# USING LIFE CYCLE ASSESSMENT TO ILLUSTRATE THE BENEFITS OF BLINDS AS PASSIVE AND SUSTAINABLE ENERGY SAVING PRODUCTS IN THE DOMESTIC ENVIRONMENT IN THE UK

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Blinds and shutters create privacy during the day and night in residential and commercial buildings. They are also widely used in warm locations to keep rooms cool when sunny and to reduce heat loss at night or in winter; in turn this reduces use of air conditioning, heating, associated energy, carbon and costs. Although these benefits have not been fully recognised in the UK, some can be assessed via 'Shade Specifier' (an online tool developed by the British Blind and Shutters Association and London South Bank University), to promote their wider and more correct use. Recent research has confirmed the importance of blinds and shutters in passive temperature control, which indicates that they contribute positively to sustainable living; their overall level of sustainability has not been fully determined however because to date the majority of research has only considered operational energy savings and/or carbon equivalent inputs and outputs.

This paper seeks to present a more holistic and accurate evaluation of the environmental impact of blind use as an aid to sustainable living in a typical domestic setting in the UK. Life Cycle Assessment is used to model the overall product life and associated impacts of 4 different types of blind, different product life spans, levels of energy consumption and potential savings during the heating season in order to demonstrate the real benefits of this type of window covering in the UK.

Keywords: blinds and shutters, energy saving, life cycle assessment, overall environmental impact.

## INTRODUCTION

Global energy consumption has increased exponentially since the Industrial Revolution and almost 9,000 Mtoe energy were consumed in 2012 alone. It is predicted that consumption will continue to rise by between 37% (EIA, 2014) and 56% (IEA, 2014) by 2040 concurrently with development in non-OECD countries and population increase. Although a very efficient source of energy, fossil fuels also produce CO2 and other greenhouse gases during combustion, many of which have been shown to have direct and indirect detrimental impacts on the environment, human populations and ecosystems in general.

As a naturally occurring substance CO2 has always been present in the atmosphere and prior to the Industrial Revolution the concentration was about 250ppm. Since then the level has increased to 400ppm as a direct result of human activity. At 450ppm however it is unlikely that humans will be able to reverse climate change, the impacts of which could be catastrophic (IPCC, 2007). The need to reduce the level of CO2 and similar emissions therefore is of paramount importance and could be achieved in part by reducing energy consumption. It is equally important to consider other inputs, outputs and their contribution overall environmental impact to ensure that carbon reduction in one area does not lead to or increase damage to another. Therefore this paper assesses the overall environmental impact of one particular energy saving product, namely window blinds, to find out how sustainable or otherwise this type of product really is.

## Energy consumption and thermal comfort in UK homes

In the UK energy is consumed across 4 main sectors, namely transport, industry, services and domestic and consumption by each sector is 38%, 17%, 13% and 27% respectively (DECC, 2015). Energy is used in the domestic sector for lighting and appliances, water heating, cooking and space heating and in 2012 accounted for 502 TWh energy. Although the number of homes in the UK has increased by 40% since 1970, overall energy use by this sector has only increased 16% because individual household energy use has fallen from 23,800 to 18,600 kWh per year. The decrease in household energy consumption is mainly due to more efficient lighting, appliances, space and water heating systems, and insulation. Space heating currently accounts for about 60% of domestic energy use because consumer expectations have changed with the widespread installation of central heating and internal temperatures are 4oC higher than they were in 1970 (DECC, 2013).

Improved insulation has helped to reduce heat loss through roofs (by approximately 20%), floors and walls and typically a contemporary insulated cavity wall has a U-value of 0.2 W/m2K. Heat loss through windows has also been reduced from 5.8 W/m2K in a single glazed window to 2.9 W/m2K in a double glazed window, from which about 90% of homes in the UK now benefit. Use of special coatings (that reduce emissivity and increase solar gain), optimum cavity width, inert gas (e.g. argon), warm edge spacers, and triple glazing can further reduce heat lost to 1 W/m2K although the number of homes with this type of window is very limited. These figures clearly show that even through the most technically advanced windows heat loss is greater than other building elements.

Windows also contribute to thermal gain, which is becoming an increasingly important factor in the UK due to changes in weather, climate, and building design (specifically larger windows, glazed walls, doors, and roofs). A number of studies show that in the workplace productivity increases when employees have individual temperature control (World Green Building Council, 2013). In the home the effects of temperature are also very dramatic particularly in the case of babies and people over the age of 65. Living room and bedroom temperatures should be no lower than 18oC (to reduce risk of heart attack and strokes in older people) (Wookey et al, 2014) and no higher than 25oC (to avoid thermal stress and dehydration) (ODPM, 2006). Babies should also sleep in rooms between 16-20oC to reduce the risk of Sudden Infant Death Syndrome, which has been linked to overheating (Lullaby Trust, 2014).

In the UK numerous commercial buildings have heating and cooling systems but, unlike many other countries, domestic electro-mechanical cooling systems are comparatively rare. Nevertheless a number of studies illustrate the value of blinds and shutters to both control internal temperature and reduce demand on electro-mechanical cooling systems. The benefits vary according to glazing type and size, building aspect and construction but range from 30-70% (Dolmans, 2006) and (Hutchens, 2015). Blinds and shutters and their correct use will of course become more important in the UK as climate changes and temperatures rise (CIBSE, 2015).

## Blinds and shutters in UK homes

The above data relating to heat-loss through windows is based on uncovered windows but blinds and other window coverings have been shown to be a very important means of reducing U-value and heat loss (BBSA, 2011); the same prior studies show that correct use of window coverings during the heating season (where they are open during the day and fully closed at night) can reduce energy consumption by at least 25% in the case of single glazed windows and by at least 15% in the case of double glazed windows (Dolmans, 2006) and (Hutchens, 2015).

Although window coverings can help to control thermal loss and gain it is of course essential that windows are not covered permanently to allow natural light into buildings; in addition to reducing Seasonal Affective Disorder studies show that this type of light improves mental function and memory, learning speed and test scores, workplace productivity, helps patient recovery in hospital, and increases retail sales (World Green Building Council, 2013). Occupants' requirements vary according to activity but light levels should be between 20-500 lux on average (CIBSE, 2015).

Unlike roller blinds and curtains other than semi-transparent sheer curtains, slatted blinds and shutters can of course be adjusted to allow natural light into buildings; it is therefore unsurprising that venetian blinds are the most popular type of domestic blind in the UK and account for 30% of sales. All types of domestic window covering are important to residents and in 2103 in the UK alone sales of all window coverings and associated products exceeded £1.1billion, over 51% of which (£565 million) were for blinds (AMA Research, 2014). These sums highlight the importance of blinds and shutters as part of the domestic interior as do the energy saving benefits discussed above.

## Carbon footprint studies and their limitations

To date analysis of the overall environmental impact of blind and shutter use has been very limited and studies have only measured carbon and its equivalents (as carbon footprints) rather than overall environmental impact. One such study considered use of external slatted roller blinds in the UK (Ylitalo et al, (2011) and another use of motorised external venetian blinds (Würzburg Schweinfurt Institute, 2013). In both cases use of blinds was found to be reduce carbon and its equivalents. More specifically the earlier study showed that, providing that the blind is recycled at end of life, the payback for life cycle greenhouse gas emissions is only 6 months but 3 years if it is not recycled. The later study showed that with a 20 year product life, carbon savings (8.5 tonnes) were 57 times greater than the carbon embodied in the blind (150kg).

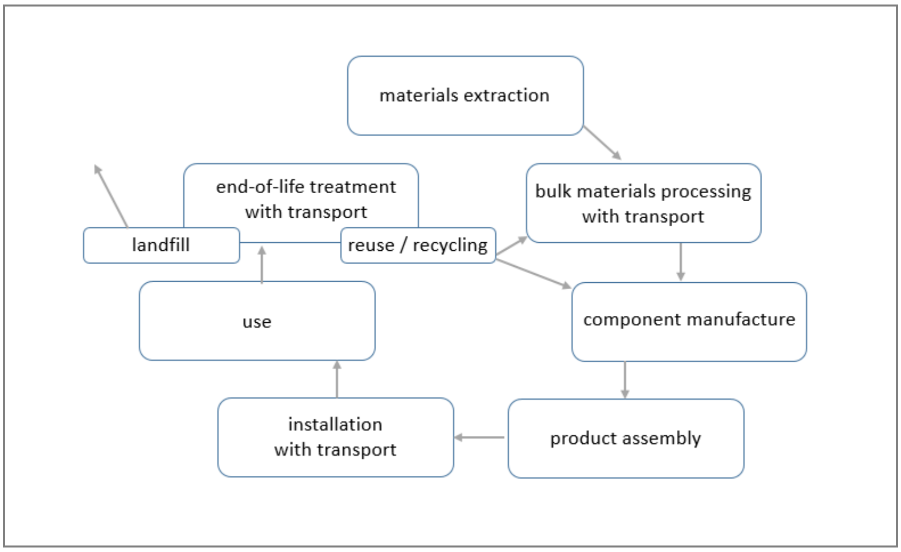
'Carbon footprint' studies are a popular guide to environmental impact but, as previously stated, they only measure one type of substance and its associated impacts and consequently results can be misleading. Life Cycle Assessment (LCA) is a far more comprehensive means of measuring environmental impact and includes hundreds of material, gas and liquid inputs and outputs including emissions to land, air and water, the impact on ecosystems, resource supply and human health. A recent study that compared a Life Cycle Assessment and a Carbon Footprint of the same supermarket refrigerated display cabinet clearly illustrated the limitations of carbon footprints. It is appreciated that the majority of impacts related to this type of product derive from use (because the unit almost continually consumes energy); however a typical cabinet is comprised of 1.5 tonnes materials which produce many impacts in addition to carbon. The results of this carbon footprint study show that 97.5% of impacts derive from operational energy and only 2.5% impacts from product manufacture and treatment at end-of-life. The ratio of impacts measured by the LCA results were somewhat different however and show that 80% of impacts derive from operational energy and 20% from product manufacture and disposal (Bibalou et al, 2013).

To date even though some manufacturers state that they have LCAs of window coverings the published results only show CO2 (Velux, 2015). There is a therefore a definite need to present a more comprehensive assessment of the overall impacts, benefits and otherwise of window coverings.

## Life Cycle Assessment (LCA) and research methodologies in this study

The stages of a Life Cycle Assessment include extraction of raw materials, bulk materials processing, component manufacture and assembly, use, treatment at end-of-life (landfill, reuse, remanufacture, recycle) and transport. In this study all of the numerous inputs, outputs, and impacts are assessed using the Eco-indicator 99 method and Ecoinvent Database in SimaPro LCA software. This is a simplified LCA in which weighted results are presented as Ecopoints so that dissimilar impacts can be easily compared. The datum for this unit (1000 Ecopoints) derives from the average impact of 1 European person per year. Uncertainties in this study are also limited by weighting the results with the default Hierarchist weighting set in which the effect of impacts are considered over a medium timescale, it is predicted that many problems can be avoided through proper policies, and inclusion of evidence / data is based on expert consensus.

*Figure 1: Life cycle processes for blinds*




At present it is unknown how domestic blinds are treated at end of life in the UK. If they are not disassembled they may be combusted with energy recovery (in an energy from waste plant) or in the case of metal blinds, the polymeric parts could be combusted as waste during the metals recycling process. Two end-of-life scenarios have been modelled to address some of these uncertainties: in the best case it is assumed that 100% materials are either recycled or reused and a worst case end-of-life scenario it is assumed that 100% materials are sent to landfill.

There are so many variables that affect energy saving through blind use including operational type, materials, and colour of blind, which affect the transmittance, absorption and reflection of light (and therefore the U-value); building orientation, type of glazing (Dolmans, 2006 and Hutchens, 2015) and occupant behaviour (Bennett et al, 2014) also have a considerable impact on energy saving. It has already been stated that the average energy savings for single glazed windows can exceed 25% and those for double glazed windows 15% providing that blinds are open all day and fully closed at night during the heating season. Energy savings of 5%, 10%, 15%, and 20%, are modelled in this simplified LCA study to account for variation in the above criteria and to determine the point at which use of blinds becomes environmentally advantageous. It is also assumed that all windows are double glazed because this is the most predominant type of glazing in the UK.

The functional unit in the model is one average house which has 7 blinds that cover a total of 14.5m2. Annual average annual energy consumption for space heating is 60% of the total of domestic energy use (although it varies according to external temperature); this is therefore calculated as 11,160 kWh per household (DECC, 2015).

The life cycle impacts of 4 typical types of blind are calculated to ascertain whether there is much difference in the impact of these individual products. It is not untypical for different types of blind to be installed in the same house so the average impact of these blinds will be calculated to create a representative product. The 4 blinds could be used in either a residential or commercial context but in this study they are used in the former.

The models are based on real products and each blind was reverse engineered in order to and identify and quantify all materials and manufacturing processes, details of which were discussed with a manufacturer. The blinds are a polyester blackout roller blind, a linden (basswood) wood venetian blind (50mm slats), an aluminium venetian blind (25mm slats) and a vertical blind (89mm polyester vanes). While the materials for the window covering components obviously differ, the materials in the mechanisms are more similar and include polymers (nylon 6, acetal, PVC, and polyester) and metals (aluminium, brass, nickel plated, mild and stainless steel). Associated manufacturing processes include wood cutting and machining, injection moulding, extrusion, sheet and bar production, metal forming and machining, yarn production and braiding, paint and powder coating. Materials selection has been optimised for function: for example polyester is widely use because it does not stretch and or deteriorate in sunlight like natural fibres. Similarly engineering polymers (nylon 6 and acetal) are wear and abrasion resistant and consequently are used for bearings and other moving parts. The specific type and quantity of components varies according to blind type and operation method and in this case the roller blind has the lowest and the vertical blind the highest number of components.

The UK blind industry currently employs about 16,000 people and although the largest companies employ over 500 people a significant majority (73%) of businesses employ 1-5 people (Experian, 2014) and many blinds are assembled by hand; mechanisms and components are designed accordingly and most push-fit, which also facilitates disassembly and therefore reuse and recycling. Not all materials and components are produced in the UK however and the model therefore assumes that 25% by mass are shipped from China where components are also manufactured.

In addition to life cycle stages product life span is considered in the model because this also affects overall environmental impact. The carbon footprint studies discussed above (Ylitalo et al, (2011) and Würzburg Schweinfurt Institute, (2013)) are based on a 20 year life, which is realistic because external blinds are more expensive, durable and difficult to install than internal blinds; in both models blinds are raised and lowered automatically. Internal blinds may be subject to misuse or damage because they tend to be raised and lowered manually; they are also seen as interior furnishings and may be changed in conjunction with other interior decoration activities. Anecdotal evidence shows that product life is often less than 20 years and that some residents decorate as frequently as every 3 years; many more residents decorate every 5 years and others every 10-15 years ((Graham & Brown, (2015) and Kingfisher Group, (2012)). These different time periods are also included in the model to address uncertainty about length of product life.

# RESULTS

## Comparative LCA of 4 blinds

As stated above the 4 blinds that were assessed are a polyester blackout roller blind, an aluminium venetian blind, a linden wood blind, and a polyester vertical blind. Assessment of the product only (materials and manufacturing processes) shows that the roller blind has the lowest impact followed by the wood venetian, the vertical and the metal venetian. In fact the impact of the materials and manufacture in the metal venetian is more than twice that of the roller because of the high energy inputs required for the aluminium parts even though the model is based on a typical standard production mix which includes recycled as well as virgin material. The wood blind includes painted slats; the impact of painting is higher than that of embedding colour in the polyester fabrics but there is a trade-off and the impact of wood is reduced during the growing stage when it absorbs $CO_2$ during photosynthesis. The vertical blind uses slightly more polyester fabric than the roller and the impact is higher due to this and to additional processing such as cutting. The impact of the vertical blind is also increased by the inclusion of distinctive ballast weights and stainless steel spacers. These results usefully illustrate the differences between the impacts of materials and manufacture but the end-of-life stage must be included for assessment of a complete life cycle.

The two different end-of-life scenarios make a significant difference to the overall life cycle impact and, predictably, all products that are sent to landfill have a higher impact than those that are reused / recycled. This is partly because in the LCA method it is assumed that materials are not stockpiled after disassembly but are recycled and reused in the manufacture of new products. Furthermore in addition to being wasted, the materials that are sent to landfill can produce emissions to air, water and soil as they break down, which in turn increases environmental load.

When recycled at end of life the blind with the lowest impact is the wood venetian, followed by roller, metal venetian and vertical. When sent to landfill however that with the lowest impact is the roller followed by the vertical, the wood venetian and the metal venetian. On average the impact of sending the blinds to landfill is more than twice that of recycling at end-of-life which highlights the benefit of recycling. Although technically possible it can be difficult to find markets for some of the recyclate materials however; this is particularly true in the case of polymers so reuse could be a preferred option proving that the components are not worn or damaged.

## Combined LCA of energy consumption of blinds

Prior research shows that use of blinds can save in excess 15% of energy for space heating in the UK. The original intent of this paper was to measure the overall environmental impact of blinds and to compare this with the reduced environmental impact of related energy savings. A typical UK generation mix that includes various fossil fuel and renewable technologies was used for the model and the results are summarised in figures 2 and 3.

*Figure 2: The benefits of blind use when recycled at end-of-life space heating energy savings of 5%, 10%, 15% and 20% and 3, 5, 10, 15 and 20 year product (blind) life spans*

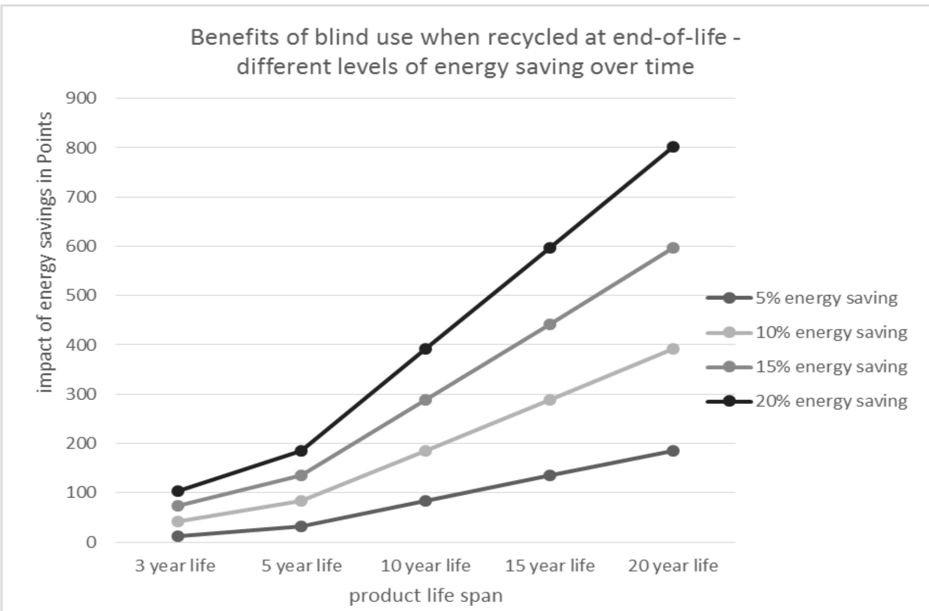
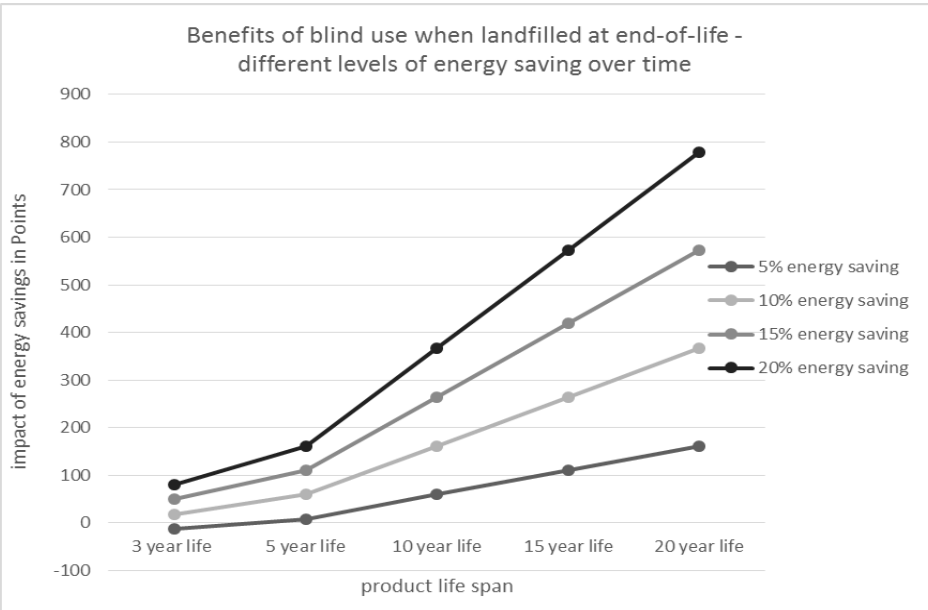


Figure 2 shows that, providing the blinds are recycled at end-of-life the overall environmental impact will be reduced through energy saving. After 3 years with 5% energy saving the benefits are very limited and overall environmental impact is reduced by less than 2%. As time progresses benefits becomes more apparent however and after 5 years with 15% energy savings or 10 years with 10% energy savings overall impact is about 13% lower than it would have been in a house without blinds. Over time the impact of the blinds themselves obviously becomes less significant so that by 15 years with 15% energy savings impact is reduced by more than 14% and at 20 years with 20% energy saving impact is almost 20% lower than it would have been without use of blinds.

The results in Figure 3 - where the blinds are sent to landfill - follow a similar pattern to those in figure 2 although the benefits are slightly less notable. After 5 years with 15% energy saving, use of blinds has only reduced environmental impact by about 10%. Over time the ratio of blind-energy changes and by 20 years with 20% energy saving it is almost 19%. The most dramatic difference however occurs if product life is very short and the blinds are sent to landfill after 3 years and only 5% of energy has been saved: in this case the impact of blind use is higher than not using a blind. Hopefully disposal of blinds after such a short time period is limited and residents either pass them on to other users or disassemble and recycle parts.

*Figure 3: The benefits of blind use when sent to landfill at end-of-life space heating energy savings of 5%, 10%, 15% and 20% and 3, 5, 10, 15 and 20 year product (blind) life spans*




## CONCLUSIONS AND DISCUSSION

The research undertaken and the simplified LCA studies clearly show that in a typical UK household use of blinds during the heating season is environmentally beneficial. Even if the blinds are not used 'correctly' (i.e. are fully open during the day and fully closed at night and therefore energy savings are below the potential maximum of

15%), the installation of blinds will reduce overall environmental impact as long as they are used for at least 3 years and are recycled at end-of-life. If blinds are sent to landfill use will still be environmentally beneficial as long as product life is at least 5 years and energy savings are above 10%.

It is important to note that the carbon savings recorded in the studies of the two external blinds appear to be higher than the overall savings calculated in these Life Cycle Assessment studies. This is due to the fact that carbon footprint studies only measure one type of substance whereas the LCA studies consider the impacts of hundreds of substances and are therefore more accurate; furthermore the blinds in these studies are external and are more efficient (i.e. reduce thermal gain and loss) more than internal blinds. A full LCA of an external blind should be undertaken to compare like with like. Similarly other types of interior and exterior blind in addition to the 4 blinds in this study should also be modelled and compared to identify the optimum product(s).

It is acknowledged that the data used in this study is generic and future studies should include more specific data about the origin of materials and how blinds are treated at end-of-life including reuse and energy from waste scenarios for example. A more comprehensive LCA that conforms to ISO 14040 standards should also be carried out.

It is essential to undertake real world studies of blind use for domestic solar shading during the summer months in the UK in order to assess its effect on interior temperature and overall environmental impact. Solar shading will become increasingly important in the UK for thermal comfort, health and well being in anticipation of future climate change and the need to continually reduce carbon emissions and overall environmental impact. These studies must also include consider the differing effects and impacts of natural and artificial light levels associated with use of blinds as well as variables in user behaviour.

Finally sustainability includes environmental, economic and social factors; the emphasis of this LCA is environmental impact however, and at present economic considerations are excluded. Similarly the Eco-indicator 99 LCA method includes some impacts on human health (e.g. damage to the ozone layer and respiratory substances) but it does not include a comprehensive assessment of social factors such as ethical and safe working conditions, child labour and its impact on education etc. Social LCA is an emerging process which, in conjunction with economic factors should be included in future studies of blinds from cradle-to-cradle and operational energy in order to determine their complete level of sustainability.

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