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THE USE AND IMPACT OF MANUAL AND MOTORISED BLINDS AS AIDS TO THERMAL AND VISUAL COMFORT IN DOMESTIC BUILDINGS IN THE UK

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INTRODUCTION

There is significant evidence that the combustion of fossil fuels for energy has contributed to an increase in CO_2 and other greenhouse gases in the atmosphere since the Industrial Revolution; there is also evidence of a parallel increase in global temperatures, all of which have contributed to climate change and detrimental environmental impacts. The built environment has made a notable contribution to these issues and in 2011 for example it accounted for 62% of global energy consumption. Up to 85% of this energy was operational (as opposed to embodied)[1] and in the EU 50% was used to operate heating and cooling systems in buildings[2]. Consequently, several strategies have been developed to reduce energy consumption and associated environmental impact from the built environment including improved insulation. Although this has proved environmentally beneficial by reducing energy demand for heating, in conjunction with changing climate and weather patterns however, it has also contributed to a rise in the overheating incidents in buildings. This in turn has increased the demand for electro-mechanical cooling (e.g. air-conditioning and fans), the use of which negates some of the benefits of reducing energy for heating.

There are many examples of contemporary buildings that have been designed to minimise thermal gain in summer and/or warm locations; this can be achieved through appropriate building orientation and/or technical design features such as those in Jean Nouvel's Arab World Institute in Paris, France (which includes an intelligent shading system on the south façade to manage light and solar gain)[3] and Alejandro Aravena's Siamese Towers in Santiago, Chile (which incorporate a double skin to remove heat from the building)[4]. Many buildings do not include this type of feature or good insulation however as a result of which interior temperatures are high in summer and low in winter, and although appropriate design and correct orientation of new buildings could mitigate these issues, there is a considerable quantity of new and old building stock in the UK that does not address one or both factors successfully.

Blinds, shutters and other shading products can be both retrofitted in existing buildings and incorporated into new building designs. In addition to creating privacy and security for building occupants, they can address some of the above problems in that, if correctly used, they attenuate daylight and help to reduce energy use and associated impact by limiting thermal gain in the summer and thermal loss in the winter. In the UK use of motorised and automated shading systems is increasingly popular in commercial buildings with shading systems. However the emphasis of this study is domestic buildings, where interior space, user behaviour and levels of energy consumption often dramatically differ from that in commercial buildings; for example, air conditioning is installed in very few domestic buildings and manual shading products are the most widely used. This could change as use of motorised blinds has been shown to encourage user interaction and thus improve thermal comfort, well-being and energy savings. While component materials and manufacturing processes for this type of blind system differ from those in manual blinds, they also consume electrical energy for operation and therefore overall environmental impact is higher than that of manual blinds.

This paper briefly considers thermal and visual comfort, health and well-being of building occupants; it then compares the embodied and operational environmental impact of motorised blinds and associated energy savings to determine their overall environmental impact and concludes by discussing a major challenge to the construction industry that is also limiting the potential benefits of blind use.

CONTEXT AND BENEFITS OF BLIND USE

Blinds and shutters have been used around the world for hundreds of years to cover unglazed and glazed window openings although the precise origin and date of invention is unknown. Early examples of blinds and shutters made from natural materials such as bamboo and reeds were developed in the Far and Middle East. Slatted wooden 'venetian' type blinds were also developed in Persia prior to widespread use across Europe and America while patents dating from the middle of the 18th century illustrate the development of blind mechanisms. Today various types of interior and exterior blind (such as roller, slatted, pleated, vertical, panel) made from both natural and synthetic materials (including wood, textiles, aluminium, and polymers) are available.

Both blinds and shutters are used for privacy and contribute to building aesthetics, while shutters (which are usually made from wood or metal) also enhance security. Furthermore the 'correct' use of blinds helps to keep buildings warm in the winter and cool in the summer although what is 'correct' varies according to geographical location[5] and type of blind (opaque, semi-opaque, roller, slatted, fit-to-window / cassette etc.). Nevertheless incidences of overheating in buildings are increasing; this is due in part to changes in weather and climate, rising numbers of heat waves in the UK[6], as well as changes in, performance of and inappropriate specification of building products such as glazing and insulation. These factors further highlight the importance of correct blind use[7] which also contributes to human wellbeing by controlling glare, natural light levels, access to view and interior temperature. This is particularly important for the very young and the elderly who are more susceptible to ill health (and even death) as a result of exposure to high[8] or low[9] temperatures, which is not only unpleasant for them but can lead to additional health service costs; there are also indications that the previously described environmental factors can enhance productivity in the workplace[10] and various related real time research projects are on-going (for example at LSBU).

As aids to temperature control and thermal comfort blinds and shutters reduce energy consumption, and a wide range of impacts including associated CO_2, and other greenhouse gas emissions. In fact the ‘correct’ use of blinds can reduce energy consumption by up to 15% for double glazed windows[11] and 25% for single glazed windows[12] in both residential and non-residential settings. Consequently blind use has the potential to reduce heating costs during the winter and cooling costs during the summer.

THE ENVIRONMENTAL IMPACT OF MANUAL BLINDS

It must be remembered however that, like all products, blinds have embodied impacts and a research project was undertaken in 2015 in order to ascertain the extent to which this affects their overall environmental profile[13]. Life Cycle Assessment was used to quantify the average impact of different types of manual blind (namely wooden and metal venetian, polyester vertical and roller) in a typical UK house. This study differs from ‘carbon footprint’ studies, which, as the name suggests, only consider the impacts of carbon and its equivalents. Life Cycle Assessments 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[14]. LCAs are therefore more holistic and accurate than carbon assessments as illustrated in the study of a refrigerated display cabinet that compares the results of an LCA and a carbon study of the same product. The results highlight the shortcomings of carbon assessments and show that the ratio of embodied to operational impact is proportionally higher than in that in the carbon assessment[15].

The LCA results of the manual blinds were positive and showed that, even if energy savings were very low (5%) and life short (3 years) providing that the blinds were recycled at end-of-life, their use has a lower environmental impact than not using blinds. Furthermore if energy savings are similarly low (5%) and the blinds are sent to landfill at end-of-life they are also environmentally beneficial as long as they are used for at least 5 years.

USER INTERACTION AND MOTORISED BLINDS

Despite their potential contribution to human well-being and energy saving in the UK in non-residential premises in particular the installation and use of air conditioning (and associated energy and emissions) is increasing because the various properties and benefits of blind use is not recognised[16]. There are a number of reasons why this is so including inaccurate specification of blinds and inadequate fitness for purpose, poor understanding of correct use and associated user behaviour. In their longitudinal study in Switzerland Paule et al[17] found that users do not move (i.e. raise and lower) blinds regularly or frequently and therefore potential reductions in thermal loss and/or gain are unfulfilled. This same study identified an interesting change in user behaviour when different control strategies were implemented: building occupants with motorised blinds moved their blinds far more frequently than occupants with manual blinds and the researchers concluded that this was because the motorised blinds were easier to use than manual blinds.

Therefore it is fair to conclude that motorised blinds could be a positive means of encouraging more effective and proactive blind use. This type of blind has higher embodied and operational environmental impacts than manual equivalents however because they require electrical energy, additional mechanical and electronic mechanisms, electrical and operational components to function. This in turn raises a question as to what overall environmental benefits derive from use of this type of blind: i.e. whether the environmental impact of energy savings exceeds the combined embodied and operational environmental impacts of the products.

THE ENVIRONMENTAL IMPACT OF MOTORISED BLINDS

This paper now describes comparative Life Cycle Assessments of the overall environmental impact of two types of motorised blind, namely mains (hard wired) and battery operated. By considering the impact of blinds in a domestic context both the earlier study and this study differ from many others, which have measured performance and impacts in commercial premises[18], [19]. This study employs the same methods and many of the same parameters as the study of manual blinds as follows:

- the blinds were all reverse engineered and quantified in a screening LCA created with SimaPro software and the Ecoinvent database and hierarchical (average) weighting set
- the functional unit in the model is one average house with seven blinds that cover a total of 14.5m^2 double-glazed windows
- annual average annual energy consumption for space heating is 60% of the total of domestic energy use (although it varies according to external temperature), which is calculated as 11,160 kWh per household[20], [21].

The manual blinds study included a 100% polyester dimout roller, a wooden venetian, an aluminium venetian and a vertical blind with polyester vanes to reflect the fact that different types of blind are commonly installed in individual houses. This current study only includes motorised roller blinds however because they are the most popular choice of interior domestic blind. The models include different fabrics, namely dimout fabrics (which reduce thermal loss during the winter and night) and a screen fabric (which reduces thermal gain and improves visual comfort during the day). The list of parameters in the model are as follows:

- 3 typical fabrics:
    - 100% polyester multilayer dimout
    - 72% PVC / 28% glass fibre composite dimout
    - 64% PVC / 36% glass fibre composite screen
- 2 types of motorised system:
    - 1 x mains powered / hard wired system
        - standard electrical and electronic components, metal and polymer housings, 2-core wire to mains, 13 amp plug
        - operational energy input is based on raising and lowering blinds for 30 seconds per day
        - blinds are controlled by handheld remote with rechargeable Li-ion battery (details of recharge and product life below)
    - 2 x battery operated systems
        - controlled by
            - a ‘wand’ control attached to the blind mechanism

        - a separate remote control
    - Electrical / electronic components: size and specifications vary according to whether they are part of the 'wand' or the 'remote control' based system. The inputs, outputs and results for these two complete systems are averaged
- Batteries in blind mechanisms and controllers use Li-ion rechargeable batteries. Battery charge lasts for 6-12 months depending on level of use and so the model includes electricity input for 1.5 charges per year.
- Battery life is limited and they are replaced once every 5 years

The following parameters are the same as those in the models for the manual blinds:

- Energy savings of 5%, 10%, 15% and 20% are modelled. However it is expected that average energy savings will be higher than those for manual blinds because user interaction with and levels of movement of motorised blinds is higher than that of manual blinds.
- Product life is set as 3, 5, 10, 15, 20 years; this is dependent on customer preference and quality and durability of the blinds themselves.

The overall environmental benefits of recycling manual blinds at end-of-life have already been described above; however many blinds are disposed of before components reach the end of their functional life and so the new study also includes reuse / replacement of some components. The models are based on the following parameters:

- End-of-life scenarios represent best and worst cases namely all parts recycled and all parts sent to landfill.
- Reuse and replacement: some components deteriorate as a result of direct exposure to sunlight and fabrics can fade and/or discolour and as the most visible part of the blind, customers are most likely to want to replace fabric when they redecorate, typically every five years[22]. A fabric 'refresh' (replacement) every 5 years is therefore modelled (Good quality blinds that are not misused or abused can last for more than 20 years; all components other than fabric and batteries are therefore reused once (at 5 years), twice (at 10 years), 3 times (at 15 years), and 4 times (at 20 years) over product life.

Results for the reuse models are compared with results for complete product replacement.

LCA RESULTS AND DISCUSSION

The dimout and screen blinds fulfil different functions and while the dimout blinds will generally be used at night they could also be used during the day if the property is unoccupied or with artificial light. The screen blinds will be used during the day to improve visual and thermal comfort. Once again in order to reflect a typical mix of blinds in a domestic interior, the impact of the blind fabrics was averaged. Predictably the environmental impact of the motorised blinds was higher than that of the manual blinds because of the additional components, the impact of which was determined by both the mass and type of materials and manufacturing processes associated with the various electrical and electronic components, product casings, batteries, energy input for charging and transport. The benefits of reuse and recycling were apparent despite the fact that the batteries had to be recharged at least once a year and were replaced every five years.

Figure 1. The environmental benefits of hard wired and battery operated motorised roller blind use in a typical house in the UK
Key: A = complete product replacement
B = replace fabric and batteries; reuse all other components
✓ = impact of blinds + operational energy is lower than not using blinds;
X = impact of blinds+ operational energy is higher than not using blinds

	product life	5 years				10 years				15 years				20 years			
energy saving	end-of-life scenario	landfill		recycle		landfill		recycle		landfill		recycle		landfill		recycle	
	operating system	mains	battery	mains	battery	mains	battery	mains	battery	mains	battery	mains	battery	mains	battery	mains	battery
5%	A	X	X	✓	✓	X	X	✓	✓	X	X	✓	✓	X	X	✓	✓
	B	X	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10%	A	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	B	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15%	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20%	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	B	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The results clearly show that use of motorised blinds is environmentally beneficial providing that they are recycled at end-of-life. This is not the case if they are sent to landfill and the impact of mains powered blinds is higher than not using blinds (as shown by X in Table 1 and confirmed through analysis of the complete numerical results). Use of mains-powered blinds also has a higher impact than that of battery-operated blinds when:

- energy savings are 5% and under
- complete products are replaced after 5 or 10 years rather than being 'refreshed' (i.e. only batteries and fabric are replaced)
- when the product life is only 5 years and energy savings are 10% and below

It is expected that use of motorised blinds will create greater energy saving for heating and cooling as consumers interact with and move these blinds more frequently than manual blinds. Although mains-powered blinds have a higher impact than battery-operated blinds in some respects they may be more attractive to consumers because they are easier to maintain: in the case of mains-powered blinds only the batteries in the remote control have to be recharged and replaced whereas batteries for both the roller mechanism and the remote control have to be recharged and replaced in battery-operated blinds. Mains-powered blinds would probably need an electrician to install them which could limit their application in the DIY market and increase overall cost.

Nevertheless, like manual blinds whichever system is installed use of motorised blinds has the potential to reduce environmental impacts and overall direct energy costs, to improve occupants' well-being and subsequently to produce further indirect economic benefits by reducing medical and health issues.

LIMITATIONS TO THE POTENTIAL BENEFITS OF BLIND AND SHUTTER USE

At present, even though research shows that blinds could reduce energy use up to 15% for double glazed windows and 25% for single glazed windows in domestic and non-domestic settings it is almost impossible to accurately quantify the impact and benefits of particular blinds and shutters on specific buildings. This is partly due to unpredictable and/or misinformed user behaviour but also due to the lack of accurate data about the performance of blinds and shutters in industry standard software.

The models generated as part of this research include variables of 5%, 10%, 15% and 20% to account for the lack of precise data about energy saving and although appropriate for the methodology in the LCA studies, such imprecision is not appropriate for building modelling. Currently the performance of blinds and shutters is under-estimated by many programs as a result of which their value as passive and/or low energy and sustainable aids to temperature control, energy saving and well-being are not fully recognised. The reasons for this are various and complex but are summarised in a National Energy Foundation report to which some of the authors also contributed:

> "In general mainstream software appears outdated with regard to assessing the performance of solar shading as it does not conform to the latest international standards" [23].

The various developments in materials composition, lamination technology, blinds design and structure (e.g. concertina and cassette) are being measured however and results added to an international database managed by the European Solar Shading Association.[24] . The intention is to incorporate this higher calibre data into industry software so that architects, designers and engineers can properly understand the benefits and use of blinds and shutters. This in turn will help to change perception of blinds and shutters as décor alone to important parts of building fabric.

CONCLUDING REMARKS

This paper began by briefly describing the history of blinds and the contribution of shading devices to occupants' health and wellbeing. Current designs, materials and manufacturing processes, potential energy savings from heating and cooling and associated environmental impact resulting from correct blind use in the domestic context were also discussed. Non-domestic buildings will also benefit from use of shading products although user behaviour, the size and layout of spaces and levels energy consumption differ from those in domestic buildings. Furthermore, motorised and automated shading systems are increasingly common in non-domestic buildings that include shading products as a result of which 'correct' use of blinds is more likely; these combined factors mean that levels of energy saving, associated environmental and health benefits therefore differ from those in the domestic environment where the majority of shading products are still manually operated.

Research indicates that motorisation of domestic blinds will positively impact on user interaction and encourage more correct use. However, the embodied impact of motorised blinds is higher than that of manual blinds. A study shows that the environmental benefits of manual blind use significantly

outweigh their embodied impacts; this paper builds on that study and includes comparative Life Cycle Assessments of motorised blinds. The results also showed that their use is also environmentally beneficial because the benefits of potential energy savings also outweigh embodied impact although the point in time when this occurs is later than that of manual blinds and longer product life should therefore be encouraged.
This paper describes the diverse benefits arising from use of shading products like blinds and shutters. Their importance in the built environment was also advocated in a CIBSE technical report and journal article that urges construction professionals to include shading products in building models and property developers to install them[25]. As discussed above however there is a need to update and improve the quality of data available to professionals in the construction industry to enable them to create accurate models based on current and changing weather and climatic conditions. Only then will the full potential of blinds and shutters as aids to sustainable construction be properly realised.

REFERENCES

[1] John E. Anderson, Gebhard Wulfhorst, Werner Lang, Energy analysis of the built environment—A review and outlook. Renewable and Sustainable Energy Reviews 44 (2015) 149–158
[2] European Commission Overview of support activities and projects of the European Union on energy efficiency and renewable energy in the heating & cooling sector https://ec.europa.eu/energy/sites/ener/files/documents/overview_of_eu_support_activities_to_h-c_-_final.pdf
[3] Tim Winstanley AD Classics: Institut du Monde Arabe / Enrique Jan + Jean Nouvel + Architecture-Studio; 2Cotober 2011. Accessed 17 July 2017 from http://www.archdaily.com/162101/ad-classics-institut-du-monde-arabe-jean-nouvel
[4] Anonymous Siamese Towers / Alejandro Aravena Architecture Daily 25 May 2018; Accessed **17 July 2017 from** http://www.archdaily.com/1277/siamese-towers-alejandro-aravena
[5] Isis Bennet , William O'Brien , H. Burak Gunay Effect of Window Blind Use in Residential Buildings: Observation and Simulation Study 2014; Accessed July 6 2016 Proceedings of eSIM2014, Ottawa, Canada
[6] CIBSE (Chartered Institution of Building Services Engineers) Environmental design guide; 8th edition,, 2015. Lavenham Press, UK
[7] Michael Swainson, John Henderson and Will Wright "*Solutions to overheating in home Evidence Review*"; BRE for Zero Carbon Hub. Accessed 1 August 2016. http://www.zerocarbonhub.org/sites/default/files/resources/reports/ZCH-OverheatingEvidenceReview.pdf
[8] Lullaby Trust, Fact Sheet on Temperature; Accessed February 6, 2017. http://www.lullabytrust.org.uk/file/Fact-Sheet-Temperature.pdf
[9] Rachel Wookey, Angie Bone , Catriona Carmichael and Anna Crossley , Public Health England; Minimum home temperature thresholds for health in winter: A systematic literature review; Public Health England 2014. Accessed 20 July 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/365755/Min_temp_threshold_for_homes_in_winter.pdf
[10] World Green Building Council, The Case for Green Building, A Review of the Costs and Benefits for Developers, Investors and Occupants, 2013; Accessed February 6, 2017. http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf
[11] Dick Dolmans., Energy saving and CO2 Reduction Potential from Solar Shading Systems and Shutters in the EU-25; Accessed February 6, 2017. http://www.es-so.com/images/downloads/ESCORP-EU25%20volledig.pdf
[12] Michael Hutchens High Performance Dynamic Shading Solutions for Energy Efficiency in Buildings; Accessed February 6, 2017. http://www.es-so.com/images/downloads/Downloads%20presentations/ES-SO_RT- 2015_Hutchins-M_V6_final.pdf
[13] Deborah Andrews, Zoe De Grussa, Andrew Chalk and Dave Bush," Using Life Cycle Assessment To Illustrate The Benefits Of Blinds As Passive And Sustainable Energy Saving Products In The Domestic Environment In

The UK" Going North for Sustainability Leveraging knowledge and innovation for sustainable construction and development, London South Bank University, November 23-25 2015.

[14] Jeroen B. Guinée, Reinout Heijungs, and Gjalt Huppes, Alessandra Zamagni, Paolo Masoni, and Roberto Buonamici, Tomas Ekvall and Tomas Rydberg, Life Cycle Assessment: Past, Present, and Future; *Environ. Sci. Technol.*, 2011, *45* (1), pp 90–96 DOI**:** 10.1021/es101316v

[15] Dan Bibalou, Deborah Andrews, Issa Chaer, Graeme Maidment and Matt Longhurst, " A Carbon Footprint Study and a Life Cycle Assessment of an identical Refrigerated Display Cabinet: comparative analysis of the respective ratios of embodied and operational impacts"; proceedings of the 3rd International Congress on Life Cycle Assessment, Lille, 4-5 Nov 2013.

[16] Alan Abela, Lorna Hamilton, Roger Hitchin, and Christine Pout, "Study on Energy Use by Air-Conditioning": Final Report; BRE Client Report - for the Department of Energy & Climate Change, HPR218-1001 June 2016. Accessed February 6, 2017. http://bre.co.uk/filelibrary/pdf/projects/aircon-energy use/B_AirConditioningEnergyUseAnnexBFinal.pdf

[17] B. Paule, J Boutillier and S Pantet. Global lighting performance, Annual report 2013R2014. Project 81 0083 : Swiss Federal Office for Energy, Lausanne, 2014. Accessed Februry 6, 2017. http://www.estia.ch/daylighting/lp8we

[18] Kenneth Ip, Hanna Ylitalo and David Marshall Environmental performance of external roller blinds in the UK ; accessed July 2 2015 from about.brighton.ac.uk/ccp/index.php/download_file/view/462/306

[19] Würzburg Schweinfurt Institute in ES-SO A New Vision on Solar Shading 2013; accessed July 20, 2015 from http://www.verozo.be/sites/verozo/files/files/Brochure_SolarShading_screen_LR.pdf

[20] DECC, United Kingdom Housing Energy Fact File; Accessed February 6, 2017.: https://www.gov.uk/.../united-kingdom-housing-energy-fact-file-2013

[21] DECC, Energy Consumption in the UK; Accessed February 6, 2017. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449102/ECUK_Chapter_1_-_Overall_factsheet.pdf

[22] Graham and Brown How often should you redecorate? 2015 Accessed July 20 2015 https://www.grahambrown.com/uk/blog/inspirations/how-often-should-you-redecorate

[23] Federico Seguro and Jason Palmer for NEF (National Energy Foundation) *Solar Shading Impact. Business Case | Strategic Vision | Action Plan*, June 2016; National Energy Centre, Milton Keynes UK

[24] ES-SO (the European Solar Shading Association) ESS-DA Database. Accessed February 6, 2017. https://es- so-database.com/

[25] Liza Young Getting Warmer: CIBSE's new guidance to assess overheating risk in homes is timely, as UK summer temperatures soar. CIBSE Journal August 2017 https://www.cibsejournal.com/archive/PDFs/CIBSE-Journal-2017-08.pdf

BIBLIOGRAPHY

Abela, Alan Hamilton Lorna, Hitchin Roger, and Pout, Christine "Study on Energy Use by Air-Conditioning": Final Report; BRE Client Report - for the Department of Energy & Climate Change, HPR218-1001 June 2016. Accessed February 6, 2017. http://bre.co.uk/filelibrary/pdf/projects/aircon-energy use/B_AirConditioningEnergyUseAnnexBFinal.pdf

Anderson, John E. Wulfhorst Gebhard, and Lang, Werner "Energy analysis of the built environment—A review and outlook". *Renewable and Sustainable Energy Reviews* 44 (2015) 149–158

Andrews Deborah, De Grussa, Zoe Chalk Andrew and Bush Dave," Using Life Cycle Assessment To Illustrate The Benefits Of Blinds As Passive And Sustainable Energy Saving Products In The Domestic Environment In The UK" Going North for Sustainability Leveraging knowledge and innovation for sustainable construction and development, London South Bank University, November 23-25 2015.

Anonymous Siamese Towers / Alejandro Aravena Architecture Daily 25 May 2018; Accessed 17 July 2017 from http://www.archdaily.com/1277/siamese-towers-alejandro-aravena

Bennet Isis, O'Brien, William and Gunay H. Burak "Effect of Window Blind Use in Residential Buildings: Observation and Simulation Study 2014"; Accessed July 6 2016 Proceedings of eSIM2014, Ottawa, Canada

Bibalou Dan, Andrews, Deborah Chaer, Issa, Maidment Graeme and Longhurst Matt, " A Carbon Footprint Study and a Life Cycle Assessment of an identical Refrigerated Display Cabinet: comparative analysis of the respective ratios of embodied and operational impacts"; presented at the 3rd International Congress on Life Cycle Assessment, Lille, 4-5 Nov 2013.

CIBSE (Chartered Institution of Building Services Engineers) “Environmental design guide;” 8th edition,,2015. Lavenham Press, UK

DECC, United Kingdom Housing Energy Fact File; Accessed February 6, 2017.: https://www.gov.uk/.../united-kingdom-housing-energy-fact-file-2013

DECC, Energy Consumption in the UK; Accessed February 6, 2017. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449102/ECUK_Chapter_1_-_Overall_factsheet.pdf

Dolmans. Dick, “Energy saving and CO2 Reduction Potential from Solar Shading Systems and Shutters in the EU-25”; Accessed February 6, 2017. http://www.es-so.com/images/downloads/ESCORP-EU25%20volledig.pdf

ES-SO (the European Solar Shading Association) ESS-DA Database. Accessed February 6, 2017. https://es-so-database.com/

European Commission “Overview of support activities and projects of the European Union on energy efficiency and renewable energy in the heating & cooling sector”. Accessed 20 January 2017 https://ec.europa.eu/energy/sites/ener/files/documents/overview_of_eu_support_activities_to_h-c_-_final.pdf

Graham and Brown How often should you redecorate? 2015 Accessed July 20 2015 https://www.grahambrown.com/uk/blog/inspirations/how-often-should-you-redecorate

Guinée Jeroen B, Heijungs, Reinout, Huppes, Gjalt Alessandra Zamagni, Masoni, Paolo, Buonamici, Roberto, Ekvall Tomas and Rydberg Tomas,” Life Cycle Assessment: Past, Present, and Future”; Environ. Sci. Technol., 2011, 45 (1), pp 90–96 DOI: 10.1021/es101316v

Hutchens Michael, “High Performance Dynamic Shading Solutions for Energy Efficiency in Buildings”; Accessed February 6, 2017. http://www.es-so.com/images/downloads/Downloads%20presentations/ES-SO_RT-2015_Hutchins-M_V6_final.pdf

Ip Kenneth, Ylitalo Hanna and Marshall David, “Environmental performance of external roller blinds in the UK”; accessed July 2 2015 from about.brighton.ac.uk/ccp/index.php/download_file/view/462/306

Lullaby Trust, Fact Sheet on Temperature”, Lullaby Trust; Accessed February 6, 2017. http://www.lullabytrust.org.uk/file/Fact- Sheet-Temperature.pdf

Paule,B, Boutillier J and Pantet S. Global lighting performance, Annual report 2013R2014. Project 81 0083 : Swiss Federal Office for Energy, Lausanne, 2014. Accessed Februry 6, 2017. http://www.estia.ch/daylighting/lp8we

Seguro Federico and Palmer Jason for NEF (National Energy Foundation) “*Solar Shading Impact. Business Case | Strategic Vision”| Action Plan, June 2016; National Energy Centre, Milton Keynes UK*

Swainson, Michael, Henderson John and Wright Will, “Solutions to overheating in home Evidence Review”; BRE for Zero Carbon Hub. Accessed 1 August 2016 http://www.zerocarbonhub.org/sites/default/files/resources/reports/ZCH-OverheatingEvidenceReview.pdf

Winstanley, Tim AD Classics: Institut du Monde Arabe / Enrique Jan + Jean Nouvel + Architecture-Studio; 2Cotober 2011. Accessed 17 July 2017 from http://www.archdaily.com/162101/ad-classics-institut-du-monde-arabe-jean-nouvel

Wookey Rachel, Bone Angie Carmichael, Catriona and Crossley Anna, Public Health England; “Minimum home temperature thresholds for health in winter: A systematic literature review;” Public Health England 2014. Accessed 20 July 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/365755/Min_temp_threshold_for_homes_in_winter.pdf

World Green Building Council, “The Case for Green Building, A Review of the Costs and Benefits for Developers, Investors and Occupants”, 2013; Accessed February 6, 2017. http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf

Würzburg Schweinfurt Institute in ES-SO “A New Vision on Solar Shading 2013”. accessed July 20, 2015 from http://www.verozo.be/sites/verozo/files/files/Brochure_SolarShading_screen_LR.pdf

Young Liza, “Getting Warmer: CIBSE’s new guidance to assess overheating risk in homes is timely, as UK summer temperatures soar”. CIBSE Journal August 2017. Accessed 29 August 2017 https://www.cibsejournal.com/archive/PDFs/CIBSE-Journal-2017-08.pdf