Using street surveys to establish Air Conditioning incidence in UK's commercial offices stock

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Abstract

The rate at which air conditioning continues to penetrate the commercial offices' market is mostly estimated based on sales data. But AC unit sales figures may not indicate which plant is new, and which is sold as replacement. Also market data provides little information on the types of buildings in which it is installed, and the activities carried out in those buildings.

Many developers, building owners and tenants believe that air conditioned spaces result in more satisfied and more productive employees, and often higher rental values. However the same effect obtained by means of mechanical ventilation or cooling could be achieved with much less energy use in buildings carefully designed or managed to maximize the use of natural ventilation and passive cooling particularly in temperate climates such as in the UK.

There is evidence that fuel costs for air conditioned buildings can be more than twice than of naturally ventilated buildings and result in twice the CO_2 emissions [*DETR, 2003*].

There is concern that an increase in the frequency of spells of hot weather will be a driving force for a steep increase in sales of Air Conditioning (AC) systems to developers, owners and tenants, to whom 'uncooled' space may well be seen as an increasingly risky commercial option.

In order to have a more robust representation of the current state of affairs regarding the penetration of Air Conditioning into commercial offices a methodology to collect data in a large number of buildings was devised and tested as part of the CaRB research project (*Carbon Reduction in Buildings, UK*). Low depth street surveys were carried out in different climatic regions of the UK and data was collected on air conditioning, built form, architectural features and other individual circumstances presented in a building that are likely to impact on the need for cooling. This paper describes in detail the methodology used and summarizes the preliminary findings resulting from analyzing the data gathered.

1 - Introduction

Modern commercial buildings represent a complex end-use system with substantial energy demands. The offices' sector presents a considerable potential for reducing energy requirements and for changing the energy supply pattern through the introduction of new technologies and therefore have been the object of many and diverse studies, and publications along the last decades [e.g. *Hitchin and Pout, 2000; Wade et al, 2003; Knight and Dunn, 2005*]. Within the commercial sector, offices are one of the most significant contributors to energy use with a share of 22% of the AC energy use in the UK. As the services sector grows and other economic sectors shrink, there has been a rapid expansion in floor space with offices [*DTLR, 2001*]. In the past, energy consumption was significantly greater in winter due to heating demand. However, the summer demand has been growing dramatically which is primarily due to the increased use of air conditioning. Energy consumption for cooling is particularly high in offices. Electricity demand for cooling is expected to increase rapidly in coming years. According to the *Building Research Establishment* [*Hitchin and Pout, 2000*], if current trends continue, energy use and the consequent carbon emissions associated with air conditioning

will increase substantially by 2020, and may quadruple 2000 levels in a “business as usual” scenario. The growth in demand for space cooling may be attributed to an increase in internal loads i.e. Higher occupancy ratios, more IT and office equipment, and lighting, or to an increase of average summer temperatures.
Also, HVAC technology is becoming cheaper for each kW of cooling provided, more flexible, sophisticated and easier to retrofit. As a result sales have grown quickly.
The wide spread use of space conditioning has nevertheless to be viewed as one of the greatest technological achievements of last century. It is well documented that people working in a thermally pleasant environment can bring substantial side benefits, namely in terms of improved health and productivity. However the technical solutions commonly adopted to provide the required levels of comfort, specifically cooling, are most often energy intensive and far from being the most energy efficient or environmentally friendly. Thermally driven chillers powered by waste heat, solar assisted cooling, passive cooling and other emerging low carbon solutions [*CADDET, 1990*] still represent a fairly low percentage of the total despite of their demonstrated potential to reduce electricity consumption drastically.

2 - Description of the methodology used for data collection

This section reports on the methodology adopted to collect building data. Most of the data was collected by visual inspection, where possible, of the accessible external parts of the building, walking around areas which contained significant numbers of commercial buildings and noting main building characteristics that could impact on energy use for space cooling and HVAC components when visible. One of the major merits of this method is that it allows a survey team to quickly and cost effectively cover large urban areas with minimal time expenditure as compared to methods that require contacting building occupants and/or observations carried out within the building.

To take into account the macroclimatic and microclimatic influences characteristic of different regions, like solar radiation and temperature, the surveys were conducted in three different locations of England: London in the South East, Leicester and Sheffield towards the North of England. The cities chosen are located in two distinct climatic regions, Leicester and Sheffield, having cooler summers when compared with London. The regional cooling degree-days for England’s Midlands and East Pennines are below 50 whilst for the Thames Valley region, it is between 50 to 100.

The first city to be surveyed was London, located in the Thames Valley region where the greatest concentration of commercial offices is found in the UK. Being in the South East of England its climate is largely influenced by the continental proximity. In London the heat island effect can add several degrees to the average regional temperatures. Summer temperatures can occasionally climb to more than 30°C. London has a population of around 8 million. A good mix of modern and old converted residential buildings was surveyed primarily in central London.

The next town to be surveyed was Leicester, located in the Midlands with a population of 280,000, although it is the main local commercial centre for around 0.6 million. In the central urban regions, several streets were surveyed, mostly in the city centre. Care was taken to ensure a mix of business areas (e.g. low cost areas, prestige city centre, financial district, etc.). Almost 100% of the premises have been photographed, such that building age, construction, and other details can be gauged from pictures at a later stage. The sample comprises mostly modern large size corporate purpose built office buildings.

Finally, Sheffield was surveyed located in the East Pennines region in the North East of England, with a population of 500,000 being further north some 50 km of Leicester. It was chosen as one of the fastest developing cities in the country. Conversely to Leicester the majority of the buildings surveyed were converted residential buildings of small size.

Type of field data collected:

The criterion for information collection was to prioritize the elements that would most heavily impact energy consumption i.e. the building envelope, its orientation, and other design parameters directly affecting the demand for heating or cooling. Fenestration deserved special attention. Modern buildings are designed to use as much of the exterior as possible for glazing. Although this vastly improves lighting conditions heat loss and gains are increased. Decreased thermal mass and increased glazing causes greater swings in internal temperatures and more energy for space conditioning is required. The following summarizes the type of data collected:

- Building geographical information and identification (i.e. location and address)
- Building type and use (i.e. principal building activity, ownership/occupancy)
- Building characteristics (i.e. orientation, percentage of fenestration area versus total wall area, operable windows and fixed glazing, type of glazing, shading devices, structure, space planning)
- Internal and external HVAC components. The internal HVAC components actually visible are ‘Cassettes’, ‘Split’ units and air diffusers. In spite the presence of air diffusers not necessarily meaning that the building has chillers installed, it should be noted that mechanical ventilation and the distribution of air is also a great contributor towards energy intensity and CO_2 emissions and can represent the largest electrical energy end-use of the HVAC system being responsible for nearly 15 to 20 % of a buildings’ energy consumption [*DETR, 2003*].

The following pictures attempt to illustrate how the data was collected:

Figure 1 - Split AC system condensing units

Figure 2 - Wet cooling tower

Figure 3 - Weather or Acoustic louvres

Figure 4 - Condensing units located below pavement level

Figure 5 - Cassette - Ceiling split unit

Figure 6 - Air diffusers

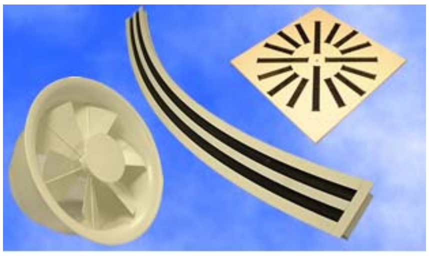


Figure 7 - Portable split

Figure 8 – Portable Units’ Exhaust pipes

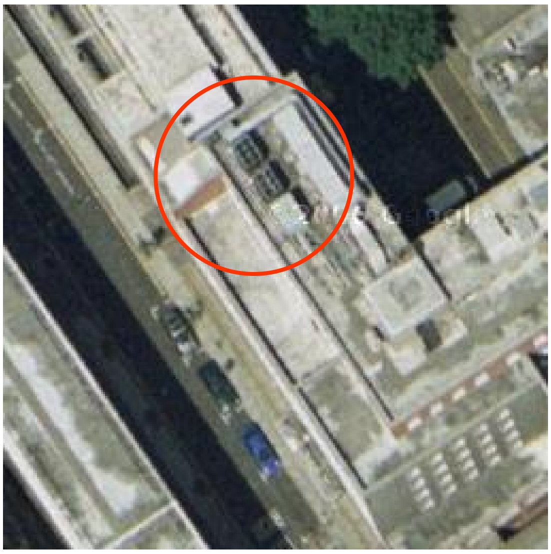
Desk based data gathering:

To complete field work some important data was also obtained from maps and from the photos taken:

- Building age - assessed from the pictures taken
- As measurements from scale plans were not possible total square meters of building floor area were obtained from ordnance maps using appropriate computer aided design software. Internal partitions like walls and space taken up by columns, projections and obstructions were not accounted in the floor area working out. Floor areas should therefore be viewed as gross internal areas i.e. total building area measured inside external walls.

- Aerial and satellite photos were used complementarily to check out installed cooling towers and other external AC components not visible from street level (e.g. Figure 9)

Figure 9 – Satellite picture of a rooftop cooling tower



The first aim of these street surveys was to estimate the incidence of air conditioned buildings in urban areas and to relate to building types, built form, architectural features and location. When possible the types of AC were identified to gauge some of the most common types being used. Priority being given to obtaining statistically useful sample sizes, it was accepted from the start that the amount of data that could be collected was limited and coarse in detail when compared with full on site surveys and that not enough information would be available to estimate cooling loads.

In a large number of cases, HVAC components are not immediately visible (e.g. if the glazing is opaque or there is internal shading) making it impossible to determine if the building has any type of mechanical cooling. To overcome this difficulty an alternative approach was adopted. As simple as it sounds, it was found that in a hot day occupiers of non air conditioned offices would generally open their windows to benefit from free cooling produced by natural ventilation. Conversely, in air conditioned offices windows are unable to be opened, or be kept closed to keep the cold in and avoid warm air infiltration.

To confirm the validity of this basic assumption a pilot study was undertaken in the summer of 2006. The sample analyzed, consisted of 129 office buildings, only including buildings either clearly identified as being air conditioned, or without any type of air conditioning visible. The percentage of open windows out of the total of openable windows was computed floor by floor. The results showed that for up to 15% of open windows, the probability of a building being cooled was found to be 95% and for over 40 % of open windows the likelihood of a building being cooled was found to be close to zero. Thus, given suitable weather conditions, the method was shown to be reliable and can be used complementarily to visual inspection of AC components.

4 – Analysis and discussion of results

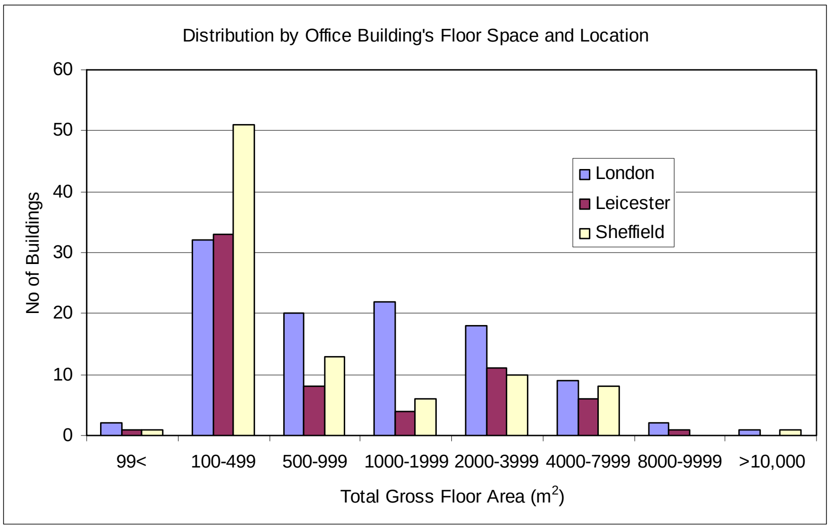
The results shown in this section are drawn from a dataset of 260 office buildings, totaling 626 floors where was possible to identify the existence and type of AC. A reduction on the originally surveyed figure was imposed for the purposes of accuracy. Table 1 summarizes the sample main characteristics.

Table 1 - Summary of Results

	London	Leicester	Sheffield
Total number of buildings inspected	106	64	90
Total floorspace corresponding (m^2)	188,239	97,881	117,773
Largest building (m^2)	10,506	9,365	12,154
Smallest building (m^2)	63	66	74
Mean area (m^2)	2987	1483	1591
Maximum number of Floors	7	13	12
Largest floor area (per single floor, m^2)	1,751	1,892.87	1,768.08

Despite the apparent large variations in office numbers the sample is fairly heterogeneous in terms of the buildings' total floor space distribution (see Figure 10).

Figure 10 – Offices' total gross floor area distribution by city



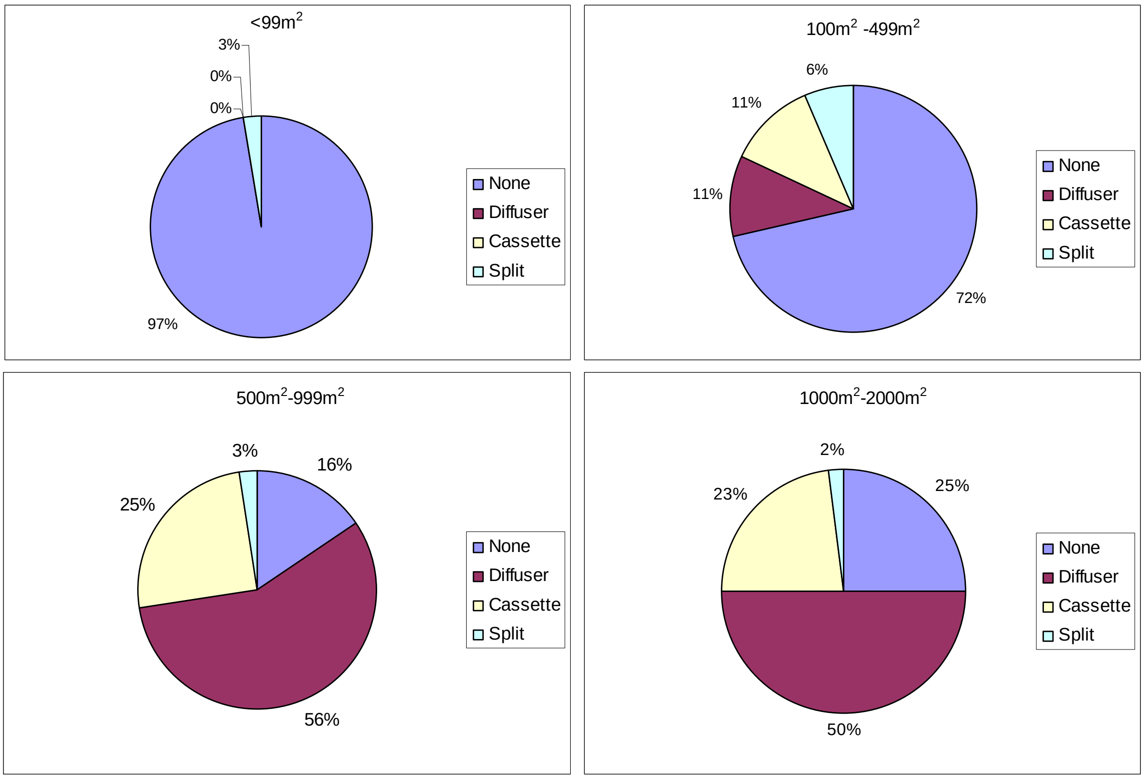
Understandably it is in the very small to small floor plate size offices, most of them being converted residential accommodation ranging from 0-99 m^2 and 100-499 m^2 respectively (Figure 11), that less AC is used. This kind of offices tends to be envelope dominated and thus their energy use is more subject to the weather. They have a relatively greater surface to volume ratio and therefore natural ventilation can provide much of the cooling load in the summer. Room units dominate in this segment although some partially centralized systems could also be seen.

Following an increase in size the predominant type of AC system starts to be the large centralized systems (Figure 11) and the number of offices where AC components could not be seen is greatly reduced.

For London, Leicester and Sheffield it was estimated that the cooled space was around 62%, 58% and 67%, respectively.

Sheffield stands out as being the city with the largest number of small office buildings surveyed (Figure 10). But on the other hand a relatively large number of medium to very large office buildings were also surveyed. This can in some way explain the similarity with London's estimated AC incidence.

Figure 11 – AC type distribution by floor plate size



5 – Conclusions and further work

Although the conclusions that may be drawn from this preliminary analysis are limited the results to date support the anecdotal observation of an increasing incidence of air conditioning in the office stock. The results point out to a much higher penetration of AC in commercial offices (About 62%) than previous work carried out at the end of 1994 pointing to an AC penetration of around 20% of floor area cooled [*Hitchin and Pout, 2000*]. These results suggest a 40% increase in AC penetration in just 14 years.

It can be speculated that these figures may even be higher since in a large proportion of the surveyed stock, around 42%, it was not possible to identify any AC components for some of the reasons discussed earlier. Additionally there are categories of HVAC systems that can only be inferred from street surveys, such as chilled ceilings or beams and induction units.

The results of the preliminary analysis demonstrate the need to diversify and expand (cover more regions, smaller locations, offices in industrial sites) the size of the survey sample so to make it more statistically representative. If performed in a hot day, street surveys allow easily identifying, floor by floor, which offices are being air conditioned. If a cross analysis with other sources is made then the conclusions will become much more robust. Street surveys can also provide the starting point for more detailed on site surveys.

The analysis of this relatively small sample analyzed has already shown its potential to estimate the growth of AC use in the last 10-15 years. It should be noted that the results of summer surveys are still not accounted in this study and also there is still plenty of analysis to be carried out e.g. relating AC incidence with buildings' characteristics.

The results of the current study also give indication that almost a quarter of the treated floor area might be cooled by direct expansion split systems commercially known as 'Cassettes' and 'Splits'. Although packaged and split systems provide a convenient way to air condition small buildings or specific areas within an office building they can also provide heating. Direct expansion air conditioners use electrically powered heaters, being responsible for higher CO_2 emissions than if a conventional high efficiency condensing boiler was used. The impact of using this technology on the carbon footprint of a building can be significant.

6 – References

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