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Shedding Light on Domestic Energy Use: a Cross-Discipline Study of Lighting Homes

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Despite the availability of compact fluorescent light (CFL) bulbs and significant efforts to drive down energy usage for domestic lighting, demand stubbornly continues to increase. To explore the underlying causes, this paper looks at lighting demand from a socio-technical perspective drawing on recent in-depth interview data. This research reveals that use of lighting relates as much to establishing a mood as clarity of vision; a desire to have stylish interiors can over-ride environmental principles, and lighting practices are heavily influenced by the presentation of household lighting in the media. It is argued that these findings demonstrate that we need new designs for lighting technologies which incorporate low energy sources with a flexible approach to lighting involving novel ways of light distribution. This paper concludes that support of the media should be enlisted to demonstrate that style does not have to be compromised for environmentally friendly lighting schemes.

Keywords: lighting, domestic, energy, demand.

INTRODUCTION

There have been numerous campaigns over the past decade to encourage householders to reduce their lighting demand. 'Switch off' campaigns encourage us to turn off lights in rooms likely to be unoccupied for more than 15 minutes. Compact fluorescent lighting (CFL) has been available as a low energy technology for over 20 years (MTP, 2006) and, with government subsidies, over 17 million CFL bulbs were distributed between 1994 and 2000 (Ofgem/EST, 2003). Yet energy demand for domestic lighting in the UK rose during the nineties by more than 10% and now contributes nearly a fifth of the total domestic electricity demand (DTI, 2002). Whilst improvements in efficiency for other appliances and energy labelling has caused a levelling off in energy demand or for some end-uses (e.g. cooling and washing appliances) a decrease, lighting demand remains stubbornly resistant to interventions (Hull, 2006).

Several studies have been carried out in the UK to understand the nature of the demand. Detailed data were collected in the mid-nineties by the Electricity Association in 100 homes which revealed that levels of lighting demand were related to occupancy, the built form of the house, the number of rooms, levels of income and lifestyle factor (EA, 1998). The DELight study was a comprehensive review of lighting across the EU and revealed a far higher energy demand for lighting in the UK than previously identified (Palmer and Boardman, 1998).

The increase in lighting demand is believed to arise because of the greater number of dwellings with lower occupancy (more homes occupied by 'singletons'), as well as a significant increase in the number of lighting appliances per household (21.6 bulbs in

1996, with a predicted 20% rise by 2020) (MTP, 2006). The latter represents a shift in lighting styles in UK homes, from a single central light fitting in the ceiling to a more continental style of multiple lower level appliances distributed around the room.

Understanding the drivers of lighting demand is not always straightforward. There are not only issues about the use patterns for lighting but also the purchase decisions surrounding both bulbs and light fixtures. Whilst there are just three major bulb manufacturers in Europe, there are thousands who provide light fittings (Palmer and Boardman, 1998). Whilst CFLs are increasingly available from many DIY outlets and supermarkets, many existing light fittings are not suitable for use with CFL bulbs and there are few new designs specifically aimed at low energy bulbs. Changes to Part L of the UK Building Regulations introduced in 2002 (revised in 2006) requires 'reasonable use of energy efficient lamps' both inside and outside of newly built homes, with at least one per $25m^2$ of floor space or one in four appliances (ODPM, 2006). Anecdotal evidence suggests that new occupants dislike the appearance of these fittings and will replace them with more stylish and less efficient designs.

Thus, in spite of extensive studies into household lighting and significant interventions to reduce demand, there seems to be something lacking. This paper seeks to address some of the missing links. Where are the holes in our understanding and what more can be done? As part of the wider study into energy demand in communities being conducted by the Carbon Reduction in Buildings (CaRB) team, the hidden factors in lighting demand are being investigated and the potential for alternative strategies examined. The CaRB studies are somewhat uncommon in combining traditional energy monitoring together with sociological research on quantitative and qualitative bases. The aim of the project is to provide a better understanding of the social factors involved in energy demand and to incorporate them into a comprehensive energy demand model, to be used by policymakers for a more successful reduction in energy use.

This paper investigates the underlying nature of lighting demand in the home. It begins by discussing the types of lighting technologies used in UK households, and the shape of lighting demand. It then presents the findings from eighteen qualitative in-depth interviews conducted during March 2006 which explored householders' lighting practices. This research reveals that use of lighting relates as much to establishing a mood as clarity of vision, and a desire to have stylish interiors can over-ride environmental principles. This is followed by a discussion of the implications, with suggested shifts in the way lighting is delivered in homes and new possibilities for energy reduction strategies. It is argued that lighting provision in homes is about far more than the obvious visual requirements.

LIGHTING DEMAND

In the late nineties, the average UK home owned nearly 22 light bulbs, of which the relative proportions of bulb type were:

21%	40W incandescent bulbs
48%	60W incandescent bulbs
20%	100W incandescent bulbs
7.4%	Fluorescent strip
3%	CFL

Halogen bulbs represented less than 0.6% of bulbs surveyed (MTP, 2006). Since the late nineties the use of halogens bulbs, LED lighting and fluorescent strips has increased and it is assumed that by 2020 over 13% of bulbs will be CFLs. Multiple

halogen spotlights have become especially popular (as discussed in the section that follows).

In homes, the bulk of the energy demand for lighting arises from interplay between the activity of the occupants and the availability of daylight. Daily profiles of lighting demand show two peaks, the height and spread of which depend on the overlap of sunrise and sunset in relation to morning and evening activities (see Figure 1). For an average of homes, the morning peak around breakfast time is always narrower and lower than the evening peak, which has a spread of between 5 to 10 hours. This is most likely because, on a weekday, the morning activity in a typical home relates to preparation for going to work and school (with a relatively small number of rooms being illuminated), whilst the evening demand relates to a much wider range of activities (e.g. food preparation and consumption or entertainment) which requires more rooms to be lit.

The daily demand profile, when averaged over a group of homes, is different for weekdays compared to those for Saturdays and Sundays. The main difference arises in the morning peak, which is broader and much reduced, mainly due to the significant diversity in the time that people wake up at weekends. The evening peak is largely similar across all days of the week. Whilst there is clearly an energy saving to be made if activity in the home is delayed until after sunrise when natural lighting is available (compare the demand levels from 07:00 to 09:00), the data indicate that demand is higher when people are active in the home, even when natural lighting is available (compare levels from 10:00 to 15:00). Such issues are likely to become increasingly important as the trend for working at home continues to gain pace.

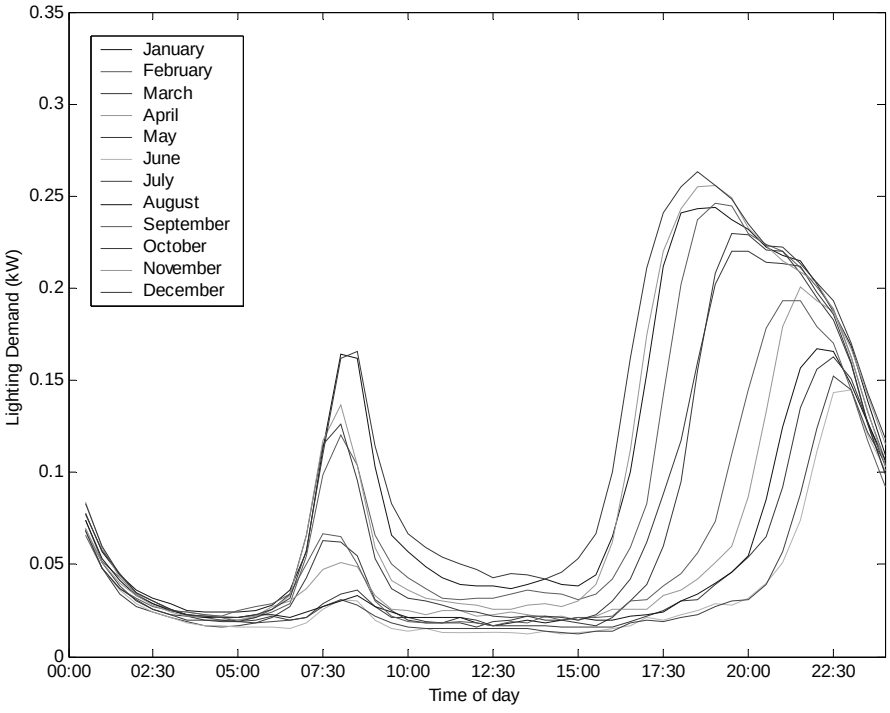

Fig. 1: Daily pattern of demand for lighting (for weekdays, monthly averages, half-hourly demand, group averaged. Based on data from the Load Research Group (LRG), Electricity Association for 1996/7).

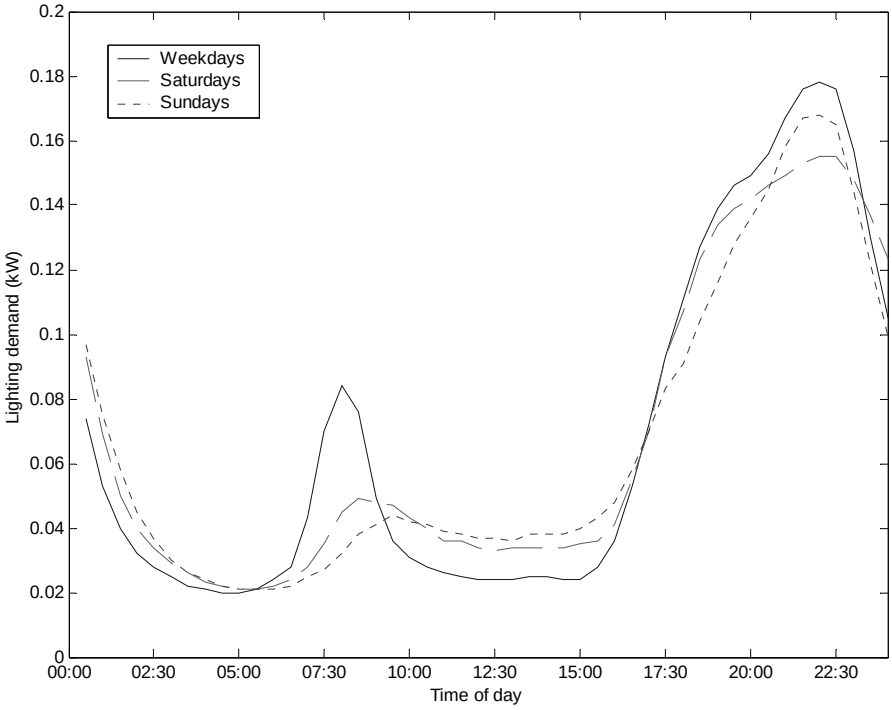

Fig. 2: Daily pattern of demand for lighting showing dependence on day type (annual averages, half-hourly demand, group averaged. Based on LRG data for 1996/7).

Lighting demand can be modelled using sinusoidal relationships with day number (Stokes, 2005), which reflects the interaction of occupant activity with sunrise and sunset times, together with a normally distributed random factor which largely represents the variation in weather from one day to the next. There are very slight sinusoidal patterns in lighting demand even at times of the night when no sunlight is available on any day of the year. This also demonstrates that to fully understand lighting demand, it is necessary to consider not only the number and types of lighting appliances but also the motivations for switching lights on and off, as well as the interaction of lighting needs and human behaviour (both the physiological effects of light on behaviour and the human need for light under different conditions). Such issues will be of particular importance if the patterns of natural lighting change as a result of climate change.

On a finer time scale and for a single house, it can be seen that lighting demand is made up of lighting demand, lasting for more than one hour, together with short bursts in demand, lasting just a few minutes (Stokes *et al.*, 2004). These latter generally arise from movement around the house, requiring rooms to be lit for less than 5 minutes. The peaks in the lighting demand can have a significant contributory effect on the overall peak demand for the electricity demand as a whole. (N.B. this study is for a single house. The distribution of duration of lighting events is likely to be very dependent on the number of occupants, the size of the house and patterns of behaviour. A more extensive survey of lighting events will be part of the wider scale data collection within the CaRB project.)

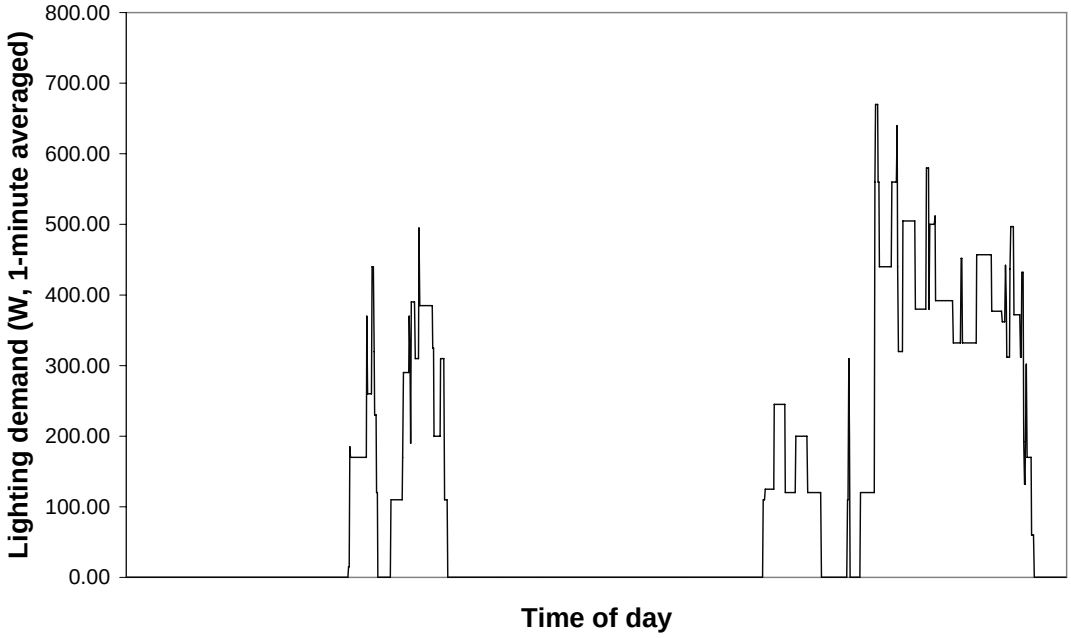

Fig. 3: Lighting demand in a single house during a single day (2nd April, 4-person household, detached house) on a 1-minute averaged basis, showing longer term and short bursts in lighting requirements.

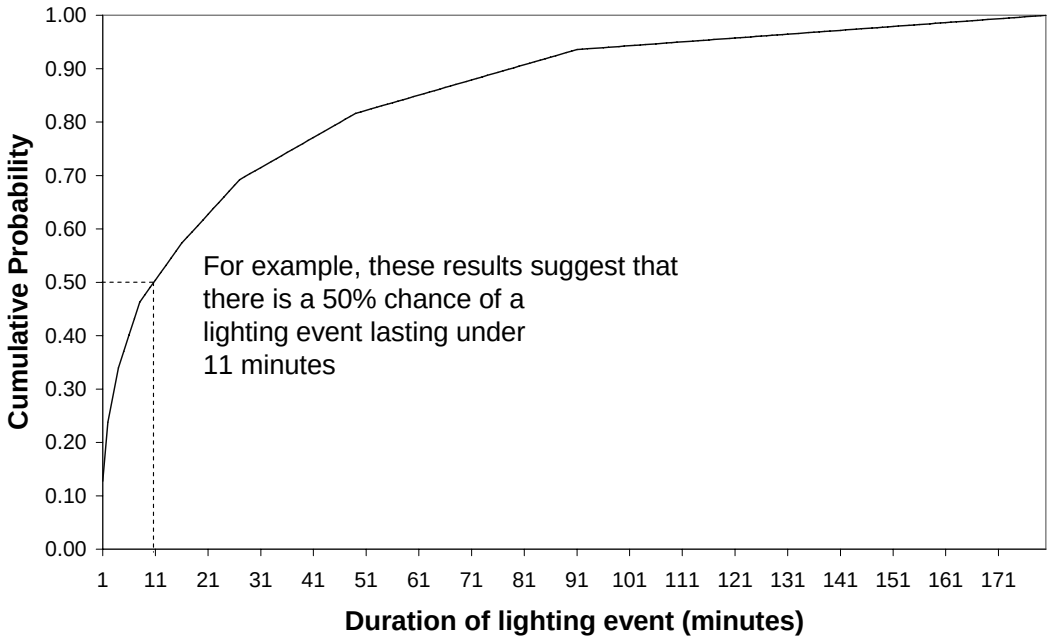

Fig. 4: Distribution of the duration of lighting events (shown as a cumulative probability) showing that 50% of lighting requirements last less than 11 minutes (based on a single home, data taken over a one week period in April).

This may have significance because these data suggest that for almost a fifth of situations when a room is lit, the requirement is for just one minute. The short delay (under one second) in a CFL achieving peak levels of illumination is therefore likely to be a more significant feature of the lighting event and even more important if the CFL is

used whilst people are moving between spaces. In certain situations (such as lighting under PIR control), the lighting response needs to be instantaneous. However, owing to the poor visual appeal of many CFL fittings or the unsuitability of many existing light fittings to CFL bulbs, low energy lighting is often relegated to rooms which are less frequently occupied; yet it is in these spaces that the lighting requirement has to be instant and functional.

LIGHTING PRACTICES

Whilst monitoring energy use in homes can tell us the 'what' and the 'how' of lighting demand and points towards some important 'human' aspects of lighting use, it cannot tell us 'why'. Why do people choose to switch lights on, even when daylight is available? Why do people choose particular lighting appliances and distribution of lighting in a room? Without an understanding of these issues we cannot know if we are we developing the right technologies and policies to reduce energy consumption (Shove and Wilhite, 1999; Guy, 2004; Chappells and Shove, 2005).

To scope some of the human factors of lighting demand, 18 respondents were interviewed to investigate how they currently light their homes, how this may differ from the ways they lit their homes in the past, what type of household lighting they aspire to in the future and why they made particular lighting choices. The interviews were designed to reveal the decisions made that influenced relatively rare behaviours (such as purchasing light fixtures and bulbs), as well as more frequent activities (such as switching lights on or adjusting brightness).

Previous studies have identified the influence of culture on the use of lighting (Wilhite *et al.*, 1996). In a comparison between lighting used in Norwegian and Japanese homes, it was identified that 'cosiness' was a significant feature in lighting the Norwegian homes whilst 'brightness' was a significant driver for Japanese householders. As a consequence, Japanese homes tended to be lit by a ceiling-mounted, central fluorescent tube, whilst Norwegian homes used more distributed lower level lighting. A survey of promotional literature of lighting in the UK reveals similarities to the Norwegian requirements for light quality:

mixing different kinds of light can create a cosy and welcoming atmosphere and encourage us to enjoy our homes more… often a combination of different types of lamps is required to create a comfortable light… move the lamps about in the room; vary them, until you find a lighting scheme that is as functional as it is cosy and relaxing (IKEA 2006).

[u]se table lamps dotted around the outside edges of the room on shelves and tables, [claiming that] [t]hey'll radiate light inwards, making the room feel spacious yet cosy (BBC 2006).

Interviewees referred to previous lighting practice in the UK which tended to use single, ceiling-mounted lighting. Comments such as, "years ago we only had one light in the middle of the room [and] now we have at least three or four in each room" and "when I was a girl we only had one light in the ceiling and maybe the odd lamp, I think we simply have more lights now" were common. When asked about multiple lighting appliances in each room, the interviewees often mentioned "flexibility", a "better atmosphere" and a desire "to create different moods". People talked about the wish to change the position of lighting as well as the level, using tracked lighting, multiple distributed lamps and dimmer switches.

"I would like to have little silver lines that you move your lights along, so that if you put a new picture up or something you can move the light to shine on it and it can create a lot of different moods without having to change your lighting".

Older people mentioned a need for brighter lighting, attributed to their increasing age.

Style was quoted by many respondents as being the main driver when selecting light fittings (and generally the required bulbs). Many of those interviewed mentioned style programmes on television and articles in magazines as being highly influential in their decision making process:

One respondent stated, "I think I would like some really nice beautiful designer fancy lamps and touch wall lighting where you touch them and they come on". When asked where she had seen the type of lighting she would like, the respondent replied "the wall touch lights I have only seen on the television, it was one of those renovation programmes where they get a designer in to do it all for them".

Some of those interviewed claimed to have a strong environmental conscience. One had spent a period of time selecting low energy kitchen appliances, recycled waste, switched off unnecessary lighting and appliances on standby but was in the process of choosing halogen lighting for a room undergoing restyling. When questioned on the issue she said, "I was fully aware when I bought them that halogen lights are not really environmentally friendly or ecologically sound, it was a specific style choice". In other parts of the house the respondent had replaced incandescent lighting with CFLs. The prime factor in her choice of halogens was "my partner designs bathrooms and kitchens to be honest when I have gone to see finished jobs the right lighting is the finishing touch".

Another respondent was considering a significant capital outlay on renewable technologies for her second home. When asked why she had used inefficient multiple lighting for her kitchen, she replied, "I know they use a lot of energy, but I need bright light now I am getting older and I like they way they look, they give a good effect".

It was clear from these interviews that lighting is used not only to be able to see when natural lighting is unavailable or dim, but also to adjust mood. Whilst respondents showed a strong willingness to adopt new lighting technologies (currently, multiple halogen down-lighters or LEDs), they were far more swayed by style, as dictated by magazines and TV than by environmental issues, even though some respondents had made the link between climate change and energy use. The challenge to reduce energy consumption therefore becomes a far more complex set of problems.

DISCUSSION

If energy demand for lighting is to be reduced, designers of homes must take account of user needs. Lighting is being used by occupants partially to allow them to see when natural daylight is not available, but more importantly to vary the mood of a room.

With respect to the more obvious function of lighting - to provide light when natural lighting is not available or dim - in many spaces that relate to transitions (hallways, exterior, stairways, etc.) there is a need for instant lighting which low energy CFL bulbs do not deliver. Alternatively for rooms which are frequently occupied, lighting is being used to change the mood of the living space. Levels of illumination and the distribution of lighting are important to consumers, who have a strong desire to have the facility to vary both. Lighting is used to influence mood and the concept of 'cosiness' is clearly a feature of UK culture with respect to lighting demand.

The effect of light on human physiology is an important aspect of lighting demand. Most research in this area relates to the effect of light on the circadian pacemaker, a chemical process which maintains synchronicity with the variable hours of natural daylight. A study into the effects of short bursts of artificial light in the evenings suggested that relatively small changes in light exposure during the late evening can affect several physiological cycles that influence the human pacemaker (Zeitzer *et al.*, 2000). Transitions from dim to bright light in the early morning can offset the effects of sleep deprivation (Leproult *et al.*, 2001). Clearly lighting is regarded as having influence on how people feel and thus to reduce lighting energy demand it is critical that designers of homes understand the associated physiological influences.

The CaRB project is ongoing and aims to explore in more detail the human side of energy use. In terms of lighting, it is clear that the technology of low energy lighting fails to provide people with the kind of control and illumination that is required. Low energy lighting shows a poor response to demand and tends to be ugly. Consumers want greater control over switching, distribution and levels of illuminance. Until new technologies address these needs together with energy efficiency, consumers will continue to be persuaded by style over energy efficiency. If low energy lighting has to be provided in an 'unstylish' way then home designers should concentrate on ways in which light is distributed. As with heat distribution, it is suggested that light sources could be practical rather than stylish. The emphasis then shifts to the distribution process. Light pipes could transfer natural light to rooms when daylight is available or artificial light can be provided centrally as an alternative, using highly efficient but unattractive light sources. Consumers could be provided with a far more flexible way of controlling lighting with more extensive use of distributed lighting, possibly using light pipes or fibre optics rather than discrete light sources.

CONCLUSION

This study has shown that simple monitoring of energy data without understanding the deeper human requirements of energy use tends to miss some of the essential requirements of energy delivery. Significant efforts to reduce lighting energy demand have not entirely established the reasons why demand continues to rise even though CFL bulbs use less energy and have an extended lifetime. The initial study of domestic lighting for the CaRB project has revealed that lighting is intrinsically linked to mood and well-being, and such factors need to be considered when designing low energy systems in homes. It is suggested that the emphasis in home design should shift to systems with a low energy supply and a more flexible method of distribution. The support of the media should be enlisted to demonstrate that style does not have to be compromised in environmentally friendly lighting schemes. The CaRB project continues to explore both the human/technology interface of lighting behaviours.

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