Lighting and the environment:

A personal view of environmental considerations in lighting design.

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Artificial Lighting is a key part of our daily life, a key component of our environment that has in the last century and a half extended our living time from between dawn and dusk to a potential 24 hours in every day. It has also permitted the construction of increasingly dense work places, no longer governed by the requirement for large areas of glazing to bring daylight to the work place. The proliferation of artificial light has brought with it an increasing use of energy primarily in the delivery of light and secondarily in the requirement to remove heat, the end product and waste of artificially created light.

The last 30 years or so have seen increasing concern over humanity's apparent profligate use of non renewable energy sources and the secondary problem of the generation of green house gasses in the conversion of these non renewable resources to usable energy. As with other now seemingly essential uses of energy Lighting has been targeted as an area where potential reductions in energy use can be achieved. How do we resolve the question of whether we should have primary regard in our work for the Environment in a global sense or the environment in the sense of the space inhabited by the people for who we are designing?

This is of course not a straight forward question with a simple answer. It is unfortunate that issues of energy use are easily demonstrated in a numerical model, which is neither available or desirable for the total impact of a lit environment on the Global Environment or for that matter on a human user. Considering the easily quantified quest for energy efficiency has lead to manufacturers continuing quest for measurably more light output per watt of electricity consumed. This has resulted in a failure to develop the quality of colour appearance and rendition in fluorescent lamps. Almost all new lamps are being supplied in colour 80 series phosphors, this goes for the plethora of new shapes of compact fluorescent lamp and more worryingly for the new technology induction lamps. Potential for qualitative gain in colour rendition and appearance through the use of higher colour quality phosphors in the 90 series for example, which are less efficient in total light output, has been sacrificed in favour of an apparent quantitative gain in energy efficiency. In discharge lamps there is a similar pattern of accepting colour rendering indices in the 80s as acceptable high quality

Unfortunately some of the promised gains in energy efficiency are not as substantial as is claimed when considered in practical use. For example, in the case of domestic market compact fluorescent lamps intended to replace GLS lamps it is standard practise to claim an equivalent performance for say an 18W CFL and 60W GLS. In this case there is more than 15% reduction in actual lamp output for the compact fluorescent lamp and that is when the CFL is running at optimum temperature. This is damaging the perception of CFL in the domestic market where they are often perceived to provide gloomy light in comparison to the equivalent GLS lamp which it has been used to replace. When subject to frequent switching and short running times, common in the domestic environment for example in a toilet or cupboard, these lamps never achieve full operating temperature and therefore full light output, neither are they likely to achieve their intended operational life.

Another Environmental problem raised in connection with domestic CFL lamps is the waste disposal issue. By the nature of their construction excess mercury is being introduced into the Environment and many non life expired control gear units are being disposed of. These contain a variety of non renewable materials and a considerable amount of embodied energy expended in their manufacture.

Briefly, to clarify what I mean by emnbodied energy, I consider it to include all the energy used in the winning and refining of the raw materials, the transport treatment and processing required to manufacture a finished product, and energy used for the transport of the finished product to site and the energy used in the installation of the product. At end of life some of this can be reclaimed if the materials are recycled, sadly this is not often enough the case in respect of lighting equipment which largely is disposed of to landfill.

Embodied energy is an area with little solid research covering any of the building services. The principal reason given is that the energy used throughout the life of the equipment vastly outweighs the embodied energy in its manufacture and installation. I cannot accept that the embodied energy can be dismissed so simply. In researching this topic direct enquiries to manufacturers have elicited little response other than that you should look at the costs of the products compared to the cost of energy used by them, this is a tenuous argument when applied to new equipment given the profits and mark-ups in the supply chain between manufacturer and end user and redundant when considering the issue of replacing an existing installation. The available information on embodied energy in materials relates largely to the mass building materials, concrete, timber, structural steel, and finishing materials including various insulation materials, plaster, paints etc.

One example where this issue raises questions is the assumed desirability of replacing functioning switch start fluorescent equipment with new equipment containing electronic ballasts. I am not saying that electronic gear is not significantly better than switch start from the point of view of energy efficiency, or for that matter user comfort, I do however question the Environmental benefit when this is solely calculated on the basis of future direct energy cost saving. We need to look at the question of embodied energy in the existing and replacement installations.

Given the minimal amount of available data, the model I am presenting here is essentially very crude. It is based on embodied energy in materials information publicly available from the University of Manitoba and manufacturer‰s catalogue information for fitting weights and composition. Lamp information is excluded as these are considered as consumables within the life of the installation :

Weight of 600 X 600 lay in luminaire 2 X 18 W with switch start gear and basic louvre : 6.8Kg Composition: Gear: steel &copper 4 Kg embodied energy 13 Kwh/Kg = 52 KwH Body: sheet steel painted 2.5 Kg embodied energy 10Kwh/Kg = 25 KwH Diffuser / Louvre: Plastics 0.3 Kg embodied energy 10 Kwh/Kg = 3 KwH Total 80 KwH

Weight of 600 X 600 lay in Luminaire 2 X 18W with High Frequency Gear and Cat 2 Louvre : 6.1 Kg Composition: Gear: plastics, steel, copper etc. 3.2 Kg embodied energy 20 Kwh/Kg = 64 KwH Body: sheet steel painted 2.5 Kg embodied energy 10 Kwh/Kg = 25 KwH Louvre : Aluminium 0.4 Kg embodied energy 56 Kwh/Kg = 22.4 KwH Total 111.4 KwH

Therefore before we see any environmental benefit to the replacement we need to have saved a minimum of 191.4 KwH. Assuming landfill disposal of the old system.

Looking at Comparison Charts for control gear in the Osram catalogues we find that conventional wire wound gear gives a total circuit wattage of 46 for the two lamps compared to 38 circuit watts for the electronic gear however there is also a 4% reduction in light output. Our 8 watt saving would take 13,925 hours of operation, or 11 years and 6 months at 40 hours per week before the energy used in the replacement of the fittings is recovered and there is a clear environmental benefit

We have not considered the energy in transport and installation. For building materials this can represent up to 67% of the total embodied energy (Miller, A. Transportation Energy Embodied in Construction Materials Deakin University Nov 1996), even if we half that figure on the basis that we are dealing with small volumes of relatively high value product this brings the beginning of environmental benefit payback to 8 years. For a unit for unit replacement this means there will be an environmental deficit rather than a benefit by replacing switch start equipment before its end of life.

It is also essential to consider the disposal of functioning equipment containing non renewable resources, very largely to land fill. Recycling of switch start lighting equipment is frequently considered too expensive by metal recyclers as the main weight in a combined copper and steel component which is difficult to separate. Some fluorescent gear contains PCPs which are inherently dangerous and should be disposed of by incineration. This is not an energy cost but is a significant Environmental impact.

Clearly a full study of this would be of interest, however this cannot be undertaken without considerable cooperation with manufacturers who insist that much of the relevant information is too commercially sensitive to release. Generally the manufacturers have resisted any environmental legislation or research that has not had a direct and useful marketing message enabling them to produce and sell more lamps and equipment. Both substitution compact fluorescent lamps and the replacement of switch start fittings as strategies for environmentally friendly energy saving are to the substantial benefit of the lighting industry in selling product, in the former case often at unjustifiably high end user prices and in the latter case in volume brought about by replacing equipment prior to its natural end of life with the manufacturers claiming substantial Environmental Credit in the process.

Influence by lamp and fitting manufacturers in the regulatory process is insidious. They tend to vastly outnumber designers, engineers, environmental professionals and end users in panels advising governments. In the UK this influence was seen enshrined in the Building Regulations section L. In it‰s original incarnation the environmental quality of a new installation was measured as the proportion of high efficiency light sources used , guidance as to the effective use of these sources was not legislated leading to the fatuous situations where a 70W metal halide fittings were used to comply with the legislation where a 50W low voltage TH fitting would be more suitable, or , as I have seen happen on two projects, where compact fluorescent down lights have been specified in auditoria to comply with the perceived legislative requirement where a fully dimmable tungsten halogen source was required to allow the auditorium to function effectively.

To some extent the revised section L2 of the building regulations in England and Wales and section J in Scotland that came into force this year have somewhat improved the situation and recognise that other light sources are more appropriate for some purposes. In this legislation consideration is given to the efficiency of light fittings and is more considerate of reasonable arguments for a diverse range of lighting situations where energy efficient lamp technologies are not the most appropriate. There is also recognition of the contribution of lighting control systems in overall power use calculations however the margin of 20% does not reflect the energy savings over connected load provided by well considered lighting design schemes

Technologies that are considered to be energy efficient are also seeing some new developments. One of these is Infra Red coated tungsten halogen lamps (THIR). Using an infra red reflective coating on the lamp envelope these lamps recycle a proportion of the radiated heat to the filament causing it to operate at a higher temperature and therefore more efficiently. These lamps have been in the market for about five years and offer a 25% energy saving over conventional tungsten halogen in the common 300W and 500W linear lamps. Just think of the number of these lamps actively in use now and what the combined energy saving would be if they were all re-lamped today with the THIR technology. I am glad to see that this technology is appearing in the marketplace applied to the Low Voltage TH lamp families notably by Osram. Again benefits of 20% to 30% are available in direct energy saving with minimal impact on embodied energy and these immediately obtainable on re-lamping existing equipment.

On the other hand LED light sources are being heavily promoted as Low Energy Well that they may be however in terms of energy efficiency and light output they remain a long way behind even tungsten light sources. They are at an exciting stage in development and may, in the future provide a real mainstream light source and achieve acceptable energy efficiency. The present marketing is not just irresponsible but potentially damaging to the future reputation of this technology. As Lighting Designers what can we contribute to this situation? The most important consideration is to decide on a project by project basis what will provide the optimum solution considering all environmental issues in a holistic manner.

1 direct energy use,

2 selection of materials and equipment that minimise embodied energy

3 allow for achieving a full useful life through ease of maintenance

4 provide an optimum quality of light for the users of the space

5 provide for re-use and recycling at end of life of the entire installation

6 consider quantity and materials of lamps and light sources consumed in the life of the installation

The relative weightings of these criteria must be considered and matched to each project The result will be a compromise based on experience and judgement taking into account relevant legislation.

Inconclusion, the Environmental impact of a lighting scheme is not as simple as is frequently suggested. Direct energy use alone is an insufficient measure and itself must be carefully considered in relation to the overall design and aims of the project. Balance must be achieved between the quality of the lit environment from the users viewpoint and all aspects of the Environmental impact of the installation throughout its operating life.

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and with thanks to the researchers at Google Answers for an extended discussion on this topic.