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Energy Saving Developments in Lighting

Kevin Kelly

Recent developments in artificial lighting design, lamp technology and control options provide potential for significant energy savings going forward. Historically, equal illuminance across the whole *working plane* was the goal of lighting designers, however this is now considered wasteful of energy. For example, in an office setting the working plane was interpreted as the whole plan area of the room at desk height; 300 to 500 lux was specified, depending on whether work was mainly PC based or paper based. This resulted in arrays of lights that provided high levels of lighting throughout the space, whether needed or not, and often for periods extending beyond the working day, as evidenced in large cities where empty office blocks had lights switched on well into night hours. This criterion of near equal illuminance across a working plane also tended to lead to rather boring and monotonous interiors. Today such energy inefficiency is unacceptable. LED lamp development also provides potential for energy savings as these lamps replace less efficient lamps.

New recommendations, such as those specified in the SLL Code for Lighting 2012,[8] offer pragmatic design advice to ensure adequate and efficient lighting while maintaining balance in financial outlay (purchase, energy cost, and end-of-life disposal) and environmental impact (electricity load, chemical pollution, and light pollution at night). The code is based on quantitative recommendations that meet minimum lighting requirements but also acknowledges that there is a need to target lighting more carefully and address quality issues. For example, modelling of people in offices to ensure good visual interaction becomes important and good quality lighting and energy efficiency are now as important as quantitative specifications about light levels.

Good quality and efficient lighting in buildings starts with the need to maximize daylight penetration. Maximizing daylight offers opportunities to lift the spirit with natural light and so daylight must be carefully designed into a building in tandem with the artificial electric lighting and controls to create good quality efficient lighting in the space. Human beings have a preference for natural light over artificial light and side lit interiors often automatically offer good modelling by providing a strong cross vector of light. This means that people can see other people more easily as light falls on their faces from the side windows. More recently, the need to maximize daylight is also driven by the necessity to reduce energy used by electric lighting. Maximizing daylight and minimizing energy used by electric lighting must take place in a way which minimizes overall energy consumption in the building. It is counterproductive to maximize daylight in order to reduce light energy consumption if thermal energy requirements increase due to the need for extra heating or cooling. It should be noted that extra glazing will increase heating load in winter and cooling load in summer, whilst electric lighting can also contribute significantly to building cooling load requirements. A balance needs to be sought with building type, method of construction, orientation, and occupation, usage and location.

Daylight availability charts can be used to conclude that there is an external illuminance of in excess of 10,000 lux for seventy percent of the office working day in London.[9] This suggests that a room with a five percent daylight factor would have an average illuminance of 500 lux minimum for seventy percent of the working day. The artificial lighting in a space with this level of daylight might be turned off or at least dimmed without any significant disadvantage to work efficiency in such an area. A room with this level of daylight factor (above five percent) would merit consideration of daylight detection. This should be incorporated into an automatic control system. Experience to date indicates that without such an automatic control system, the potential energy saving benefit of daylight is unlikely to be fully realized. Ensuring user satisfaction throughout the working day would require integration of the lighting control system in an acceptable way to ensure lights are on when needed and off or dimmed at appropriate times. It is important that clients and facilities managers are adequately briefed about the operation of the automatic control system, in order to ensure optimal operation while realizing effective energy savings.

While standards, demands, and design methodologies change, major change is also underway in lamp technology. It is notable that the development of solid state lamp technology is revolutionizing the lighting industry. As with many revolutionary step changes in development and use of new technologies, there has been collateral damage to early adaptors of poor-quality light emitting diode (LED) lamps. However, the pace of growth of this technology is exponential and it is still at an early stage in development. In a study by Philips Lighting it is estimated that while only six percent of lighting was solid state in 2010, seventy-five percent of lighting is expected to be LED lighting by 2020.[10] At present the biggest applications of LED lighting are for stage, external lighting, architectural lighting, retail, cold rooms, transport, and hospitality. Going forward, LED lamp technology is expected to impact office and general interior lighting, but what is the current status? Exaggerated performance of LEDs by some newly emerging companies has resulted in disappointment among clients who have expressed growing skepticism. Lighting designers complain that there are not sufficient and reliable specifications underpinning LEDs, which places risk on the designers who specify them and the contractors who install them. Lighting manufacturers respond that the technology is evolving at such a fast rate that it is pointless to create specifications that are out of date as soon as they are printed. They also point out that it is impossible to reliably guarantee and measure lamp life-cycle; LED lamps should typically last in excess of eleven years (up to 100,000 hours) of constant use. At present, measurements are recorded over a time period of 9000 hours and life expectancy results are based not on lamp failure but on an accepted minimum level of lux depreciation, with data extrapolated for longer periods of time.

Present development of LED technology suggests that the efficacy of these lamps is soon to surpass even the most efficient fluorescent lamps; in the near future it is also likely to surpass the monochromatic Low Pressure Sodium (SOX) lamp used on motorways and in similar applications. McKinsey estimates that global revenue for LED lighting will be €65 billion by 2020 and LED usage will be over sixty percent of the entire market.[11] This is consistent with similar forecasts by Philips above. It is proposed there will be a focus shift from lamp replacement to fixture replacement. With fluorescent lamps, the luminaire is likely to last for a couple of decades and lamps will be replaced very cheaply every couple of years. LEDS on the other hand come hand in hand with the luminaire and if one needs replacing, usually the other does also. This raises questions about life cycle and replacement cost considerations. When replacing the whole luminaire, it is unlikely the same unit will still be manufactured due to the rapid developments in this area. This will mean that all luminaires in a space must be replaced once lamps begin to fail or their output drops markedly. The question must also be raised as to why one would replace a highly efficient fluorescent luminaire, whose lamps are providing in excess of 100 lumens per watt, with a much more expensive LED luminaire with lamps of a similar efficacy, especially when they are so expensive to buy at present. Interior lighting relies on inter reflected lighting to create an acceptable visual ambiance. Considerable light falls on walls and ceilings through reflection. However, some direct application of light onto an object or surface can create a more visually appealing and stimulating environment. At present it is this directional light characteristic of LEDs, providing color variation and visual stimuli, which provides great potential for indoor use. However, as previously mentioned, poor quality, relatively cheap LED lamps have fallen short of expectations to date. Poor heat dissipation has also been a limitation. Low-cost, modern T5 fluorescent lamps provide 100 lumens per watt, with very good color rendering and a variety of color temperatures. The long history and successful application of these fluorescent luminaire lamps enables them to retain the pole position for the general interior lighting market at present.

The cooler color temperature of many LED lamps is deemed unacceptable by many home owners and other users. The generally more appealing warmer color LEDs are available but are usually much more expensive. The present high cost of good quality LED lamps and luminaires along with the above may delay their widespread use for interior lighting. LEDs may be the future for interior lighting but they are not yet the optimal choice. However, owing to their directional accuracy, LEDs may be more suitable for many applications including outdoor use. There is a lack of reliable research in this area at present, and this needs to be addressed going forward. LEDs may also form a useful alternative to traditional lighting in future indoor applications particularly as the tendency to flood light onto a general working plane is replaced by more individual targeting of light on a specific set of task areas.

> This is an exciting and challenging time for the lighting industry with good potential for LED lighting and improved lighting controls generally. The challenge is to provide robust solutions that will maximize the benefits of new technologies whilst protecting clients from poor quality products and installations. A further goal will be to maximize light quality and minimize energy use by integrating daylight with appropriate artificial light in a way that lifts the spirit of those using the space with easy facilitation to operate and override automatic lighting controls when required. Product reliability and integrated standards will be required in order to leverage the benefits of new technologies and in so doing help reduce energy use, improve upon energy efficiency, and contribute to reduction of greenhouse gas emissions.

resulting variation from structure to structure limits one-size-fits-all solutions. In addition, the selection of one technology can impact the performance or specification of a completely separate part of a whole-building retrofit strategy. An example of this phenomenon is the influence of the level of insulation on the design and performance of mechanical heating and cooling systems. Increasing the insulation level reduces the required capacity of a building's heating, ventilation and air conditioning (HVAC) system. Installing an oversized HVAC system can negatively impact the system's efficiency, equipment life and occupant comfort. The timing or staging of installation can introduce additional complexities and potentially lead to inefficient choices. Failing to increase insulation levels at the same time the HVAC equipment is replaced results in equipment that does not match the actual heating and cooling needs of the building. The best retrofit technology upgrade strategies seek to implement all possible technologies on a whole-building basis.

Goals and expectations of owners, occupants, policy makers and taxpayers, who may subsidize or incentivize retrofit activity, can vary. What level of occupant comfort is expected? To what degree are energy use, CO_2 emissions, and property value important? Are project costs justified by cash flow, payback period, investment return or carbon reduction goals? How are the interests of those who own a rented building, and presumably pay for the retrofit, cost balanced with the interests of occupants who will benefit from the reduced cost of energy used? The answer to each of these questions is probably different depending on which stakeholder group is questioned. Some useful guidance for policy makers in examining the cost vs. benefit impacts on various stakeholders in building energy efficiency programs is provided by the US Environmental Protection Agency, which offers five principal approaches to guide public utility commissions, city councils, and utilities. They are careful to state that "there is no single best test for evaluating the cost-effectiveness of energy efficiency." If a single cost-effectiveness measure is used it may not balance the costs and benefits of all stakeholders.[12]

In addition to payback or cost vs. benefit considerations, the source of funds can influence retrofit decisions. Grants to promote energy conservation typically require some form of decision oversight by the funding agency in order to maintain