings at night and take pictures from the outside, so this is a suggested medium. Our group discussed going out one night and taking pictures of one or two buildings at fixed intervals and later assessing them to see if a pattern was apparent. However, we hadn't the time to develop a more precise methodology than this, nor to effectively sort through our buildings and select proper targets. This would be something very useful if it is found to be successful. It would remove the necessity for interviews in determining the presence of motion sensors, and in doing so, enable a more comprehensive and accurate estimate of the stocks application of motion sensors.

Bibliography

1. (2008, May 22). Engineering and Physical Sciences Research Council. Retrieved April 20, 2009, from EPSRC Web site: <http://www.epsrc.ac.uk/default.htm>
2. (2008, July 31). IRIN - Humanitarian News and Analysis. Retrieved April 21, 2009, from GLOBAL: What climate change does - The 2nd in a three-part series Web site: <http://www.irinnews.org/Report.aspx?ReportId=79563>
3. Adam, D. (2009, March 17). UK government carbon targets 'too weak' to prevent dangerous climate change, scientists say. *The Guardian*, Retrieved April, 2009, from <http://www.guardian.co.uk/environment/2009/mar/17/uk-climate-budget-advice-weak>
4. Burnham, L (1992). *Renewable Energy: Sources for Fuel and Electricity*.
5. Buttel, F.H. (1987). *New Directions in Environmental Sociology*. Annual Reviews.
6. Carbon Reduction in Buildings (CaRB): A socio-technical, longitudinal study of carbon use in buildings. Retrieved April 20, 2009, from <http://www.carb.org.uk/> Web site: <http://www.carb.org.uk/>
7. City of London, Impacts of climate change on London. Retrieved April 25, 2009, from City of London Web site: http://www.cityoflondon.gov.uk/Corporation/LGNL_Services/Environment_and_planning/Sustainability/Climate_change/impacts.htm
8. Committee on Climate Change, (2007). Carbon Budgets. Retrieved May 3, 2009, from Committee on Climate Change Web site: <http://www.theccc.org.uk/carbon-budgets>
9. Di Cesare, A., DiLullo, N., & Krasko, K. (2008). Investigation of Carbon Reduction from Overnight Lighting in Non-Domestic Building Stock. 170.

10. Department for Environment, Food and Rural Affairs. (2005). *Climate Change and Energy*. Retrieved April 19, 2009, from <http://www.defra.gov.uk/environment/climatechange/index.htm>
11. EPA (2009, March 9). Fossil Fuel Combustion Waste. Retrieved April 19, 2009, from United States Environmental Protection Agency Web site: <http://www.epa.gov/osw/nonhaz/industrial/special/fossil/index.htm>
12. Farhar, B. (1994). Trends in US Public Perceptions and Preferences on Energy and Environmental Policy. *Annual Reviews*. 19, 211-232.
13. Fischlowitz-Roberts, B (2002). Carbon Emissions Climbing. Retrieved April 21, 2009, from Earth Policy Institute Web site: <https://www.earth-policy.org/Indicators/indicator5.htm>
14. Frank, R.H. (1988). A Theory of Moral Sentiments. *Emotion*. 293-294.
15. Freeman, S., Walker, M.R., Borden, R., & Latané, B. (1975). *Diffusion of Responsibility and Restaurant Tipping: Cheaper by the Bunch*.
16. Hudson, J.M., & Bruckman, A.S. (2004). The Bystander Effect: A Lens for Understanding Patterns of Participation. *The Journal of the Learning Sciences*. 13, 165-195.
17. Jenkins, G.J., Perry, M.C., & Prior, M.J. (2008). The climate of the UK and recent trends. *UK Climate Projections*.
18. London Climate Change Partnership (2009). Our changing climate - London. Retrieved April 25, 2009, from London Climate Change Partnership Web site: <http://www.london.gov.uk/lccp/ourclimate/>
19. Levin, M. (2003). *The Myth of Laziness*. New York: Simon & Schuster.

20. London Energy Partnership. (2004). *Energy In London*. Retrieved April 19, 2009, from <http://www.lep.org.uk/energy.htm>
21. Mayor of London. (2004). *Green Light to Clean Power: The Mayor's Energy Strategy*. Retrieved April 19, 2009, from <http://www.london.gov.uk/mayor/strategies/energy/download.jsp>
22. Mayor of London, (2007 February). The Mayor's Climate Change Action Plan. Retrieved April 20, 2009, from London Web site: <http://london.gov.uk/mayor/environment/climate-change/ccap/index.jsp>
23. The Need Project, (2008). Efficiency Conservation: Energy Consumption. Retrieved April 19, 2009, from Efficiency Conservation: Energy Consumption Web site: http://www.need.org/needpdf/infobook_activities/IntInfo/ConsI.pdf
24. Pachauri, R.K., & Reisinger, A. (2007). *Climate Change 2007 Synthesis Report*.
25. Pelletier, L.G., Dion, S., Tuson, K., & Green-Demers, I. (2006). *Why Do People Fail to Adopt Environmental Protective Behaviors? Toward a Taxonomy of Environmental Amotivation*. Ottawa: Wiley Periodicals, Inc..
26. United Nations Framework Convention on Climate Change. (2005). *Kyoto Protocol*. Retrieved April 18, 2009, from http://unfccc.int/kyoto_protocol/items/2830.php

Appendix A: Interviews

Appendix A.1: Questions for Building Managers

Hello, we are students working with University College London on a research project concerning overnight lighting in office buildings. We were wondering if you would mind speaking with us for a few minutes.

1. Initial greetings
 - a. Project Description summary
2. Opening
 - a. Ask interviewee to use name in proposal
 - b. Ask if interview can be recorded
3. Personal Background
 - a. What is your position in the company?
 - b. What are the responsibilities for the position?
4. Lighting
 - a. Do people have access to the building to work after hours?
 - b. How long do you allow lighting use after hours? Any policies or rules?
 - c. Are any lights in the building purposefully left on all night? which ones and why?
 - d. Are any lights often accidentally left on all night?
 - e. Is anyone responsible for turning all the lights off at the end of the work day? Who?
 - f. Are the light switches throughout the building easily accessible?
 - g. Do you use any automatic switches of any kind (e.g. heat, motion sensor)? Where?
 - h. How many lights does one switch control (e.g. grid size)?
 - i. Is there often a master switch provided for an entire suite, which the office manager can use to turn off all of the suites lights?
 - j. Do you have a timed grid system?
 - k. Is the cleaning or security staff required to turn off lights not in use?
 - l. Do you inform your tenants of the ecological effects of energy use? (to hopefully make them more conscious of its conservation)
 - i. If not, what might be a good way to inform them?
 - ii. If so, how are you informing them and have you seen an effect?

5. Greenness

- a. Can you think of anything that could be done to reduce overnight lighting usage?
- b. What do you currently know about what your company is doing to decrease lighting energy usage?
- c. Are the tenants responsible for their own electric bill?
- d. Does your company offer benefits for conserving energy?

6. Survey

- a. If we provide you with a copy to approve beforehand, would you mind us distributing a survey in the building lobby at some point?

7. Further Information

- a. Are there any other people or groups that you think we should contact?

8. Closing

- a. Is there anything that you can think of that we should know about that we haven't asked about?
- b. Do you have any questions for us?

9. Thank John/Jane Doe

Appendix A.2: Questions for Office Managers

Hello, we are students working with University College London on a research project concerning overnight lighting in office buildings. We were wondering if you would mind speaking with us for a few minutes.

I. Initial greetings

- a. Project Description summary

II. Opening

- a. Ask interviewee to use name in proposal
- b. Ask if interview can be recorded

III. Background

- c. What does the company do?
- d. What is your position in the company?
- e. What are the responsibilities for the position?
- f. How many people work in the office space?
- g. How long has the company occupied the suite?
- h. When was the last major refurbishment of the suite?
- i. Approximately how old is the building?

IV. Lighting

- a. Do people have access to the office to work after hours?
- b. How long do you allow lighting use after hours? Any policies or rules?
- c. Are any lights in the office purposefully left on all night? Which ones and why?
- d. Are any lights often accidentally left on all night?
- e. Is anyone responsible for turning all the lights off at the end of the work day? Who?
- f. Are the light switches throughout the office easily accessible?
- g. Do you use any automatic switches of any kind (e.g. heat, motion sensor)? Where?
- h. How many lights does one switch commonly control (e.g. grid size)?
- i. Are there individual room or section switches throughout the office, or is there often only one switch to control an entire area?
 - i. Or are both provided?
- j. Do you have desk lights?

- k. Do you have a timed grid system?
- l. Is the cleaning or security staff asked to turn off lights that are not in use?
- m. Do you try to inform the workers of the ecological effects of energy use? (to hopefully make them more conscious of its conservation)
 - i. If not, what might be a good way to inform them?
 - ii. If so, how are you informing them and have you seen an effect?

V. Greenness

- n. Can you think of anything that could be done to reduce overnight lighting usage?
- o. What do you currently know about what your company is doing to decrease lighting energy usage?

VI. Survey

- p. If we provide you with a copy to approve beforehand, would you mind us distributing a survey in the office at some point?
- q. Would you mind maybe setting up a small focus group? (explain)

VII. Further Information

- r. Are there any other people that you think we should contact?

VIII. Closing

- s. Is there anything that you can think of that we should know about that we haven't asked about?
- t. Do you have any questions for us?

IX. Thank John/Jane Doe

Appendix A.3: Suggested Questions for Building Managers

Hello, we are students working with University College London on a research project concerning overnight lighting in office buildings. We were wondering if you would mind speaking with us for a few minutes.

I. Opening

1. Introductions
2. Ask if interview can be recorded

II. Background

1. What is your title/position?
2. What are the responsibilities for this position?
3. How old is the building?
4. When was the last major lighting system refurbishment?

III. Lighting

1. How long do you allow lighting use after hours? Any policies or rules?
2. Is anyone responsible for turning all the lights off at the end of the work day? Who? (cleaning or security staff)
3. Are any lights in the building purposefully left on all night? which ones and why?
4. Are the light switches throughout the building easily accessible?
5. Do you use sensor switches of any kind (e.g. motion, heat)?
 - i. Where (Hallways, bathrooms)?
 - ii. How long do they stay on each time they are engaged?
 1. Is it more or less in bathrooms or hallways than in a regular working space?
 2. Does this time decrease at night?
 - iii. Is the time user adjustable?
6. Do you use daylight harvesting sensors?
 - i. Where?
 - ii. Are they disabled at night?
7. Do you have any automatic timed systems outside of sensors?
 - i. When do they come on and off?
 - ii. How are the timed lights controlled after regular business hours?

8. How many lights does one switch or sensor control (enough for # of people, one hallway)?
9. Are the lights banked in regression from the windows?
10. Do you inform your tenants of the ecological effects of energy use?
 - i. If not, what might be a good way to inform them?
 - ii. If so, how are you informing them and have you seen an effect?
11. Do the systems throughout the building always function properly?
 - i. If not, How often/which ones/why?
12. Are the tenants responsible for their own electric bill?
13. Is there anything additional that is being done to reduce lighting use in the building?

IV. Survey

1. If we provide you with a copy to approve beforehand, would you mind us distributing a survey in the building lobby at some point?

V. Further Information

1. Are there any other people or groups that you think we should contact? Any office managers in the building that would be interested?

VI. Closing

1. Is there anything that you can think of that we should know about that we haven't asked about?
2. Do you have any questions for us?

VII. Thank John/Jane Doe

Appendix A.4: Suggested Questions for Office Managers

Hello, we are students working with University College London on a research project concerning overnight lighting in office buildings. We were wondering if you would mind speaking with us for a few minutes.

I. Opening

1. Introductions
2. Ask if interview can be recorded

II. Background

1. What does the company do?
2. What is your position in the company?
3. What are the responsibilities for this position?
4. How many people work in the office space?
5. How long has the company occupied the suite?
6. When was the last major lighting system refurbishment in the suite?

III. Lighting

- u. Do people have access to the office to work after hours?
- v. How long do you allow lighting use after hours? Any policies or rules?
- w. Are any lights in the office purposefully left on all night? Which ones and why?
- x. Are any lights often accidentally left on all night?
- y. Is anyone responsible for turning all the lights off at the end of the work day? Who?
(cleaning or security staff)
- z. Are the light switches throughout the office easily accessible?
- aa. Do you use sensor switches of any kind (e.g. motion, heat)?
 - i. Where (Hallways, bathrooms)?
 - ii. How long do they stay on each time they are engaged?
 1. Is it more or less in bathrooms or hallways than in a regular working space?
 2. Does this time decrease at night?
 - iii. Is the time user adjustable?
- bb. Do you use daylight harvesting sensors?
 - i. Where?

- ii. Are they disabled at night?
- cc. Do you have any automatic timed systems outside of sensors?
 - i. When do they come on and off?
 - ii. How are the timed lights controlled after regular business hours?
- dd. How many lights does one switch or sensor control (enough for # of people, one hallway)?
- ee. Are the lights banked in regression from the windows?
- ff. Do you have desk lights?
 - i. Throughout the office or only some?
- gg. Do you try to inform the workers of the ecological effects of energy use?
 - i. If not, what might be a good way to inform them?
 - ii. If so, how are you informing them and have you seen an effect?

IV. Survey

- hh. If we provide you with a copy to approve beforehand, would you mind us distributing a survey in the office at some point?
- ii. Would you mind maybe setting up a small focus group? (explain)

V. Further Information

- jj. Are there any other people that you think we should contact (office managers)?

VI. Closing

- kk. Do you have any questions for us?

VII. Thank John/Jane Doe

Appendix B: Surveys

Appendix B.1 Survey Distributed to WPI Faculty

14. Do you use lighting in your office after hours?

- a. Yes, Always
- b. Yes, Sometimes
- c. Yes, Rarely
- d. No, Never

15. If you are using lighting after hours, how many hours do you use them for typically?

16. Are lights used after hours because of...? Select all that apply

- a. Work late
- b. Safety, deter crime
- c. Comfort, like a bright room
- d. Inconvenient to turn off
- e. Forget
- f. Other _____

17. Do you know where switches controlling your entire suite or floor are?

- a. Yes
- b. No

18. Do you check before you leave and turn off any extra lights not in use?

- a. Yes, Always
- b. Yes, Sometimes
- c. Yes, Rarely
- d. No, Never

19. In regards to Question 5 why or why not?

20. Are there often lights left on overnight with no one using them?

- a. Yes, Always
- b. Yes, Sometimes
- c. Yes, Rarely
- d. No, Never

Appendix B.2 Survey Conducted at WPI

1. Do you use lighting in your office after hours? If so, for how long?
 - a. Yes – 21 responses
 - i. Average use of lighting for 3 hours
 - b. No – 10 responses
2. Why do you use lighting in your office after hours?
 - a. Work late – 20 responses
 - b. Safety, deter crime – 4 responses
 - c. Comfort, like a bright room – 6 responses
 - d. Forget/inconvenient to turn off – 0 responses
3. Do you have/use...
 - a. Available desk lights? – 12 responses
 - b. Lighting switches for entire floors/sections? – 9 responses
 - c. Timed/ motion sensitive lights? – 6 responses
 - d. Lights that remain on all night in your office/suite? – 2 responses
4. Are you instructed to turn off your lights before you leave or to conserve energy by a supervisor?
 - a. Yes – 6 responses
 - b. No – 25 responses
5. Do the lobby lights in your building remain on all night?
 - a. Yes - 11 responses
 - b. No - 11 responses
 - c. Don't Know - 9 responses

Appendix B.3 Survey Distributed to Buildings in Study

Thank you for your time, feel free to leave comments anywhere on the survey. If this survey is being completed digitally, please e-mail it as an attachment to carbreduce@googlemail.com.

Date: _____

21. If you are using lighting after hours, how many hours a night do you use them for typically?

22. Do you use lighting in your office after hours?

- a. 7 nights a week
- b. 6 nights a week
- c. 5 nights a week
- d. 4 nights a week
- e. 3 nights a week
- f. 2 nights a week
- g. 1 night a week

23. Why do you use lighting after hours? Select all that apply, if any

- a. Work late
- b. To deter crime
- c. Comfort
- d. Inconvenient to turn off
- e. Forget
- f. Other: _____

24. How much lighting does one switch or sensor often control?

- a. Enough for 3 or less people
- b. Enough for 4 to 10 people
- c. Enough for more than 10 people
- d. Other: _____

25. Are you aware of any policies in your office concerning lighting usage?

- a. Yes
- b. No

26. If your office does have a lighting policy, is it enforced?

- a. Yes, always
- b. Yes, most of the time



- c. Yes, some of the time
- d. No

27. Are you concerned with energy conservation in general?

- a. Very Concerned
- b. Concerned
- c. Somewhat Concerned
- d. Not Concerned

28. Do you think turning lights off that are not in use is important?

- a. Very Important
- b. Important
- c. Somewhat Important
- d. Not Important

29. Do you think lighting is a significant portion of energy use in office buildings?

- a. Very Significant
- b. Significant
- c. Somewhat Significant

Only applicable if your office has non-timer or sensor controlled lighting (regular switches):

30. When leaving the office at the end of the day, do you notice lights left on with no one using them?

- a. 1 night a week
- b. 2 or 3 nights a week
- c. 4 or more nights a week
- d. No, never

31. Do you know if there are switches controlling your entire suite or floor?

- a. Yes, there are
- b. No, there are none
- c. Don't know

32. Do you know where switches controlling your entire suite or floor are?

- a. Yes
- b. No
- c. There are none/Don't know

33. Do you check before you leave and turn off any extra lights not in use?

- a. Yes, always
- b. Yes, sometimes
- c. No, never

Appendix B.4 Survey Conducted in London

1. If you are using lighting after hours, how many hours a night do you use them for typically?

Average of 3.625 hours

2. Do you use lighting in your office after hours?

- a. 7 nights a week – 0 responses
- b. 6 nights a week – 0 responses
- c. 5 nights a week – 1 response
- d. 4 nights a week – 0 responses
- e. 3 nights a week – 1 response
- f. 2 nights a week – 0 responses
- g. 1 night a week – 2 responses

3. Why do you use lighting after hours? Select all that apply, if any

- a. Work late – 3 responses
- b. To deter crime – 0 responses
- c. Comfort – 1 response
- d. Inconvenient to turn off – 0 responses
- e. Forget – 0 responses
- f. Other – 1 responses

4. How much lighting does one switch or sensor often control?

- a. Enough for 3 or less people – 0 responses
- b. Enough for 4 to 10 people – 3 responses
- c. Enough for more than 10 people – 1 response
- d. Other – 0 responses

5. Are you aware of any policies in your office concerning lighting usage?

- a. Yes – 1 response
- b. No – 3 responses

6. If your office does have a lighting policy, is it enforced?

- a. Yes, always – 0 responses
- b. Yes, most of the time – 1 response
- c. Yes, some of the time – 0 responses
- d. No – 0 responses
- e. Not applicable – 3 responses

7. Are you concerned with energy conservation in general?
 - a. Very Concerned – 1 response
 - b. Concerned – 3 responses
 - c. Somewhat Concerned – 0 responses
 - d. Not Concerned – 0 responses
8. Do you think turning lights off that are not in use is important?
 - a. Very Important – 3 responses
 - b. Important – 1 response
 - c. Somewhat Important – 0 responses
 - d. Not Important – 0 responses
9. Do you think lighting is a significant portion of energy use in office buildings?
 - a. Very Significant – 1 response
 - b. Significant – 2 responses
 - c. Somewhat Significant – 1 response

Only applicable if your office has non-timer or sensor controlled lighting (regular switches):

10. When leaving the office at the end of the day, do you notice lights left on with no one using them?
 - a. 1 night a week – 0 responses
 - b. 2 or 3 nights a week – 0 responses
 - c. 4 or more nights a week – 0 responses
 - d. No, never – 3 responses
11. Do you know if there are switches controlling your entire suite or floor?
 - a. Yes, there are – 2 responses
 - b. No, there are none – 0 responses
 - c. Don't know – 1 response
12. Do you know where switches controlling your entire suite or floor are?
 - a. Yes – 2 responses
 - b. No – 0 responses
 - c. There are none/Don't know – 1 response
13. Do you check before you leave and turn off any extra lights not in use?
 - a. Yes, always – 1 response
 - b. Yes, sometimes – 2 responses

c. No, never – 0 responses

Appendix C: Interview Notes

Appendix C.1 ID #7

Building Manager Phone Interview on May 18, 2009

- Deals with common areas only
- Lights left on for access and emergency situations – emergency lights
- Lights on a time switch (external included)
- Some tenants have motion sensors
- No master switch to knowledge
- Cleaners not responsible for turning off lights
- Tenants should know about lightings and effects on environment
- Tenants have own electric bill
- Pass surveys onto tenants themselves
 - Bring surveys to him and he'll distribute

Appendix C.2 ID #9

Office Manager Phone Interview on May 18, 2009

- Turn lights off at night – motion sensors in bathroom
- Tenant
- Anyone who leaves office last is responsible
- No master switch
- Pay own electric bill
- Try to inform employees of ecological effects of energy use
- Approved survey
- Cleaning staff required to turn off lights

Appendix C.3 ID #32

Interview with Office Manager on May 15, 2009

- Access to office after hours
 - No rules/policies
- 24 hour security and cleaners turn off lights
- 6-12 months ago installed motion and daylight system
 - Doesn't work
- Light switches are easily accessible
- Small grid size – separate banking with offices and meeting areas
- No desk lamps
- No timed sensors
- There is a sustainability policy but not functional
 - Bought power cables but use it some don't
- Windows are similar to a shop front
- E-mail out survey
- Developer is buying up most of the area
 - Will be out of building in 18 months

Appendix C.4 ID #35

Phone Interview with Building Manager

- Looks after building – building management
- Standard hours (8am – 6pm)
- Lights not purposely left on
- Security does patrols to turn off lights
- No motion sensors/timed grids
- No master switch
- Cleaning crew comes in during office hours
- Only tenant in building
- In 2 months the building will be shut down

Appendix C.5 ID #57

Interview with Building Manager

- Building built in 1910
- Access afterhours if need be
- Security turns off lights on their patrol
- Not many lights left on often
- Light switches very accessible and easy to use
- Motion sensors – putting them in
- Master switch – yes but not generally available
- Cooperation of London – control external lighting
- Keep people informed about the environment
 - Walking around observing – Methods: emails and focus groups
- Only tenant pays own electric bills

Appendix C.6 ID #58

Interview with Building Manager

- Lights could be left on but only control common areas
- Tenants responsible for everything
- External lights (timed)
- Common areas cleaned and lights turned off after cleaning crew
- No active policy to turn off lights
- If issues occur, letters are sent out
- Light survey due

Appendix C.7 ID #115, 5

Phone Interview with Building Manager

- GIA equation
- Dali lighting system – lights on can be programmed
- Have daylight harvesting, grid systems (timed), and motion sensors
- Lights on at half power until someone moves
- Building manager goes around and turns them off
- External lights are turned off automatically
- Building built with these systems in place
- Office manager controls lights
- Cleaning staff turn off remaining lights
 - Or 24hr security to turn lights off on their rounds
- Lighting in staircases and reception areas
- Tenants responsible for own electric bills

Appendix C.8 ID #42

Interview with Building Manager

- Except for stairwell and lift lobbies, everything is on a motion sensor
- 24 hour security personnel and lobby lights always on
 - Patrol every 4 hours
- PC/Monitor turned off at 7pm
- Recycling system exists

Appendix C.9 ID #8

Interview with Office Manager

- Strip lights
- 20 people
- 18 years occupancy
- Not refurbished in past 5 years
- Old building
- No access afterhours
- No lights left on accidentally
- Last person to leave turns lights off
- Switches accessible
- No motion sensor
- Switches sectioned “half and half”
- No desk lights
- No timer
- Cleaners come in afterhours
- Send out e-mails and signage to get people to be greener

Appendix C.10 ID #28

Interview with Office Manager

- Other people in building but they sublet
- Landlord – owner of lighting
- Timers and sensors used in common areas
- Security turns lights off at end of the day
- 140 people
- No refurb
- 8 years in building
- Access after hours
- No policies, a lot of people work after hours
- Common area lights always left on
- 1 switch controls from 1 office to 40 sq.ft.
- No desk lights
- Try to inform people through e-mail/viral
- Survey allowed

Appendix C.11 ID #39

Interview with Office Manager

- ~100 people
- 2.5 years occupancy
- Major refurb when moved in
- 5 Floors
- Access afterhours
- Policies
 - Into green environment
 - Motion sensors
 - Grid systems
- No lighting left on
- Accidental lights – not typically
- Light switches accessible
- Rooms divided by switches
- Some desk lights
- No timed systems
- Have security
- Inform employees – reeducating people
 - E-mail (super effective!)

Appendix C.12 ID #51

Interview with Building Managers

- Building from mid 90's
- Access afterhours
- Electric bill included in rent
- Common areas lights on
- Cleaners forget to turn off lights
- Have sensors in offices and switches for common areas
- Cleaners are responsible
- Security is here
- Switches are accessible
- 1 switch controls 3 -4 lighting banks
- Master switch – only in a fuse box
- No timed lights
- Inform tenants with posters and pro recycling
- No benefits for turning off lights

Appendix C.13 ID #58

Interview with Office Manager

- 350 people
- Occupied building for about 1 year
- New building - no refurbishment
- Access afterhours
 - Building manned 24/7
- Lights on PIR
- 7-8 PIR on each floor
- Meeting rooms controlled by PIR
- PIR – timed and motion sensor
 - 30 min timer
- No desk lights
- When janitor clean client areas, they turn switches off
- Try to inform workers – work in progress “fairly new”
- Computers off at 10pm
- AC turns off at 6:30 pm

Appendix C.14 ID #102

Interview with Building Manager

- 820 people
- 40 year occupation
- Refurb last year
- Building built in 1955
- Access afterhours
- All lights switch off after last person leaves
- Automatic lights in toilets and common areas
- 1 building has switches – the rest don't
- Individual lights on for security
- Computer room lights are left on
- Switch off light policy – last one out turns off the lights
- All switches accessible
- Only certain people have access to master switch
- Tech areas have timed switch
- Have all green policies on a report basis

Appendix C.15 ID #115

Interview with Office Manager

- ~20 people in office
- Building occupied for 2 years
- No strict policy
- No lights left on purposely
- No accidental lights left on
- Light switches accessible
- No motion/heat sensors
- 4 master switches
- No use for desk lamps
- No timed systems
- Cleaning staff turn on and off lights
- Try best to inform people – effective to a point