Promoting Energy-Efficient Lighting: The Need For Parallel Processing

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ABSTRACT

Energy-efficient lighting is a noble cause. Electric lighting is essential for modern life but for many reasons – economic, environmental and ecological - it is desirable to minimize the energy consumed. Attempts to promote energy-efficient lighting have concentrated on new lighting technology and the regulatory and marketing activities necessary to get the technology into use. While the development of energy-efficient technology is valuable; alone, it is not sufficient to change lighting practice. This address provides an overview of the factors which need to be considered if behavior conducive to minimizing energy consumption is to be stimulated. In doing so, it suggests a number of activities which, so far, have been neglected in the quest for energy-efficient lighting.

ENERGY-EFFICIENT LIGHTING: THE BIG PICTURE

Life without electric lighting is inconceivable to a modern society. As the wealth in an economy increases, as the population grows and as the twenty-four hour society becomes more widespread, the use of electric light sources tends to increase. Yet generating electricity involves the consumption of natural resources, the production of materials which cause atmospheric pollution and the investment of considerable economic resources. These effects are sufficient to justify an interest in ensuring that when lighting is provided, it is provided with minimum energy consumption. Unfortunately, it is also true that for many people the energy consumption of lighting is a remote irrelevancy. Lighting is not provided in order to consume energy, it is provided in order for people to enjoy life and be productive. It is only after the lighting allows people to see what they want to see, when they want to see it and how they want to see it that the energy consumption will be considered. It is this conflict of priorities between the immediate and essential function of lighting and its distant and ancillary environmental and ecological costs that make the effective promotion of energy-efficient lighting so difficult.

While increasing the use of energy-efficient lighting is difficult, it is not impossible, and it is certainly made easier if there is an understanding of the factors which influence the behavior of people faced with choices about lighting. The purpose of this address is to present a conceptual framework of the relationships between these factors and to use this framework to explain (1) why attempts to promote energy-efficient lighting will have limited success unless all these factors are considered, and (2) where there are neglected opportunities to promote energy-efficient lighting.

A CONCEPTUAL FRAMEWORK

The ultimate aim of any program of energy-efficient lighting is to minimize the electric energy consumed by lighting. For this to occur, different people involved with the lighting have to behave in specific ways. For a start, whomever is responsible for specifying the lighting must purchase energy-efficient equipment. Whomever is responsible for the budget has to avoid the temptations of inefficient substitutes. Finally, the occupants of the space must use the lighting in an appropriate manner. Figure 1 shows the factors which influence these behaviors.

The factors can be conveniently classified under five headings: technology, economy, values, perceptions and expectations. Technology refers to the availability of

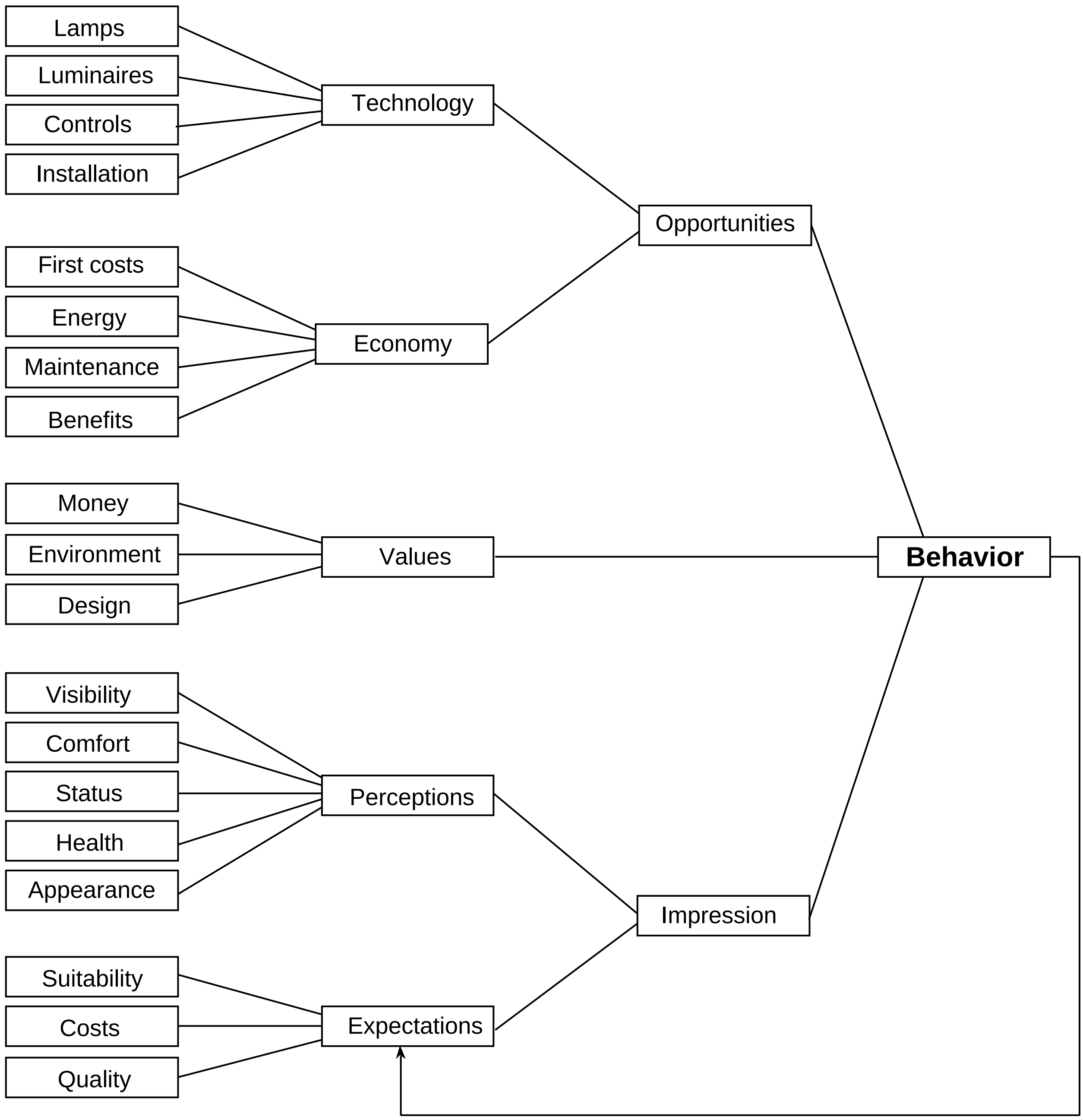

Figure 1. The Path to Energy Efficient Lighting Behavior

lamps, luminaires, control systems and installation types which can be used to reduce the energy consumption of lighting systems relative to conventional practice. Without improved technology in terms of light sources with higher luminous efficacy, luminaires with greater light output ratios and control systems which allow for dimming, there would be little point in pursuing the goal of energy-efficient lighting because there would be little opportunity to do anything about it, other than by reducing or eliminating lighting. However, the lighting industry has been nothing if not inventive. Today, there are a wide range of light sources, luminaires and control systems available which can be installed in ways which can be expected to reduce energy consumption.

Economy refers to the facts that there are several different ways to consider the cost of a lighting installation, and how the costs are considered will influence the behavior. The cost of a lighting installation can be measured as first cost and operational cost, divided into energy cost and maintenance cost. In many cases, these different costs are paid from different budgets and often by different entities, not necessarily the user. Any energy-efficient lighting technology which lowers first cost and energy cost will find a ready market. Even if first cost is increased, provided the additional cost can be recovered in a reasonable time, there is still a clear demand. This demand is strengthened if there are value-added benefits for the business such as increased sales or greater productivity.

People differ in the multi-dimensional social values which influence their behavior. Some consider everything in terms of money. They will always try to maximize the return on investment. Some are committed environmentalists who will pursue energy-efficient lighting regardless of cost. Others are very conscious of design and wish to be surrounded by things of beauty at all costs. Most people tend to cluster in the middle and balance these values by being willing to try energy-efficient lighting if it does not cost too much and provides reasonable lighting.

Perceptions is a group of factors which relate to how lighting is psychologically evaluated. The level of visibility and visual comfort provided by the lighting are obviously important factors and can often be ensured by following the recommendations of professional lighting organizations. Less obvious but no less real are the factors of status, health and appearance. Status is really a matter of what message the buyer or user of the lighting considers the lighting is communicating about themselves or how they are perceived by others. As for health, light sources other than daylight, but particularly discharge lamps such as fluorescent lamps, have always been considered somewhat unnatural and consequently unhealthy by some (Stone, 1992). Finally, the way in which a lighting installation can enhance the appearance of a space is important. Unless a lighting installation is perceived to be conducive to health and of an appropriate appearance and status, it is unlikely to be accepted, no matter how energy efficient it is.

Expectations are the assumptions the buyer or user of the lighting has about what constitutes good lighting for any specific application. People can have expectations about the suitability of the lighting installation for the application, what is a reasonable cost and what level of lighting quality will be achieved. Expectations are based on past experiences of what works and what does not and of what is used in similar applications and what is not. Different cultures have different expectations about lighting and expectations can change over time, even within cultures.

The technology and economy factors combine together to represent opportunity – an opportunity to use energy-efficient lighting. The perceptions and expectations factors combine to form an impression of the lighting; basically whether such lighting is good or bad. The weight different individuals give to these opportunities and impressions will be influenced by the values of that individual, but, usually, unless the impression is good, the opportunity will be wasted.

SOME EXPLANATIONS OF RECENT HISTORY

The value of this conceptual framework can be shown by relative success of attempts to introduce compact fluorescent lamps into the commercial and residential markets. There can be little doubt that over the last decade, the compact fluorescent lamp has become more and more widely used in commercial buildings. This success is to be expected given the fit between the applications for compact fluorescent lamps in commercial buildings and the factors listed in the conceptual framework. First, compact fluorescent lamps are an energy-efficient alternative to the tungsten and tungsten halogen lamp so the opportunity is there. Second, the people who make the decisions about the lighting to be used always consider the financial savings which might be made.

Third, the applications are well developed so that the levels of visibility and visual comfort achieved with compact fluorescents are acceptable. Fourth, the occupants of these commercial buildings expect to see fluorescent lighting.

The situation in residential buildings is rather different. The economic benefits of compact fluorescent lighting are still there but the people who make the decision about the purchase usually give more emphasis to design values rather than money values . Further, there is an almost negative expectation that fluorescent lighting be used in the home; fluorescent lighting is for work not for the home. Unfortunately, the efforts to promote the compact fluorescent in the home have been almost entirely focused on the technology and economy factors. Advertising consistently emphasizes how much money can be saved, eventually. There is virtually no mention of whether the compact fluorescent lamps can provide attractive lighting for homes, although some studies have shown that they can (Koltai and Leslie, 1995). Beckstead and Boyce (1992) used a sophisticated statistical model to show that, in up-state New York at least, people readily accepted the economic benefits of compact fluorescent lamps but were very doubtful about the health and quality aspects of the resulting lighting. Until these values, perceptions and expectations issues are addressed, promoting compact fluorescent lamps into the residential market will be an uphill struggle.

By comparison, the advance of the tungsten-halogen torchiere in the residential market has been spectacular. Millions of these cheap, indirect lighting luminaires fitted with 300 W or 500 W tungsten halogen lamps have been sold in the US, often to young people living in rented accommodation. Indeed, it is sobering to consider that this luminaire alone may have offset all the energy saving made by the use of compact fluorescent lamps rather than conventional incandescent lamps. The question is, why has this type of luminaire been so successful? It is hardly energy efficient, producing more heat than light, but it is extraordinarily inexpensive (around $20US at many discount stores). For many buyers, the fact that it consumes a lot of electricity is unknown or irrelevant. They do not pay for electricity directly, rather it is included in the rent. It is this aspect, along with questions of safety, that has prompted a number of universities in the US to ban these torchieres from their campuses and properties. As for the perception and expectation factors, the torchieres are considered modern. The light output can be adjusted to a high level for detailed work, yet dimmed down for a romantic interlude. The light they produce is very similar to the ordinary incandescent lamp. The light output is instantly available and is provided without glare. Overall, the torchieres give an attractive impression at very little cost.

I suggest that anyone who has honestly assessed the characteristics of compact fluorescent lamps and the tungsten halogen torchieres, and the way they have been promoted, against the conceptual framework, could have predicted the relative success of the two in the residential marketplace.

THE FUTURE

Given that the conceptual framework can be used to explain the past (and hindsight is always perfect), what can it suggest about the future for energy efficient lighting?

First, it suggests that a revision of priorities for those who seek to increase the use of energy efficient lighting. In practice, meeting users' expectations at a reasonable first cost is the first priority for any lighting specifier and minimizing energy consumption is a remote second. Unless this order of priorities is followed, market penetration of energy-efficient products will be limited to those who strongly value the environment but will not extend further. As an example of where these priorities were reversed, consider the early attempts to introduce compact fluorescent lamps to homeowners, by giving away screw-base fluorescents of large size and weight, which did not fit many luminaires. This attempt had two unfortunate effects. It failed to generate a self-sustaining pattern of use of compact fluorescents and it established negative expectations about compact fluorescent lighting for many homeowners. As a result, the much more sensitive approach through dedicated residential luminaires now has to overcome this barrier of negative expectations as well as those of first cost.

Second, the framework implies that education to set expectations should be an important element of any program designed to promote energy-efficient lighting. Again, the compact fluorescent lamp provides a good example of where education is needed. Based on experience, a shopper knows that one incandescent lamp is much like another; a higher wattage means more light but it will have the same spectrum. The same shopper probably has the same expectation about compact fluorescents until experience tells them that what look like identical lamps when not lit may have different lamp spectra, may start in different ways and may or may not be dimmable. Education of the user on all the characteristics of different light sources should be an essential part of any program seeking to promote new light sources for energy-efficient lighting.

Third , it is worth noting that expectations are based on past experience and are used to predict the future. As an example of this, consider the use of window blinds in large commercial buildings. No doubt you are all familiar with the sight of many windows on the sides of a building receiving the sun having blinds permanently down. This phenomenon can be explained by the fact that people undoubtedly perceive daylight to be the ideal light source (Markus, 1967), but are not so keen on sunlight if it produces thermal and visual discomfort (Langdon, 1966). If people sitting near the window have an expectation that thermal or visual discomfort will occur regularly every day and the electric lighting is adequate, they will leave the blinds down, unless they have strong values about the environment or a strong desire for daylight. Observation of windows where the blinds are lowered for years suggest that many people do not have such values or desires. Rather they show inertia, a phenomenon also shown in the way people tend to use manual switches in daylit space; namely they tend to switch the lighting on when entering the room, unless the natural light is adequate, and leave it on all day until they leave, no matter how the availability of daylight changes (Crisp, 1978). This observation suggests that technology could be developed which uses this inertia to minimize the energy consumption of lighting, by following the principle of manual on - automatic off. In other words, by automatically turning the lighting off when there is no need for lighting because there is sufficient daylight and relying on human inertia to turn the lighting on only when daylight fails. Occupancy sensors using the principle of manual on-automatic off are available. It would be very simple to apply the same approach to daylighting by developing an automatic window blind which would withdraw at dawn each day and require the user to pull it down to exclude the sun. Alternatively, a simple time switch which turned the electric lighting off at a time when there was usually plenty of daylight in the space, would use human inertia to advantage (Boyce, 1980).

Fourth, the conceptual framework suggests an approach to producing energy-efficient lighting other than through more energy-efficient technology. That is through changing expectations. Knowledge of how lighting conditions affect visual performance has shown that the visual system is capable of working over a wide range of lighting conditions with little change in visual performance (Rea and Ouellette, 1991). This implies that lighting standards, and particularly the recommended illuminances which are so widely used to determine how much light is installed, can be adjusted over a wide range with little impact on visual performance and visual comfort. This conclusion is supported by the work of Boyce and Eklund (1996) who showed that an office uniformly lit to 530 lx at a power density of 11 W/m^2, was considered as good as a uniform 1050 lx installation at a power density of 25 W/m^2. Further, it implies that recommended illuminances are matters of consensus rather than physics (Boyce 1995). Matters of consensus can be changed, and have been. Since the early 1970's the illuminances used in commercial buildings in the USA have halved, from around 1000 lx in the 1970's to 500 lx today - and this has happened without complaint. Two facts have contributed to this change. One was the decision of the Illuminating Engineering Society of North America to change the basis of its illuminance recommendations to specific visual tasks rather than general lighting applications, so there was no longer an illuminance recommendation for offices but there were recommendations for reading different print sizes. This allowed specifiers and designers much more freedom to set illuminances without having to challenge the recommendations of the authoritative lighting body. The other was the rapid introduction of computer technology into the workplace. This had two effects. With a self-luminous display, such as computer monitor, the display is more visible in less light rather than more (Lloyd et al, 1996), and the use of laser and other printers has improved the quality of many office documents; the day of the fifth-carbon copy has gone. Together these changes mean that the illuminance can be reduced without significantly affecting the visibility of printed material and yet significantly improving the visibility of self-luminous displays. In other words, for office lighting in the 90's, less light is better lighting.

This is a rather special case but it does demonstrate that expectations can be changed. As long as change is to be voluntary, the first step is to challenge the simple belief that more light is always better lighting and then to promote the more sophisticated message that lighting correctly tailored to the application is better lighting. The emphasis in this promotion should be put on better lighting, the fact that it can also be energy efficient is incidental. For such an approach to succeed, it will be necessary to use an array of persuasive methods, from the power of advertising to shape image to evaluated demonstrations to convince the lighting "priests". Probably the most important single step is to revise current national and international lighting recommendations to de-emphasize the place of illuminance as the dominant, and sometimes the only, lighting criterion considered for an application. Specifiers use these recommendations for reassurance and to provide a defense in case of complaints. So as long as illuminance recommendations are presented without equal emphasis of other quality aspects, it is unlikely that much will change.

Of course, there is always the possibility of using legislation to eliminate energy-inefficient products. This approach has been used in the US to eliminate some types of fluorescent ballasts and some forms of fluorescent lamp. It should only be used where there are suitable energy-efficient alternatives. Such an approach can be considered to represent societal values rather than individual values and can certainly be effective in changing expectations.

Finally, it should be appreciated that changing expectations has the potential to reduce the energy consumption by lighting in both developed and transition economies. Both have the means to attempt to manipulate expectations, but only the developed economies have access to and effective use for all the technological options. This does not mean that transition economies should ignore the problems of promoting energy-efficient lighting. Unless attempts are made to steer expectations away from the belief that more light is better lighting, transition economies are doomed to repeat the mistakes of the developed economies. Changing expectations to desire more sophisticated lighting solutions, but ones which are appropriate to the culture and architecture, should be good for minimizing the consumption of energy resources and might be effective in enhancing a cultural identity.

SO WHAT OF THE FUTURE

This address has two core messages.

The first is that we can do better. By recognizing the relevance of all the factors which influence peoples' decisions about lighting and by ensuring that each proposed energy-efficient solution meets all the requirements we are more likely to be successful in promoting energy-efficient lighting .

The second is that we need to be more sophisticated in our approach to promoting energy-efficient lighting, using all the means open to us to change behavior. Simple reliance on the virtue of using energy efficiently is not enough, even if accompanied by a distant economic benefit. We need to put lighting quality first and make energy-efficiency part of lighting quality. By putting lighting first, we are addressing the essential reason why people use lighting. This is likely to be much more effective in the long term. ●

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