NATIONAL ENERGY FOUNDATION

SOLAR SHADING IMPACT

BUSINESS CASE | STRATEGIC VISION | ACTION PLAN

For

BRITISH BLIND & SHUTTER ASSOCIATION

June 2016

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The National Energy Foundation is an independent, national charity based in Milton Keynes. The Foundation has been at the forefront of improving the use of energy in buildings since 1988. It aims to give people, organisations and government the knowledge, support and inspiration they need to understand and improve the use of energy in buildings.

To find out more, please visit www.nef.org.uk or contact info@nef.org.uk.

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This Report was prepared by Federico Seguro, responsible for all Sections except 'Case Study Review' and 'Legislative Review', and Jason Palmer, responsible for the 'Case Study Review' and 'Legislative Review' Sections, and was edited by Jason Palmer. The Executive Report results from the joint effort of the authors. The dynamic simulations in EnergyPlus have been carried out by Federico Seguro and Valentina Monetti.

Executive Report

Background

1. The British Blind and Shutter Association (BBSA) commissioned the National Energy Foundation (NEF) to perform an evidence-based investigation into the current and potential impact of solar shading in the UK built environment. Building on the benefits of shading that is correctly designed, specified, installed and used, NEF drew up a business case for key players, a strategic vision, and action plans to 2020 and 2050.
2. Unlike other contexts in the EU, solar shading still tends to be approached as an optional window dressing - soft furnishing rather than a passive solar control and daylight management tool. There are a number of barriers preventing mainstream uptake of solar shading in UK buildings.

Barriers

Devaluing

3. The scientific and the business case for shading is poorly understood by building professionals, institutions, consumers, and, to some extent, the industry itself. The National Building Specification misleadingly classifies shading as a general fixture / fitting rather than an active component of the thermal building envelope. Assessments of best-practice – including voluntary green building certification schemes – also allocate few credits to using shading.

Sub-optimal Performance

4. Sub-optimal shading performance occurs because of deficiencies / lack of understanding at the manufacture / design / specification / installation stage. A number of reasons lie behind sub-optimality, including: limited product development, reductionist building design (as opposed to holistic), conceptual separation from other building services, 'afterthought' installations and inadequate preventive maintenance.

Unexploited retrofit market

5. 80% of existing buildings will still be standing in 2050. Single and uncoated-double glazing, more 'permeable' to solar energy, are still common in the UK's and the EU's existing building stock. The EU aims to raise the rate of renovation from 1.2% to 2-3% a year by 2020. Despite these supporting factors, the UK solar shading industry has not managed to turn the retrofit market into a tangible business.

Ill-informed occupants

6. Poorly-informed users make it harder for shading to unlock its full potential. Even automated systems can be by-passed via manual overrides. Occupant behaviour is variable and sensitive to the individual preferences and contextual variables. Although research into energy behaviour is underway, understanding how these variables interact with each other and can be governed is complicated.

Lack of leadership

7. The UK solar shading industry has lobbied less successfully than other industries such as insulation, glass and glazing and building services. The presence of the industry in continental Europe is stronger, underlined by the Energy Performance of Buildings Directive (EPBD) recast. The EPBD steers towards prioritising passive solar control measures in the first instance to tackle externalities such as global warming, rising energy prices and power shortages. Whilst the message has been successfully circulated across the EU, the UK market is still unreceptive.

Context setting

Benefits

8. NEF summarised the benefits of best-practice in conjunction to shading systems in three broad areas: comfort, occupant implications and energy implications. Each area has been distilled into a number of key aspects, demonstrating how shading can contribute to address them, in Table 1.

Table 1: Impact of shading on comfort, occupants, and energy.

	Issue	Shading Impact
Comfort		
Thermal comfort	○ The surface temperature of inefficient glazing units differs from the temperature of other surfaces and the mean air temperature i.e. the operative temperature (surface + ambient air temperature) does not sit within the comfort range. ○ Low operative temperatures inhibit dexterity and increase sensitivity to draughts. ○ High operative temperatures increase perception of air dryness and draughts. ○ Exposure to uneven thermal radiation results in radiant temperature discomforts. ○ Mechanical air-conditioning does not alter radiant heat exchange.	○ Shading insulates the transparent envelope of the building. ○ Mitigated window surface temperatures, reduced ΔT between perimeter and interior areas of the building. ○ Experimental and modelling studies show year-round improvements in the indoor thermal environment even in colder weather, by lowering radiant temperature asymmetry and mitigating operative temperature extremes. ○ Reduce / eliminate the need of secondary perimeter heating systems.
Visual comfort	○ People in developed countries spend almost 90% of their time indoors (ES-SO, 2014). ○ Poor visual comfort affects task performance and triggers negative physiological effects e.g., headaches and eye-strain. ○ Insufficient daylight. ○ Glare disrupts the occupant's visual focus. ○ Poor colour rendition exacerbates levels of stress and reduces productivity. ○ Lack of visual contact with the outdoors.	○ More glass can be used. Increased potential for biophilic design. ○ Bias for naturally lit environments, daylight is circadian-effective and triggers positive emotional, attitudinal and cognitive responses in the individual. ○ Regulation of luminance according to varying visual comfort needs (adjustable only). ○ Addresses discomfort glare. ○ High colour rendering index.
Acoustic comfort	○ External noises (noisy neighbours, urban traffic, motorways, rail and air traffic). ○ High reverberation times due to sound-reflecting objects in the environment. ○ Acoustic design is often overlooked to prioritise aesthetics and distribution aspects. ○ Standard glazing has a low sound insulation factor i.e., is permeable to sound propagation. ○ Prolonged exposure to high noise levels interferes with mental tasks and in extreme cases can result in cardiovascular problems.	○ Limited acoustic insulation, but reduced sound transmission and reverberation time. ○ Woven or non-woven exterior shading more than 10 cm away from the glass acts as an additional layer of acoustic insulation and reduces sound waves at the critical frequency. ○ Alternative to sound absorbing glass.
Occupant implications		
Indoor air quality (IAQ)	○ Concentration of specific pollutants emitted by indoor / outdoor (airborne) sources exceeds competent bodies' allowances. ○ +20% of the occupants dissatisfied on perceived IAQ. ○ Poor IAQ affects comfort and productivity and can result in airborne respiratory infections. ○ Occupants' perception of IAQ exacerbated at higher internal temperatures. ○ Under-ventilation due to occupants / obstruction of natural ventilation outlets.	○ Improved perceived IAQ: lower solar gains, lower internal temperatures. ○ Low-pollutant emitting shading fabrics (e.g., VOCs) with low / zero pollutants. ○ Adjustable shading does not permanently affect supply of fresh air. ○ No accumulation of pollutants if regularly maintained throughout the service life.
Productivity	○ Effects of poor indoor environmental quality on human resources' efficiency and productivity in the workplace. ○ More frequent sick leave. ○ Work performance diminishes below 19-22°C and above 23-24°C. ○ Staff-related costs are a major item of expenditure in workplaces such as offices (80-90% of the total operating costs).	○ More glass can be used. Increased potential for biophilic design. ○ Contributes towards productive working environment. ○ Success stories e.g., Lockheed Building 157 showed reduced absenteeism and higher productivity on top of savings in energy bills, which more than paid back the extra investment cost.

	Issue	Shading Impact
Security and privacy	○ Untreated glass is at risk of intrusion. ○ Hazard in the event of breakage from the glass falling. ○ Low privacy with unshaded clear glass.	○ Functional / visual separation in mixed-use buildings. ○ Protective 'barrier', anti-intrusion deterrent. ○ Two-way privacy.
Controllability	○ Fixed solar shading beneficial in summer conditions comes at the price of reduced solar gains and daylight in winter i.e. higher space heating and artificial lighting loads. ○ Occupant typically interacts with shading in response to visual rather than thermal comfort needs. ○ Performance gap. Innovate UK's Building Performance Evaluation programme revealed commissioning and user-related issues where automated equipment configurations where in place.	○ Differentiated market offers – manual control in owned / shared properties (privacy, visual comfort), automatic control in un-owned properties. ○ Responsiveness to varying environmental conditions and occupants' needs (adjustable only). ○ Automation potential as a function of external variables e.g., solar irradiance, wind speed, luminance. ○ Integrating automation with overall building management system.
Energy implications		
Operational savings	○ Existing buildings in the UK are responsible for 44% of overall energy consumption. ○ 80% of the buildings in 2050 have been already built. ○ The UK government is committed to cutting greenhouse gas emissions by 80% by 2050. ○ The Cambridge Housing Model estimates 23% single glazed, and 27% pre-1950 uncoated double glazed properties in England. ○ Poor energy efficient glazing units constitute weak points in the building fabrics thermal performance. ○ Constraints around glazing upgrades in conservation areas.	○ Self-financing climate control system via solar control and daylight harvesting (more glass can be used). ○ Insulation of the transparent envelope. Reductions in double-glazing U-values from 21% to 38% (clear) and 13-25% (low-e), and g-values from 16% to 82% and 13% to 85% respectively, based on calculations of different shading types to EN 14501, EN 13363-1 and EN 673. ○ External shading positioned effectively according to the sun reduces solar gains in summer, not in winter. ○ Closed overnight, night-time insulation in winter.
Overheating	○ Global warming, higher daily mean and maximum temperatures expected in 30 years across all the UK. ○ Zero Carbon Hub estimates 20% of England homes overheat in summer. ○ Zero Carbon Hub estimates a tripling of heat-related deaths in England and Wales by 2050 (combination of climate change and ageing population). ○ Although not in the short term, existing buildings might experience overheating throughout their service life, which frequently extends beyond 100 years. ○ Hospitals increase in risk of airborne infections. ○ Highly insulated and airtight buildings frequently report overheating throughout the whole year, winter included.	○ Reducing the proportion of incoming solar radiation that is absorbed by internal objects and reradiated as thermal radiation i.e. greenhouse effect. ○ Reflective finishes on the window facing side of internal shading further reduce the incident solar radiation absorbed and reradiated as heat. ○ Energy analyses of high performing buildings against future climate scenarios show solar shading to be one of the most cost-effective solutions to tackle increasing occurrence of overheating. ○ Reduce / eliminate need for mechanical space cooling. ○ Address difficulties in cooling naturally ventilated buildings in urban settings with high pollution and noise levels.

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Case study review

9. NEF's case studies of the 52-storey New York Times (NYT) Building and, closer to home, the 95-storey Shard in London show what integrated solar shading can achieve. The NYT Building has twin-skin curtain walling with thousands of ceramic rods on all but the north facade, along with automated roller blinds inside. Modelling indicated that this setup saved 24% of the energy used in a conventional design. The Shard has triple-skin glazing, with motorised open weave roller blinds and a ventilated cavity between the inner and outer layers of glazing. The blinds are automatically controlled by a system which tracks the angle of the sun and solar gain throughout the year. With a total solar energy transmitted through the window + shading package as low as 0.12, around 88% of the total incoming solar radiation could be rejected. The Shard is estimated to have CO_2 emissions of 28.2 $kgCO_2m^{-2}year^{-1}$, which would be around a third of the average CO_2 emissions (75 $kgCO_2m^{-2}$) of the 50 new construction non-domestic buildings studied as part of the Innovate UK's BPE portfolio.

Quantifying the Impact

10. A Cost-Benefit Analysis (CBA) of representative shading configurations against a subset of alternative space cooling strategies (window films, tinted glass and fan coil systems) was conducted to quantify the impact of shading against the yardsticks of thermal, visual, functional and operational performance, aesthetics; cost, energy and CO_2 savings.

11. The exercise was informed by a literature review, in particular of the US Department of Energy-supported Window Covering & Attachments portal developed by Lawrence Berkeley National Laboratory (LBNL) and BuildingGreen Inc. (2013). NEF conducted research to infer typical cost ranges, and dynamic simulation modelling (DSM) in EnergyPlus for one highly glazed office building in London to define the energy, running costs and CO_2 emission saving potential against a shading-free baseline scenario.

12. Rather than ranking of the cost-effectiveness of competing products, the CBA highlighted that no single solution can be taken as de facto the best given the variables in the equation – the optimum will be a function of the specific needs that vary on a building by building basis. In particular, integrated external and internal solar shading systems emerge as a cost effective means of addressing cooling, heating and visual comfort (Hutchins, 2015).

13. Although it is dependent on the assumptions made, the modelling indicates that substantial energy savings – 5-12% for internal shading and 37-40% for external shading – could be achieved if the reference building was provided with standard roller shades or blinds. The optimal integration of shading from the beginning would reduce (or even eliminate) the need for mechanical space cooling as the nominal capacity of the space cooling equipment was reduced by 9% for internal and 62% for external shading.

14. When this is taken together with improved comfort, aesthetics, durability and service life, the impact of shading extends far beyond the common perceptions of merely reducing glare and overheating.

Looking to the Future

15. Although the means to address most barriers currently faced by the industry are technically available, externalities such as inefficiencies and complexities, fragmentation within the supply chain, and uncertain / unsupportive regulatory requirements exert further impediments.

16. NEF prepared a business case for different stakeholders to take action and change the status-quo – interested parties were manufacturers and suppliers, designers / specifiers, surveyors/installers, Facility Managers / investors, domestic / non-domestic users, government, trade associations, and opinion makers. A separate set of actions for each are reported in Table 2 below.

Legislative landscape

17. At least six EU countries have legislation and tax policies that provide greater incentives to use solar glazing (Austria, Belgium, France, Italy, Norway, and Poland). The problem is in two parts: first, UK legislation on energy efficiency in buildings is complicated and consequently only weakly enforced. And second, there are no tax incentives for building owners or users to install solar shading.

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Strategic vision to 2020 – The industry needs:

18. **Recognition**. A united industry voice that has been working in partnership with the government to produce technology roadmaps leveraging dynamic shading as a crucial milestone towards nearly Zero Energy Buildings after the EPBD recast. The benefits of solar shading are recognised and incorporated within design tools and calculation methods.

19. **Performance**. The solar shading industry is committed to continuous professional development and education. The market demand for best practice and assured performance drives skill updating and training. Building design is approached from a holistic angle, with shading integrated within the process.

20. **Retrofit**. The main regulatory and non-regulatory barriers to the energy retrofit of existing buildings would be addressed by upskilling professionals, R&D and innovative business models. Solar shading is integrated within novel whole house retrofit approaches à la Energiesprong.

21. **Occupant behaviour**. Learning – the industry builds on the framework and common language defined by the academic community to approach energy behaviour and quantitative research, including scientifically-sound models of occupant behaviour.

22. **Leadership**. In an effort to speed up compliance with EU requirements, the UK Government involved solar shading players in the Building Regulations' three-year revision process. BBSA-led initiatives to raise awareness and inspire best practice are afoot.

Strategic vision to 2050 – The industry needs:

23. **Recognition**. Shading is conceived as a solar control and daylight management concept pre-requisite of building design. As such, regulatory compliance is driven by dynamic whole-building performance assessment over different time horizons – short, medium and long-term.

24. **Performance**. The solar shading industry champions the construction sector with respect to R&D and innovation, and interfaces with building professionals to optimise shading in the context of the whole building from the project outset. The offer to the consumer is centred around a performance guarantee and excellent aftercare.

25. **Retrofit**. Technology advances towards renewable integrated shading and pressing governmental targets (80% less greenhouse gas emissions by 2050) boost deep renovation rates. Internationally recognised metrics of performance (comfort, productivity) and financial incentives encourage the uptake of shading.

26. **Occupant behaviour**. Quantitative models of occupant-shading interactions integrated within energy modelling to define optimal solutions on a building-by-building basis. Data monitoring feedbacks drive learning algorithms to fine tune shading in-use.

27. **Leadership**. A united industry that has been lobbying powerfully as a collective and united voice and has taken a lead at UK and EU level.

Where next

28. This Solar Shading Impact report has been envisioned as a 'dynamic' document that will be reviewed in May 2017 according to the feedback received from the readers in the interim.

29. All are invited to send comments, warts-and-all, on the report via the BBSA Shade it website. Comments will be reviewed and implemented into a revised version of the report that will be made available in the public domain.

30. An area of particular focus will be reaching a consensus on the laboratory test procedures on the basis of internationally recognised standards. Currently independent companies refer to research laboratories of their own choosing, and between themselves devise a test representative of the investigated performance. General consensus is sought on what tests are required, and which parameters companies should look at.

31. In addition, BBSA are looking for case studies for circulation/promotion that showcase the optimal use of shading with quantitative evidence of the benefits gained. A possible output of this call could be a new Architectural Competition (open to all countries).

Table 2: Action plan for shading systems in UK buildings with timescale to put the actions in place and short / long term strategic vision.

Barriers	Externalities	Actions	Stakeholders								Time horizon	
	Climate change Stricter Regulations Rising energy prices Technology progress Digitalisation		Manufacturers /sup.	Designers / specifiers	Installers / surveyors	FMs / Investors	Users	Government	Trade associations	influencers	Short term 2020	Long Term 2020-2050
Devaluing	Climate change	Identify training needs and upgrade skills	V	V	V							
	Stricter regulations	Incorporate more specific shading requirements in Part L, Part K, Part F, Part E Approved Documents						V				
	Rising energy prices	Part L to refer to g_{tot}						V				
	Technology progress	Part L to refer to shading as a pre-requisite of air-conditioning						V				
		Part L to provide detailed anti-overheating requirements rather than an averaged allowance						V				
		Part L to be informed by locally accurate climate datasets (present & future) over the building lifecycle						V				
		Part L to be informed by BIM and DSM						V				
		Emphasise beyond energy efficiency aspects such as visual amenity and occupant satisfaction						V				
		Recognise shading as key thermal element of the building envelope in construction specification database		V				V		V		
		Review construction specifications to include whole-life performance requirements		V				V				
		Collate robust body of evidence to demonstrate weaknesses in design compliance tools / Part L approach							V			
		Collate robust body of evidence to justify the business and scientific case for the regulations							V			
		Raise government awareness on the impact of shading, across the board							V			
		Learn overheating lessons from Innovate UK's BPE Programme		V					V			
		Raise the standard bar for the shading industry to perform at its best	V		V				V			
		Raise awareness internally and externally across key opinion makers (e.g., CIBSE, BRE etc.)							V			
		Work towards a CIBSE Solar Shading Guide in addition to existing TM37							V	V		
		Launch an independent overheating tool à la BuildDesk							V			
		Continue developing and promote ES-SDA (Solar Shading PCDB)						V	V			
		Lobby for better recognition of shading in good practice guidelines / mainstream certification schemes / NBS							V			
		Promotion of exemplary case studies and champions							V	V		
		Understand the reasons for using solar shading effectively – shading is not window dressing		V		V	V					
Suboptimal performance	Stricter regulations	Ramp-up R&D investments working in consortia and with academia (e.g., Innovate UK, Horizon2020 calls)	V									
	Technology progress	Recurring third-party assessment of the organisation quality and environmental management systems	V		V							
	Digitalisation (IoT, BIM…)	Formalise and implement a rigorous CPD plan	V	V	V							
		Work with BMS providers to integrate shading with building services and increase the availability of controls	V			V						
		Holistic approach and whole-life thinking for building integrated shading systems	V	V	V			V				
		Specify against Ecodesign of Energy Related Products Directive 2009/125/EC (still at draft stage)		V				V				
		Use / demand of SAP / SBEM for building regulation compliance and DSM to inform the actual design		V		V		V				
		Use / demand of BIM to define the optimal shading configuration in relation to specific boundary conditions		V		V		V				
		Understand climate datasets, the impact on the calculations and changes in future climate scenarios		V				V				
		Aim at cost optimal levels of energy performance throughout the economic service life of the building (EPBD)		V		V		V		V		
		Sensitise the user on the trade-off capital / operational cost associated with high standard building design		V		V		V				
		Increased awareness around the business case for solar shading.		V	V	V	V					
		Assist sales people / surveyors and installers to pitch the business case for intelligent shading.							V			
		Raise awareness on the reasons for using solar shading effectively. Produce User Manuals.				V			V			
		Identify and promote best practice	V	V	V	V		V	V	V		
		Promote energy performance indicators.						V	V			
		Offer post-installation support and set up helpline service throughout the liability period			V				V			
		Systematic maintenance regime, schedule and keep track of preventive maintenance measures in place				V	V					
		Follow-up issues as they arise				V	V					
		Instruct occupant on use of shading at handover / induction, incorporate guidelines in user information pack	V	V		V						
		Understand the cost-effectiveness – solar shading is an investment, not a revenue cost				V						
		Adopt energy conscious behaviour					V					
		Incorporate shading in the building services package, revise fee of building services engineers		V					V			
		Third-party certified performance rating systems for combined shading-glazing unit						V	V			
		Familiarise with EPBD recast, EN 15459 global cost methodology, energy price evolution, reference buildings		V				V	V			

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Unexploited retrofit market	Climate change	Understand technical performance, use consistent technical performance data to EN standard	V									
	Stricter regulations	Focus on bespoke products for variable window types	V							V		
	Rising energy prices	Innovate on visual appearance to minimise visual impact into existing buildings	V	V								
	Technology progress	Innovate on optimal interaction with existing façade systems, e.g. external wall insulation systems	V		V							
	Digitalisation (IoT, BIM…)	Innovate on system adaptability (catering for future scenarios)	V		V							
		Innovate on maintenance-free systems, self-cleaning materials	V									
		Innovate on integration with renewables (from passive to energy-positive systems)	V	V								
		Improve design and interface of controls for ease of use and better acceptance by the user	V									
		Work in partnership with BMS providers for shading to be integrated with existing BMS	V	V	V							
		Explore synergies with Internet of Things (IoT)	V	V	V			V	V			
		Design buildings that can be retrospectively provided throughout their service life with solar shading		V								
		Focus on whole life-cycle performance, benchmark against Reference Buildings to pinpoint cost optimality		V		V		V	V			
		Enhance specifications with more granularity		V								
		Prevent shading from being uncritically value engineered out at later stages		V								
		CPD on retrofit related aspects		V	V	V						
		Whole building approach – understand how shading interacts with the rest of the building	V	V	V	V			V			
		Offer post-installation support and set up helpline service throughout the liability period			V							
		Extend warranties to raise consumer confidence	V		V							
		Appoint accredited installers				V						
		Third-party review product design and installation practices against best practices				V						
		Follow Soft-Landings approach				V						
		Identify and implement preventive maintenance actions throughout the building service life				V						
		Revise building regulations to recognise shading as a pre-requisite to air-conditioning and complex shading						V	V			
		Recognition under future retrofit programmes						V				
		Tax breaks schemes for energy-saving technologies to include shading (e.g. Enhanced Capital Allowance)						V				
		Apply EN standards for shading	V					V				
		Revise EN standards and compliance tools to predict more accurately current and future overheating risk		V				V				
		Review the National Policy Planning Framework to steer on the uptake of solar shading						V				
		Do not scrap solar shading in deregulation agenda						V				
		Clear road-mapping how and when the government intends to retrofit the existing building stock						V				
		Comprehend purchase-decision factors and steer the industry to capitalise on them							V			
		Develop with the academia scientific robust yardsticks / rules of thumb to quantify softer benefits							V			
		Investigate working opportunities with novel whole house refurbishment approaches such as Energiesprong	V						V			
		Identify and promote best practice							V	V		
Ill-informed occupant behaviour	Climate change	Human-centric design and specifications		V								
	Rising energy prices	Better understand reasons of potential performance gap in automation systems	V	V		V						
	Technology progress	Occupant-related learnings from the BPE programme, and mitigation measures at design / specification		V		V		V	V	V		
	Digitalisation (IoT, BIM…)	Monitor occupants' interactions with shading – surveys + sensors data; rectify suboptimal behaviour				V						
		Systematic handover with key project organisations involved, instruct on shading-related best practice		V		V						
		Educate and instruct on shading optimal operation and maintenance regime in user guides and manual	V	V		V						
		Awareness raising, contests amid owned buildings to showcase and award best-practice				V						
		Fund research in the area of energy-related occupant behaviour in buildings and quantitative social research	V					V				
		Understand triggers of occupants' positive/negative response from BPE's Building User Satisfaction surveys	V	V					V			
		Learnings from IEA-EBC Annex 66 'Definition and Simulation of Occupant Behavior in Buildings'	V	V					V			
		Work with academia to characterise most common profiles of solar shading use via DSM / in-field studies		V					V			
		Disseminate solar shading best practice guidance to occupants tailored to building types		V					V			
Lack of leadership	Climate change	Aim at third-party assessment of quality and environmental management systems	V									
	Stricter regulations	Formalise and implement a rigorous CPD plan for employees	V									
	Rising energy prices	Continue to innovate	V									
	Technology progress	Identify and implement best practice			V							
		Optimise installations in relation to effects on the whole building performance			V							
		Identify and promote best practice, champions, and case studies			V			V			

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		Act as a single point of contact with the government of a collective and united industry voice							V			
		Work in partnership with governments to the establishment of a more supportive regulatory landscape							V			
		Intensify dialogue with EU and international solar shading trade associations and key influencers (BRE, Arup)							V			
		Raise the bar of the membership requirements in particular with regard to CPD commitments							V			
		Inspire the industry to be at the forefront for quality and innovation across the UK construction industry							V			

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Executive Summary

Background

1. Against the backdrop of global warming and growing energy prices, there is a pressing need to design buildings that do not overheat. Passive cooling techniques such as shading systems are identified as priorities by the EU as not energy-intensive means of reducing or even eliminating the need for mechanical space cooling systems such as fan coils.

2. The positive effects of correctly specified, designed, installed and used shading systems go beyond the energy implications (reduced overheating) to include comfort and productivity. In the UK, the efficacy of solar shading is still poorly recognised. Lack of awareness and the use of simplistic design tools can be seen as misrepresenting or devaluing solar shading.

3. The British Blind and Shutter Association commissioned the National Energy Foundation to study the UK context and particularly (i) context setting, evidence-based insights into the value of shading, (ii) qualifying the role of shading in the market, and (iii) looking to the future, identifying the steps required to fully unlock the potential of shading.

Context setting

4. Comfort – experimental and modelling studies prove year-round improvements in the thermal comfort of occupants from more even thermal radiation and less extreme operative temperatures, and in the visual comfort from regulating luminance levels and reducing discomfort and glare. Shading can also improve acoustic insulation.

5. Use – shading insulates the transparent envelope and allows more glass to be used i.e. maximising daylight, which triggers positive emotional, attitudinal and cognitive responses in the workplace. Shading also improves the perception of indoor air quality, which degrades at higher indoor temperatures, can provide privacy, functional / visual separation, and, if automated, dynamic adjustments to varying environmental conditions.

6. Energy and carbon – solar shading is a self-financing climate control system in terms of solar control and daylight management that, tuned to the sun peak seasonal angles and closed over-night, can bring energy savings even in winter. Solar shading emerges as one of the most cost-effective solutions to tackle the increased occurrence of overheating expected in future.

Quantifying the impact

7. Substantial energy savings were estimated for a highly-glazed office if it was provided with standard shading – up to 12% for internal and 40% for external shading. On top of that, the impact of shading should be approached holistically, in relation to the operational energy saving potential across the whole service life of the building (e.g., 100 years) and against future climate scenarios, thermal / visual / functional performance, durability, and aesthetics. No single solution can be assumed as optimal, and the best choice of shading varies on a building by building basis.

Looking to the future

8. A joint strategic vision / action plan over the short term (by 2020) and long term (by 2050) was drawn together with the business case for different stakeholders. This aims to change the status quo and put shading on an equal footing with other energy efficiency measures in the UK.

9. The main priority is the formal recognition of the benefits of solar shading by design tools and calculation methods.

10. Over the short term, the whole industry ought to commit to continuous professional development, training and best practice; partner with the UK government towards whole-building approach based on nearly Zero Energy Building roadmaps and contribute to revising Part L. Work is also needed to overcome regulatory and non-regulatory barriers to retrofit and learn from occupant behavioural research.

11. Over the long term, the industry should aim to lead on R&D and innovation, lobbying effectively at the UK and EU tables. Shading should be seen as a pre-requisite of building design, supported by internationally agreed metrics for 'soft' (non-financial) benefits, optimised by using occupancy-driven learning algorithms and complementing the government's energy efficiency and carbon targets e.g., 80% less greenhouse gas emissions by 2050.

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Abbreviations: ACH, Air Changes per Hour; BBSA, British Blind and Shutter Association; BEM, Building Energy Management; BIM, Building Information Modelling; BMS, Building Management System; BPE, Building Performance Evaluation; BREEAM, Building Research Establishment Environmental Assessment Methodology; BRI, Building Related Illness; CBA, Cost-Benefit Analysis; CHM, Cambridge Housing Model; CPD, Continuous Professional Development; CRI, Colour Rendering Index; DSM, Dynamic Simulation Modelling; ECORP-EU25, Energy Saving and CO_2 Reduction Potential from Solar Shading Systems and Shutters in the EU-25; EERE, Office of Energy Efficiency and Renewable Energy; EPBD, Energy Performance of Buildings Directive; ES-SDA, European Solar Shading Database; GHG, Greenhouse Gas; HVAC, Heating, Ventilating, and Air Conditioning; IAQ, Indoor Air Quality; IEQ, Indoor Environmental Quality; IoT, Internet of Things; IWEC, International Weather for Energy Calculations; LBNL, Lawrence Berkeley National Laboratory; M&V, Measurement and Verification; NBS, National Building Specification; NEF, National Energy Foundation; nZEB, nearly Zero Energy Building; PCDB, Product Construction Database; PHPP, Passivhaus Planning Package; SAP, Standard Assessment Procedure; SBEM, Simplified Building Energy Model; SBS, Sick Building Syndrome; VOC, Volatile Organic Compounds.

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01 INTRODUCTION

In the UK building culture, solar shading systems tend to be devalued as mere remedial solutions irrespective of their efficacy.

On top of an aesthetic return, correctly designed, specified and installed shading provides a wide variety of benefits including:

- More glazing – highly glazed areas can be used as shading improves the insulation of the building's transparent envelope.
- Improved comfort – optimised thermal and visual comfort, enabling a more productive internal environment.
- Reduced energy – reduced space cooling and, if properly insulated and operated, space heating loads, resulting in operational energy savings and CO_2 emission reduction.
- Compliance with Regulations – compliance with health & safety requirements and building regulations; alignment with legislation to tackle overheating.

Box **Key Term**

Solar shading

Solar shading is a broad term that encompasses all of the systems that regulate the incoming solar radiation within the built environment, such as shutters, blinds, brise soleil and awnings.

Although commonly used in building design, shading systems are not beneficial to summer periods only but also permit heating related energy savings in winter via, for instance, night-time thermal insulation (Hutchins, 2015).

A number of barriers are faced by the UK solar shading industry, ranging from poor understanding of the business case for solar shading to 'institutional' shortcomings. Part L compliance tools, the Simplified Building Energy Model (SBEM) and the Standard Assessment Procedure (SAP) can be seen as mis-representing or devaluing solar shading. Voluntary sustainability certification schemes frequently do not fully recognise and reward the benefits of shading. The National Building Specification (NBS) classifies shading as a general fixture / fitting element (Section N10).

Lack of awareness and simplistic design tools lie at the heart of poor recognition of the positive effects of shading systems.

Against this backdrop, the British Blind and Shutter Association (BBSA) commissioned the National Energy Foundation (NEF) to carry out an evidence-based study on the efficacy of solar shading and its positive impact within the UK built environment.

Under the facilitation of NEF, the project was also envisioned as a forum to engage BBSA members in a unified manner towards a united industry providing a single point of contact with the key stakeholders.

Two Project Workshops at the beginning and at the end of the project steered the study and took on the board inputs from the BBSA experts.

Aim and objectives

This *Solar Shading Impact* report aims at providing a business case to leveraging the benefits associated with using correctly specified and installed shading systems and to stimulate awareness in the UK, drawing on EU best practices.

The project took the form of four work packages set out in Table 1.

Table 1: Project outline.

Work Package	Description
WP 1: Context setting - Literature and evidence base.	Review of evidence and data regarding correctly specified and operated building shading systems in relation to: 1. Comfort (thermal, visual, acoustic); 2. Occupant implications (indoor air quality, productivity, security and privacy, controllability); 3. Energy implications (operational savings and overheating mitigation) A review of two exemplary case studies was conducted to further illustrate both the presence of overheating and glare as an issue and to advocate the role the solar shading can play when if holistic approach is applied to building design.
WP 2: Quantifying the impact and relative advantages and costs of shading systems.	A review of the relative costs and benefits of solar shading compared to alternative strategies and products deployed in a range of common building types.
WP 3: Looking to the future.	Identifying the steps required to bring about a more equitable standing for the use of solar shading in the UK given existing and emerging practices and requirements in the UK and Europe. Developing a strategic vision of the industry's position in the building sector and wide awareness of how it can contribute to meeting the 2050 greenhouse gas emission (GHG) reduction targets.
WP 4: Workshops.	Kick-off and final wrap-up workshops with BBSA representatives held at the beginning and at the end of the project to take on board inputs and discuss findings.

Methodology

The working methodology broken down into the three technical Work Packages (1-3) identified in Table 1 is outlined in this section, in terms of scope, approach and sources underpinning each WP.

WP1 Context setting, reviewing literature and evidence base

Scope

Investigation of evidence into the benefits of optimal solar shading in terms of comfort (thermal, visual, acoustic); indoor environmental quality; productivity; security and privacy; operational energy (and CO_2) savings; and mitigation of overheating risk. A classification of the products available on the market was also presented to understand the complexity of the shading market.

Approach

Collection of evidence from literature review. Two representative case studies demonstrating exemplary use of shading systems were reviewed which addressed the visual (glare) and thermal (overheating) issues and successfully adopted a holistic approach to building design.

Sources

A literature review of recent reputable industrial research, peer reviewed journal publications, grey literature and other relevant sources, including also BBSA recommended studies. Referencing all sources offered BBSA and its members a useful directory of resources for future work.

WP2 Quantifying the impact

Scope

The performance of different solar shading systems was qualified via a cost-benefit analysis, benchmarking against typical passive cooling strategies and products commonly adopted as an alternative to shading. The scope of the exercise was to shed light on the need for an informed and holistic approach to building design rather than ranking the cost-effectiveness of competing products.

Approach

Critical evaluation of key yardsticks including thermal, visual, functional and operational performance, aesthetics, cost and energy and carbon dioxide savings. Depending on the aspect under review, the performance was evaluated in qualitative or quantitative terms and coupled with cost information to produce a cost-benefit analysis.

Sources

The exercise was informed by the WP1 findings and further literature review, in particular the US Department of Energy-supported Window Covering & Attachments portal developed by Lawrence Berkeley National Laboratory (LBNL) and BuildingGreen Inc. (2013). Typical costs were determined via market research. Dynamic simulation modelling of one office buildings were carried out in EnergyPlus to assess the energy and CO_2 saving potential against a shading-free baseline scenario.

WP3 Looking to the future

Scope

It is generally recognised that considering solar shading at an early stage in design makes it easier to integrate with other parts of the building, and ultimately more successful, preventing solar control from being an after-thought added as a remedial solution. Integrated design was one of the key leverages against which the business case for solar shading was built. Drawing on EU best practices, recommendations on how to alter the policy framework and encourage greater use of solar shading were provided. Preventing shading from being value engineered out of projects even after it has been specified (as it was the case in, for instance, the Walkie Talkie skyscraper) was also a key area. A joint strategic vision / business case / action plan was developed to address the main barriers faced up by the industry – sub-optimal performance, devaluing, unexploited retrofit market, Ill-informed occupant behaviour and lack of leadership. The timescale of this forward-looking exercise was set over the short term to 2020, and long term to 2050 as the UK government has pledged to cut 80% of greenhouse gas emissions against 1990 levels by then.

Approach

Establishing a strategic vision that created the boundary conditions to better value the benefits of solar shading, not only the energy dimension, and indicated where future efforts should be concentrated to make this vision happen.

Sources

Review literature including studies from the European Solar Shading Organisation carried out in countries that show a better understanding of the business case for solar shading.

02 CONTEXT SETTING

It is difficult to capture the variety of the solar shading market in a single snapshot.

Recent years have seen product specialisation in relation to aspects such as the building orientation and location and this has further extended the market.

Technology advancement and product specialisation result in increased market offers, covering different building types and needs.

A classification proposed by Bellia et al. (2014) subdivided solar shading systems into fixed / adjustable external / internal / 'intermediate' depending on the actual configuration. The main shading types identified by the authors were overhang, side-fin and light-shelf for fixed systems; horizontal / vertical louvers for fixed/adjustable systems; and blinds for adjustable systems.

In contrast, the Solar Shading Systems Product Sheets refer to static-non retractable; dynamic-extendable / retractable; permanently integrated systems, broken down into a number of configurations (ES-SO, 2009). The performance of each variant was compared against a reference building including aspects such as service life, comfort, and impact on g- and U-values.

A granular overview proposed by LBNL and BuildingGreen Inc. (2013) categorises several interior and exterior window covering options. The first category embraces products such as drapes, curtains, cellular / pleated / roman shades and louvered shutters / blinds. The second category includes fixed and retractable awnings, roller shades / shutters and solar screens.

In the UK, the BBSA, the national trade association of companies that manufacture, supply and install solar shading products, is the single largest source of information covering the solar shading industry.

The BBSA website offers an exhaustive picture of the shading market state-of-the-art.

The BBSA member database has been used to characterise the UK market offer of internal and external shading devices, which is pictured in Figure 1 and Figure 2.

Internal shading systems include blinds, shutters, screens, mid-pane blinds, and tensile structures. External systems are condensed into the broad categories of roller blinds, venetian blinds; fixed / moveable louvre arrays (brise soleil); tensile structures / shade sails; canopies; and awnings – walkways, conservatory, folding and drop and sliding arms.

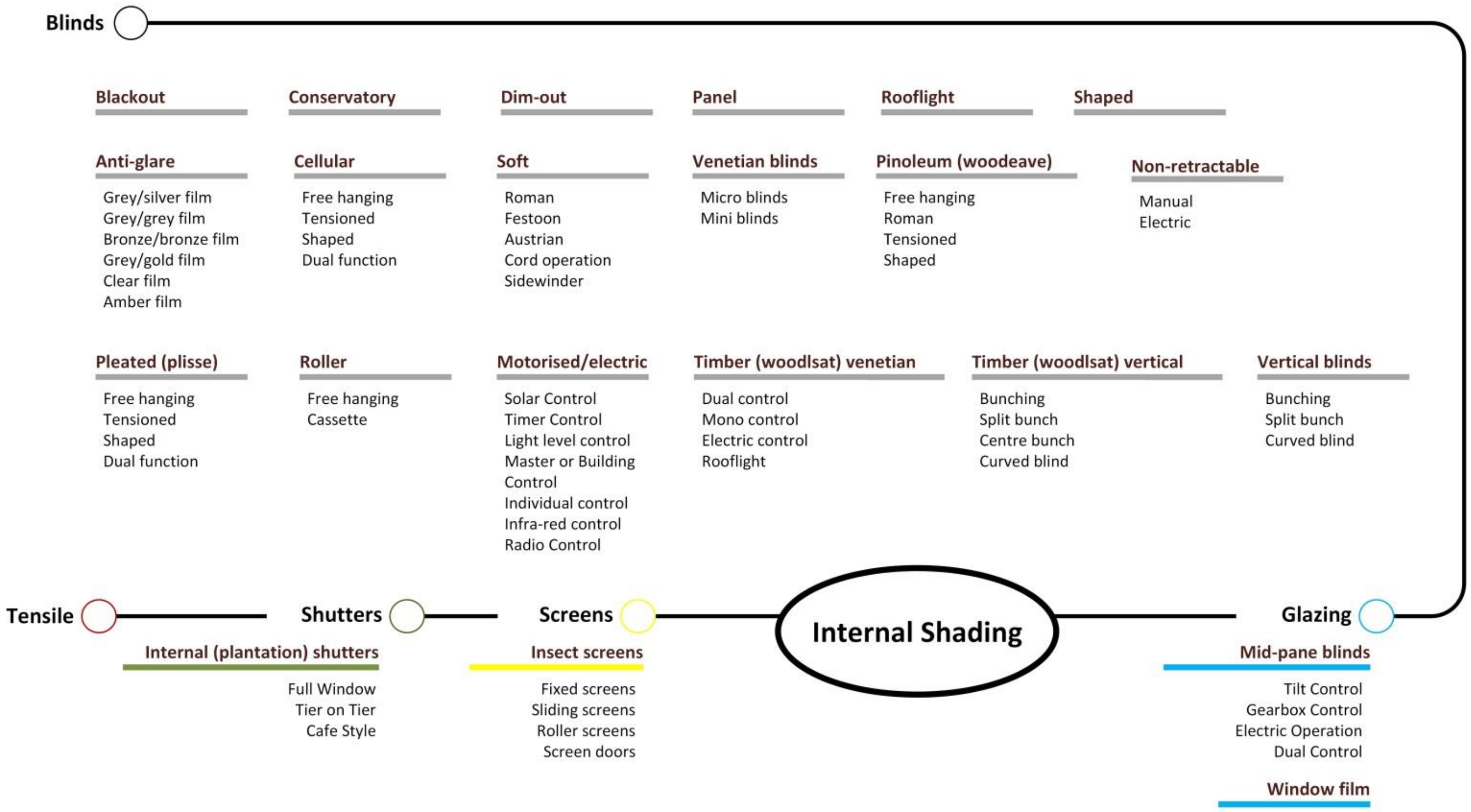

Figure 1: Internal shading: UK market offer (Source: BBSA Member Database).

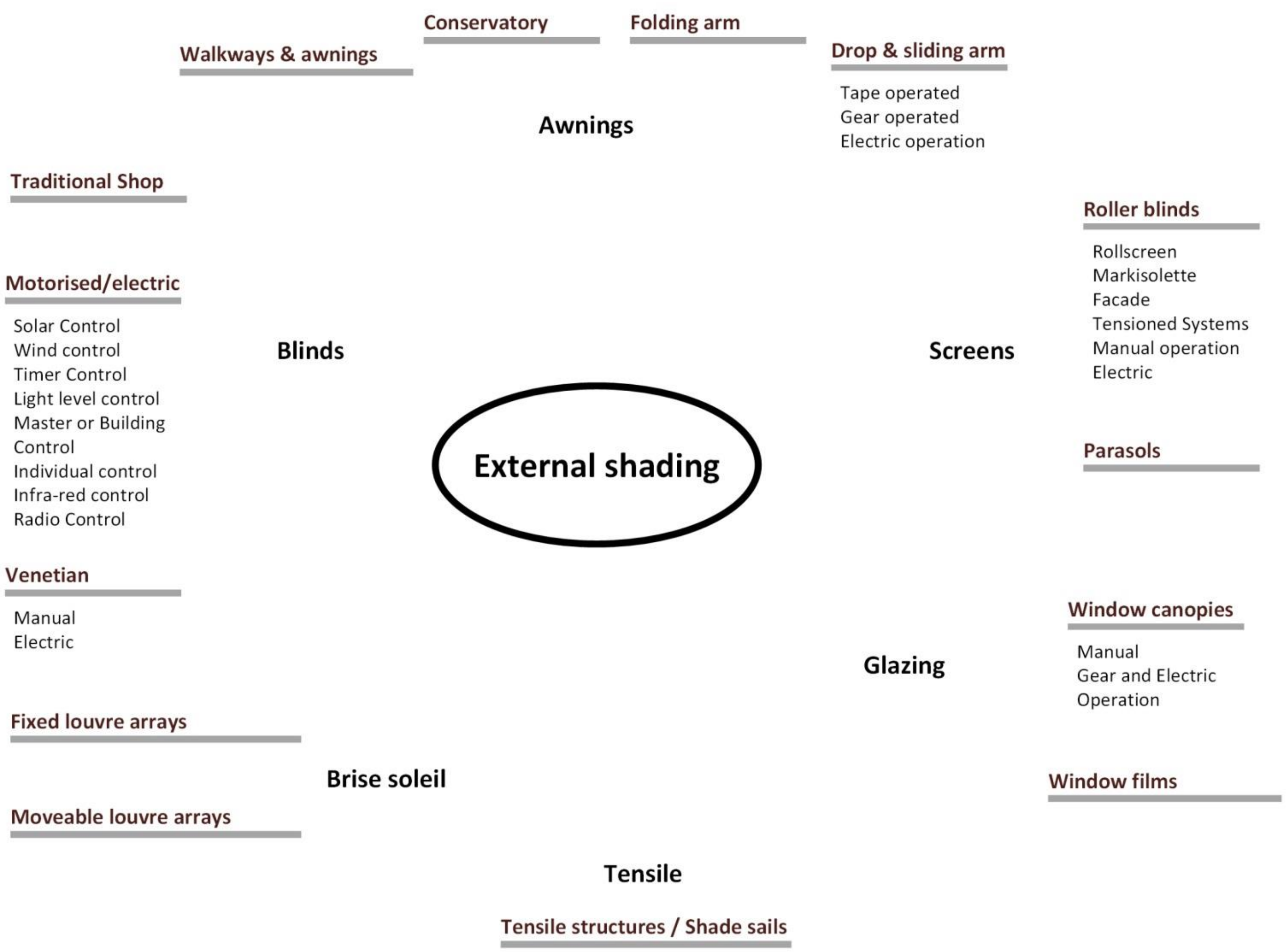

Figure 2: External shading: UK market offer (Source: BBSA Member Database).

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Accordingly, the performance of the various shading systems currently available differs greatly, and whilst there is no shading system which can be assumed as de facto optimum for the future, different configurations can meet a variety of different buildings, uses and needs.

Although the scope of this project was not an insight into the different options available, the wider range of benefits associated with solar shading were categorised under the headings of comfort, occupant implications, and energy implications.

Comfort

- Thermal comfort
- Visual comfort
- Acoustic comfort

Occupant implications

- Indoor air quality
- Productivity
- Security and privacy
- Controllability

Energy implications

- Operational energy savings
- Overheating

The effects of solar shading go far beyond reduced glare and overheating and impact on the whole liveability and indoor environmental quality.

Each aspect has been framed via three colour-coded tabs outlining: (i) the general problem, (ii) how solar shading can contribute to solve it, and (iii) how its effectiveness can be measured.

Problem – definition of the critical aspects underlying specific problems.

Solution – how solar shading can provide a potential solution to the specific problem under review.

Measuring Performance – review of the key performance parameters and tools relevant at measuring the shading performance.

A definition of the key terms adopted in the narrative is finally provided.

Thermal comfort

Problem

Thermal comfort depends on the combined effect of the ambient air temperature and the temperatures of the surrounding surfaces, embraced in the concept of operative temperature.

Thermally inefficient glazing units have interior surface temperatures differing from the temperature of the other surfaces and the mean air temperature. This results in an excessive gap from the optimal operative temperature leading to uncomfortable internal conditions. Energy intensive mechanical air-conditioning cannot alter radiant thermal exchange.

Operative temperatures that are too low have an impact on manual tasks due to reduced dexterity of hands and sensitivity to draughts. Operative temperatures that are too high are associated with increased perception of air dryness and draughts due to convective flows (Beck et al., 2010).

A poorly insulated transparent envelope can also result in local thermal discomfort due to non-uniform thermal radiation (termed as the asymmetric plane radiant temperature) e.g., in perimeter zones of the building.

Solution

Solar shading is a passive design solution that can effectively act as the insulation of the transparent building envelope (BBSA, 2015). In particular externally adjustable solar shading can mitigate the window surface temperature, improving the indoor thermal conditions and reducing the temperature difference between perimeter and interior areas.

The positive effects of shading systems on the indoor thermal environment are well-recognised in hot climates (Al-Tamimi and Fadzil, 2011; Freewan, 2014; Arifin and Denan, 2015). Although often undervalued, the impact of shading in maintaining thermal comfort is also present in colder weathers (Foldbjerg and Asmussen; 2013). Bessoudo et al. (2010) tested the effects of different shading devices (roller shades and venetian blinds) on the indoor thermal environment of a glass-façade new construction office in Montreal. On clear winter days, both roller shades and venetian blinds with tilt angle of the slats of 45° reduced the direct component of solar radiation incident on the occupant, and therefore improved the comfort conditions. On cloudy winter days, the experimental results showed that shading devices reduced the transmission heat loss through the façade. Tzempelikos et al. (2010) followed-up the experimental studies with a validated dynamic thermal model of the building. The results reinforced the improved thermal conditions resulting from decreased radiant temperature asymmetry and mitigated extremes in the operative temperature range. The conclusion was that advanced façades with integrated glazing-shading can maintain adequate comfort and even remove the need for auxiliary perimeter heating systems. Serra et al. (2010) presented the results of an extensive monitoring campaign on the prototype of an active integrated façade including an inter-pane shading configuration (venetian blind / roller screen) carried out in Turin, which found a heating effect on the ventilation air flow in terms of pre-heating efficiency and offset the ventilation losses and impacts on the unit surface temperatures.

Measuring performance

- According to ISO 7730/2005, comfort conditions lie within a range of operative temperatures typically comprised between 23°C and 26°C in summer conditions and 20-24°C in winter conditions for sedentary activities.
- The allowable radiant temperature asymmetry should be below 10°C for cool walls to prevent local discomfort.
- The European Standard EN 15251 has introduced a four category system for different levels of thermal comfort identifying the maximum allowable temperature difference between the comfort temperature and the actual operative temperature across a number of buildings.

Box Key Terms

Thermo-hygrometric comfort

Status of thermal neutrality experienced when the human body's mechanisms of behavioural and vasodilation thermoregulation are inactive. It is a function of two personal variables (metabolic rate and thermal resistance of the clothing) and four environmental variables (air temperature, mean radiant temperature, air velocity and relative humidity) (Fanger, 1970). Even with an optimal thermal neutrality however, localised over-heating or cooling conditions might result in thermal discomfort (ISO 7730:2005).

Operative temperature

Weighted average of air temperature and mean radiant temperature, which is the weighted mean temperature of the surfaces surrounding a body with whom thermal radiation is exchanged at rates varying depending on their emissivity ε (ISO 7730:2005).

Visual comfort

Problem

It is estimated that people spend almost 90% of their time indoors (ES-SO, 2014). An uncomfortable visual environment has detrimental effects on the occupant. The interplay of glare, insufficient daylight, lack of access to a window or inadequate lighting quality results in visual discomforts. Poor visual comfort not only affects task performance but is also a cause of physiological disorders, such as headaches, eyestrain and emotional malaise.

- **Poor daylighting** – insufficient daylight exposure is common in industrialised countries; laboratory and in-field studies have associated negative behavioural effects such as depression and reduced vitality (CIE 158:2004).
- **Discomfort glare** – is due to excessive levels of exterior luminance within the field of view, inadequate contrast or direct sunlight incident on the occupant's visual focus.
- **Inadequate colour rendition** – depending on the type of artificial light, a poor colour rendition can occasionally have detrimental effects in terms of stress levels and productivity.
- **Lack of contact with the outdoors** – inadequate visual contact with the outside world has a negative impact on quality of life, sleep and physical activities.

Solution

The preference for daylighting as opposed to artificial lighting is proven in buildings. Daylight is circadian-effective and triggers positive emotional, attitudinal and cognitive responses in the individual (Strong, 2012). The World Green Building Council estimates that, in an office environment, a worker exposed to daylight and visual contact with the outside sleeps 46 minutes more per night as opposed to a worker in an office with no natural light. In particular connection with nature – termed as biophilia – has recently emerged as inspirational in work environments. A study on the impact of biophilic design in the office space estimated that proximity to natural elements such as greenery and sunlight was associated with 15% improved wellbeing and creativity and 6% higher productivity, and ranked daylight and indoor plants as the top two elements desired by office workers (Human Spaces, 2015). As people in developed countries spend most of their time indoors, the liveability of well-designed workspaces becomes crucial.

To make best use of daylighting, regulation is needed to address discomfort glare and achieve appropriate levels of luminance, as excessive exterior luminance is often detrimental to visual comfort (Beck et al., 2010). The 1992 Health and Safety (Display Screen Equipment) Regulations indicates that windows should be fitted with adjustable covering to attenuate the intensity of sunlight on the workstation. Solar shading attenuates and diffuses sunlight, enabling reduced luminance ratios to be tuned to the recommended luminance relationships between visual task, central and peripheral fields of view. Dynamic shading allows daylight levels to be maintained within comfortable limits irrespective of the variability of external illuminance throughout the year.

In addition, solar shading integrated with clear glazing is associated with a high Colour Rendering Index (CRI), i.e. accurateness in rendering the colours across the visible spectrum (BBSA, 2015). In contrast, solar control glass limiting solar gain can negatively affect the quality of light as well as the glass light transmission potentially undermining the minimum daylight provision prescribed by the Building Regulations.

Measuring performance

As a rule of thumb, good visual comfort follows the 1:3:10 rule. Under daylight conditions, the luminance level of the central field of view should be no more than three times the luminance of the visual task, and between 0.1 and 10 times the luminance value of the peripheral field.

Climate-based daylight modelling allows a holistic daylight assessment based on building location and façade orientation and is deemed more accurate than simplistic daylight factors based on an average calculation not specific to the building under investigation.

Box Key Terms

Illuminance

Total luminous flux incident on a surface per unit area, expressed in Lux (1 lx = 1 lm m^{-2}). It describes the amount of light striking a surface.

Luminance

Luminous intensity emitted or reflected by a light source per unit area within a given solid angle that is measured in terms of candela per square metre (cd/m^2). It conceptually represents the brightness of an object and describes the luminous power detected by the human eye from a particular angle.

Colour Rendering Index

It describes the effect of a light source on the colour appearance of lit objects. It is expressed in a 0-100 scale with the upper limit corresponding to the spectral output of the entire visible spectrum i.e. best colour rendition).

Acoustic comfort

Problem

The acoustic environment of noise-sensitive spaces such as offices can be affected by external noise (noisy neighbours, urban traffic, motorways, rail and air traffic) and excessively high reverberation times (due to sound-reflecting surfaces). Acoustic comfort is often overlooked during project planning and design when other aspects such as functionality and aesthetics are prioritised. Constant exposure to high noise levels interferes with the individual's mental tasks. Light-weight building components such as glazing units are relatively permeable to sound propagation due to the acoustical properties of glass, frame profile and sub-optimal installation, which result in low sound insulation factor R_w.

Solution

Noise protection should be optimised in relation to the sound pressure level and the frequency of the sound source. Although solar shading acoustic absorption is limited, some systems can to a certain extent represent an alternative to costly sound absorbing glass. In particular, woven or non-woven exterior shading systems when they are closed and positioned more than 10 cm away from the glazing can help reduce the level of sound transmission as well as the reverberation time (Beck et al., 2010). In fact, they constitute an extra acoustic insulation layer and reduce the intrusion of sound waves around the critical frequency of the glass.

Measuring performance

As a rule of thumb, a comfortable acoustic environment can be assumed around 35 dB in daytime and 30 dB at night.

Box Key Terms

R_w

The airborne sound insulation index R_w provides an average proxy of the insulation performance of a building component weighted over a range of frequencies to reflect the human sensitivity to different acoustic pressure levels.

Reverberation time

Decay time required for sound to drop by 60 dB from its initial level. The optimum reverberation time varies depending on the intended use and is strongly influenced by the surfaces' absorption coefficients as well as the room volume.

Indoor Air Quality

Problem

Indoor air quality (IAQ) involves an objective (safety) and subjective (perceived comfort) component. Poor IAQ occurs when the concentration of specific pollutants in the environment exceeds the acceptability range identified by the competent authorities and more than 20% of the building occupants express dissatisfaction. Pollutants emitted by indoor sources (building materials, occupant activities, furniture and equipment) and outdoor sources in the external environment can influence health (airborne respiratory infections), comfort and productivity.

Solar gains through the transparent building envelope increase the internal temperature. Research on indoor environmental health has demonstrated that high ambient air temperatures have a negative impact on the air quality perceived i.e. diminishing acceptability levels are associated with increasing temperatures (Fang et al., 1998; 2004). Accordingly, glazing units without solar protection, which are more 'permeable' to solar energy, can make IAQ worse. Higher internal temperatures are also detrimental in respect to the emission rate of the building materials, including the shading fabrics. Further dynamics of pollution are linked with the absorption and subsequent release of airborne pollutants or as a result of accumulation of dirt, which encourages the proliferation of micro-organisms.

In contrast, solar shading devices can have an adverse effect in IAQ terms of obstructing the windows or other natural ventilation outlets, i.e. impeding the natural supply of fresh air.

Solution

Solar shading improves the perceived air quality by decreasing the amount of solar energy that penetrates into the environment and thus limiting the rise of indoor and mean radiant temperatures.

Specification – low pollutant emitting shading fabrics used internally should be specified in order to prevent air pollution by contaminants such as volatile organic compounds (VOCs). Third party labelling schemes exist that certify the toxicological information of building materials allowing the selection of materials with no, or low, pollutant emissions.

Design – in naturally ventilated buildings the position of the shading system should be defined in relation to the estimated impact on the fresh air supply through ventilation openings. Holistic building design can enable optimal decisions at design stage to be taken.

Operation – an appropriate maintenance regime should be specified and put in place throughout the whole service life of the system to ensure a good standard of conservation and prevent the formation of micro-organisms.

Measuring performance

Subjective measures of perceived IAQ were introduced by Fanger (1988) (the olf and the decipol) to quantify air pollution sources and the concentration of air pollution as perceived by humans. However the adoption of this approach is not widespread (apart from northern Europe) due to its reliance on a sample of persons able to evaluate the intensity of a pollution source.

Objective measures of IAQ are based on instrumental measurements of airborne contaminants. The concentration of internal pollutants is governed by threshold limit values that cannot be exceeded (8-hour average maximum allowable concentrations or a yearly average acceptable indoor concentration indexes).

EN 15251 specifies different categories of indoor air quality to define acceptable pollution levels.

Productivity

Problem

Along with a business organisational structure, individual attitudes/work culture, and social relationships, the indoor environment affects human resources' efficiency and productivity in the workplace (Clements-Croome, 2006).

Poor indoor environmental quality (IEQ) has been linked with sick building syndrome (SBS) symptoms prevalence leading to increased sick leave (Wargocki et al., 2006). Reductions in work performance have been objectively associated in particular with thermal discomforts, decreasing with temperatures below 21-22°C and above 23-24°C (Seppänen et al., 2006).

Low productivity is a cost. Staff related costs including salaries and benefits typically account for 80-90% of an office operating costs (World Green Building Council; Beck et al., 2010) and far outweigh the building related costs approximately amounting to 10% – thereof 70% are the costs related to construction and 30% to operation and maintenance (Beck et al., 2010). Estimated energy costs vary between 0.3-0.6% (Beck et al., 2010).

Solution

Shading optimally integrated into the building design increases glazing areas, and has the potential to enhance thermal, visual and acoustic comfort. These factors are the boundary conditions of a more productive and safe working environment (World Green Building Council). Shading systems can therefore contribute to superior work performance, increased concentration and wellbeing in the workplace. The benefit of increased natural daylighting in respect of productivity are significant. Lockheed Building 157, a daylit office building built in 1983 in Sunnyvale, California, is an example (Thayer, 1995). On top of saving $500,000 in energy bills over the first year of occupation through the passive solar daylighting strategies in place, absenteeism decreased by 15% and the higher productivity of employees raised the corporate profit paying off the extra-cost of construction in one year. Indeed, even marginal improvements in productivity have considerable financial implications. Beck et al. (2010) estimated that an improvement of 1% would allow a financial payback greater than the energy costs incurred to run the building, amortising the extra capital investment cost to achieve better quality in a short timescale.

Measuring performance

The translation of productivity in economic terms via meaningful financial metrics is difficult. Wargocki et al., 2006 introduced a quantitative model that assesses the economic impact of productivity against the investments allocated.

Box Key Terms

Sick Building Syndrome

SBS portrays a range of discomfort and illness symptoms linked with the permanence within a building whose causal factors are not identified. In contrast, Building-Related Illness (BRI) is used to refer to a building related illness with clinically identified causal factors.

Olf

Unit of measure of the strength of a certain pollution source. One olf corresponds to the emission rate of air pollutants (bioeffluents) of an average adult with a hygienic standard equivalent of 0.7 baths per day.

Decipol

Unit of measure introduced to quantify the concentration of air pollution as perceived by humans. It corresponds to the air pollution level perceived with a ventilation air supply of 10 $l\ s^{-1}$.

Security and privacy

Problem

Different buildings require different levels of security. Unless treated with appropriate technologies such as safety coatings or films, or fitted with security shutters, glazing units can constitute a weak point in the building fabric when it comes to security.

Without measures to prevent break-in, potential intrusion through the glazing elements constitutes a risk. In the event of breaking, the broken glass creates hazard to the occupants.

Privacy can be also required in a variety of situations and for a number of reasons. Untreated glass is transparent to vision from the outside.

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Solution

Shading can provide a functional separation in a mixed-use building complex between, for instance, residential and commercial uses, whilst contributing to the building's architectural identity.

Exterior shading can also be a cost-effective and an elegant alternative to glass designed for safety and privacy, for instance replacing films providing a reflective appearance on the brighter side of the glass (the outside during daytime) whilst allowing vision from the other side. Shading systems can act as a protective barrier for the glass, hiding possessions from view and deterring potential intruders. As well as providing security, shading can prevent vision through the glass for two-way privacy, although sacrificing natural light unless an automatically or manually adjustable system is used.

Controllability

Problem

Solar irradiance changes throughout the seasons. The space cooling energy savings achieved by a fixed shading system can be counterbalanced by the extra-energy use requested for space heating and artificial lighting. Unwanted solar gains in summer conditions are useful in winter in order to reduce dependence on mechanical space heating, whilst increased daylight levels will reduce energy use for artificial lighting.

As an example, Dubois (2001) estimated that an adjustable awning shading a south-facing office space in Stockholm would allow savings of 12 $kWhm^{-2}$ per year, but that an energy penalty of 11 kWh m^{-2} $year^{-1}$ would occur if the system was not removed during the heating season.

Another factor of sub-performance relates to ill-informed occupant behaviour. Mechanical operation of shading by the users is typically driven by visual rather than thermal comfort, with a bias towards interacting with it at the beginning or at the end of the day (Littlefair, 2002a). This might result in the shading being in place also when it is not needed.

Solution

Reacting dynamically to changing environmental conditions, shading systems tune the transparent envelope to the season and the occupants' varying needs with a view to maintain the energy balance of the building.

Shading can be appropriately controlled in relation to the expectations of the occupants and the associated needs (glare control / privacy / overheating etc.). Manual control is recommended in 'owned' or 'shared' environments for privacy or visual comfort purposes; automatic control can be more appropriate in 'un-owned' environments to regulate the solar gains, although it can be coupled with a manual override to bypass the automatic settings (Littlefair, 2002a).

The control operating regime can be regulated using timers or tracking systems (sensors) detecting for instance the wind speed, solar irradiance or the luminance levels. Depending on different aspects such as building complexity and available budget, controls can be stand-alone or integrated with the overall building energy management (BEM) system. BEM is an area under strong expansion that presents promising market opportunities for the next few years (Janssen, 2014).

Interesting advances are also being made on the development of solar energy driven shading systems, being shading typically required with solar energy availability. Such an effort is aligned with the concept of dynamic and adaptive building systems that are marking a cultural shift in the concept of building envelope, upgraded from building 'enclosure' to active 'living' skin (IEA-ECBCS Annex 44). The potential benefits of high performance dynamic solutions are presented in terms of energy efficiency and comfort in Hutchins (2015).

Measuring performance

A continued process of Measurement and Verification (M&V), sometimes via the BEMS, throughout the building service life to fine-tune the performance of the shading system and reach an optimal set up (Jones, 2011).

Box Key Terms

Building Energy Management System (BEMS)

Typically part of the BMS, which is the general building management system controlling aspects such as fire, security and the Closed Circuit Television, a BEMS interacts only with those aspects of the building which have an impact on energy consumption – coordinating and controlling centrally, possibly metering and monitoring, a range of building services such as heating, ventilating, and air conditioning (HVAC) and lighting, for building diagnostics purposes.

Operational savings

Problem

Under the pressure of global environmental changes, new constructions are expected to increasingly experience overheating. The space cooling energy consumption in 2050 is estimated to increase by 150% globally and between 300% and 600% in developing countries (IEA, 2013).

Existing buildings account for 40% of the overall energy consumption in the UK and are projected to constitute 80% of the 2050 building stock. Although the UK Government withdrew its Zero Carbon Home targets in November 2015 Spending Review, its pledge to cut 80% of GHG emissions by 2050 is still a push to substantially improving the energy efficiency of the building stock. Old and poorly insulated glazing systems are major contributors of transmission heat loss via the building fabrics.

According to the Cambridge Housing Model, the UK domestic energy model developed by Cambridge Architectural Research Limited for the Department of Energy and Climate Change (Palmer et al., 2013), approximately 23% of the windows used in English dwellings are single glazed, and 27% of pre-1950 homes have uncoated double glazing units (Figure 3). A similar distribution characterises the EU built environment, in which 44% of the windows are estimated to be single glazing units and 42% uncoated double glazing units (ES-SO, 2014). Glass for Europe estimates that old glazing units are 5 - 8 times less energy efficient than modern glazing solutions.

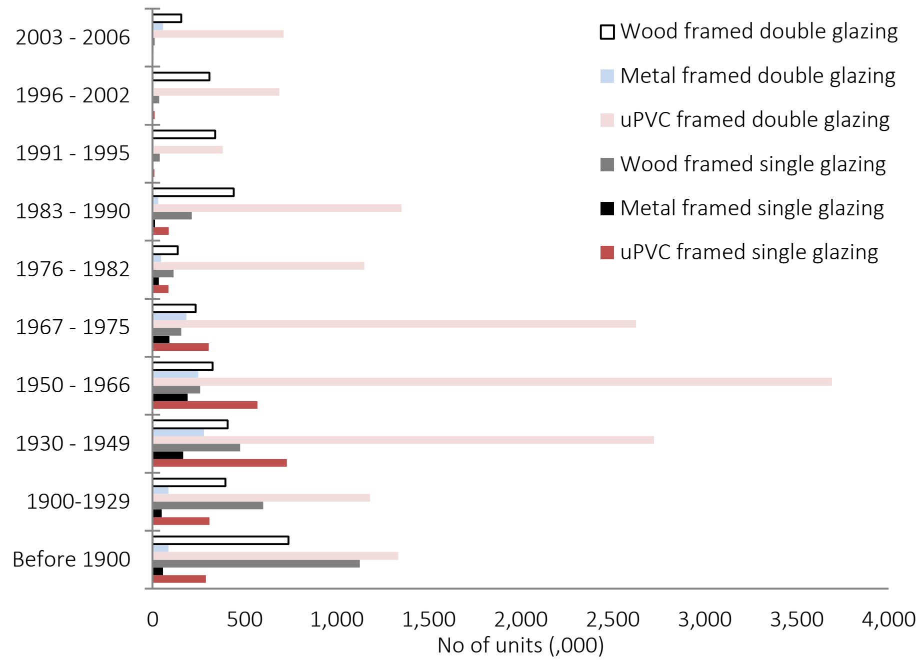


Figure 3: England dwellings by age and glazing type (based on the Cambridge Housing Model (CHM).

Historic areas (with buildings of value to the UK's built heritage) constrain the energy efficiency upgrades of the building fabrics as the intention is to preserve their character.

In Scotland, almost one fifth of the residential building stock is of traditional construction with some historical value (Baker, 2008). The Scottish House Condition Survey estimated that in 2014 approximately 97,000 detached houses and 213,000 tenement flats in the Scottish housing stock were built before 1919 (The Scottish Government, 2015). Overall, 20% of the whole stock dated back to pre-1919 construction age (The Scottish Government, 2015), which has been associated with the largest proportion of poorly energy efficient dwellings (Baker, 2008).

Energy use for lighting is also generally growing. According to the 2013 UK Housing Energy Fact File, artificial lighting in UK homes has increased by half from 1970 to 2011, despite the more widespread adoption of energy efficient lights (Palmer and Cooper, 2014). The authors estimate the overall lighting energy use to be approximately 14 TWh – or around 3% of total UK housing energy. Energy use for artificial lighting in the non-domestic sector is more significant; estimates quantify 35 TWh only in England and Wales, approximately 18% of the total energy consumption (Armitage et al., 2015).

Solution

The IEA Technology Roadmap of energy efficient building envelopes individuate in exterior shading a dynamic solar control a standard feature in the future new and existing buildings, and specifically refers to low-cost automated dynamic shading as one of the technologies where the highest potential of return on R&D investments lies (IEA, 2013). Indeed, shading constitutes a self-financing climate control system in the way it improves insulation, manages solar control and maximises daylighting from increased glazing areas (ES-SO, 2014), as such it represents an investment paid back through the savings in energy use. The influence of five different types of shading on the U- and g-values of six reference glazing units is shown in Table 2. Double glazing can have U-values reduced from 21% to 38% (clear) and 13-25% (low-e), and g-values improved from 16% to 82% and 13% to 85%, respectively, depending on the shading type used.

Table 2: U-values [g_{tot}] for reference glazing units with the addition of shades to EN 14501, EN 13363-1 & EN 673 (Source: BBSA).

Reference Glazing		Shading A[i]	Shading B[ii]	Shading C[iii]	Shading D[iv]	Shading E[v]
Single clear (EN 14501)	5.80 [0.85]	3.40 [0.18]	4.30 [0.63]	4.30 [0.37]	2.50 [0.30]	4.20 [0.29]
Double clear (EN 14501)	2.90 [0.76]	2.10 [0.14]	2.30 [0.64]	2.30 [0.39]	1.80 [0.33]	2.20 [0.33]
Triple clear (EN 13363-1)	2.00 [0.65]	1.50 [0.11]	1.50 [0.57]	1.50 [0.38]	1.40 [0.34]	1.40 [0.34]
Double low-e (EN 13363-1)	1.60 [0.72]	1.30 [0.11]	1.40 [0.63]	1.40 [0.39]	1.20 [0.34]	1.40 [0.35]
Solar Control 1 (EN 14501)	1.20 [0.59]	1.00 [0.09]	1.10 [0.54]	1.10 [0.37]	1.00 [0.34]	1.10 [0.35]
Solar Control 2 (EN 14501)	1.10 [0.32]	1.00 [0.07]	1.00 [0.30]	1.00 [0.25]	0.90 [0.24]	1.00 [0.24]

[i] External screen fabric; colour black; τ=0.04; ρ=0.05, α=0.89, Class 2 Permeability.
[ii] Internal screen fabric; colour black; τ=0.04; ε=0.89, ρ=0.05, α=0.89, Class 2 Permeability.
[iii] Internal screen fabric; colour white; τ=0.04; ε=0.89, ρ=0.62, α=0.15, Class 2 Permeability.
[iv] Internal screen fabric; metallised; τ=0.03;ε=0.14, ρ=0.70, α=0.22, Class 2 Permeability.
[v] Internal black-out fabric; colour white; (τ=0.00);ε=0.90, ρ=0.68, α=0.32.

Fixed solar shading designed according to the sun peak seasonal angles can reduce solar gains in summer but still permit heat gains from the low angle sun, contributing to reduction in space cooling and heating loads. In some cases, internal shading can add thermal resistance to the transparent envelope reducing its thermal energy transmittance i.e. heat loss by transmission. Best-performing products include insulated systems (Baker, 2008) and cellular shades containing multiple air layers in a honeycomb cross-section that are fitted into weather stripped edge tracks. Although less effective, uninsulated shutters kept in a closed position also reduce heat loss and constitute an insulating package. This occurs when the system is insulated and kept in a closed position.

In summer conditions, external shading is particularly effective at preventing the solar radiation from reaching the glazed surfaces; internal blinds can also contribute to reducing solar energy especially if a reflective finish is applied on the window-facing side (BBSA, 2015). Shading also decreases the fraction of solar radiation in the short-wave infrared range (780-2500nm) that is absorbed and re-irradiated as thermal (long-wave infrared) radiation and can eliminate the need for mechanical space cooling if coupled with cross-ventilation strategies. The potential for space cooling energy savings in UK houses is detailed in Seguro et al. (2015).

In winter conditions, shading can provide night time insulation if fully closed overnight and maximise solar gains if left opened during daylight hours (Hutchins, 2015). A control strategy should be put in place rather than delegate its adjustment to the occupants. The potential impact of advanced solar shading on the reduction of the space heating demand can be found in Hutchins (2015).

The ESCORP/EU25 study (energy saving and CO_2 reduction potential from solar shading systems and shutters in the EU-25) quantified at 80 and 31 million tonnes of CO_2 respectively the carbon that could be saved if all buildings in the EU were properly solar shaded (Standaert, 2005).

Shading can be an effective energy efficiency measure of the transparent envelope, especially under conservation constraints. In Scotland, the Centre for Research on Indoor Climate & Health at Glasgow Caledonian University tested the performance of secondary glazing, uninsulated and insulated shutters, modern roller blinds with and without low-e plastic films on the window blind-facing side, Victorian style blinds and thermal blinds in the upgrade of a timber single paned sash and casement window (U-value: 4.5 $Wm^{-2}K^{-1}$) (Baker, 2008). Thermal energy loss was reduced by 51% with timber shutters; by 28% with Victorian roller blinds; by 22% with the modern roller blinds and by 14% with curtains. Combined blinds and shutters led to a window U-value < 2 $Wm^{-2}K^{-1}$ that is below the Building Regulation Approved Document Part L1A windows in new dwellings.

Measuring performance

ISO 13790:2008 provides different calculation methods for the assessment of the building annual energy use for space heating and cooling: simplified hourly; monthly (or seasonal); and a detailed dynamic method.

Dynamic simulation modelling (DSM) is based on an integrated approach to the dynamic behaviour of the building conceived as a system with *n* inter-linked nodes (Clarke, 2001) that can for instance accurately emulate summertime building response reflecting the actual performance of shading systems. An in-depth knowledge of aspects such as building physics, thermo-fluids, heat and mass transfer, systems and plant processes etc. together with modelling and computational skills is required to effectively carry out dynamic simulations.

Box **Key Terms**

U-value

Overall heat transfer coefficient that describes heat exchange through a building element via conductive, convective and radiative heat transfer per 1K temperature differential per square meter of element.

Overheating

Problem

Occurrence of overheating in the built environment is becoming exacerbated under the push of global warming (ZCH, 2015a). Climate change effects are aggravated by a number of extrinsic and intrinsic factors (NHBC Foundation, 2012) including

- external pollution limiting natural ventilation rates through window opening;
- absence of cross ventilation;
- increased thermal insulation and airtightness reducing thermal energy loss by transmission and ventilation;
- use of high g-value glazing units maximising solar gains and triggering the greenhouse effect; and
- internal gains from equipment use and energy-intensive occupant behaviour i.e. high internal loads.

Typical UK future climate scenarios drawn by Jenkins et al. (2010) for the future 30 year time period refer to higher daily mean and maximum temperatures and warming across all of the UK. The long service life of buildings, which frequently exceeds 100 years, implies that although current buildings might be within the acceptable limits of overheating over the short to medium future, things might change in the long term (Morten, 2015).

Overheating risk can be intuitively high in sensitive building types such as hospitals. Research conducted by Cambridge University quantifies potential situations of overheating in around 90% of the UK hospital wards (Iddon, 2014). Independent research by Leeds University has found correlations between overheating risks and increased infection risks due to airborne pathogens (Iddon, 2014).

Overheating is becoming an increasing concern also in new construction houses aiming towards the nearly Zero Energy Building (nZEB) standard (ZCH, 2015b), which are well insulated and airtight. The issue is more increasingly experienced outside the summer period (IEA EBC Annex 62). The first generation of demonstration buildings see high indoor temperatures as the most frequently reported problem across post-occupancy studies (Heiselberg, 2014). The traditional focus on energy efficiency requirements compared to the indoor environment, alongside the old rules of thumb and the simplified design methods used (averaged heat loads), exacerbate the problem (Heiselberg, 2014).

A review of the evidence from the social housing projects tested under the Innovate UK's Building Performance Evaluation (BPE) programme highlighted frequent occurrence of overheating due to aspects such as sub-optimal building design and glazing specifications, and ill-informed window opening behaviour (Seguro, 2015). It is estimated that up to 20% of homes in England suffer overheating (ZCH, 2015d).

Medical evidence suggests that the human body's thermoregulation ability is affected by overheating and, if untreated, the associated symptoms can worsen quickly. ZCH (2015c) is forecasting a tripling of heat-related excess deaths in England and Wales – from 2,000 to 7,000 per year – expected by 2050 due to the combined effect of climate change and ageing population.

Solution

Shading is an effective solution to reducing excessive solar gain (ZCH, 2015d), in particular when fitted externally. Adaptable solar shading which involves a variable degree of user interaction can be adapted to meet user needs throughout the year (Heiselberg, 2014). Interior shading can also be of value, especially when the window facing side is finished with a reflective layer re-radiating part of the incident solar radiation before it is absorbed by the internal objects. In particular in urban locations with high levels of noise and pollution, reducing the convenience of natural ventilation, solar shading presents clear advantages.

Morten (2015) modelled different high performing buildings over a range of future climate scenarios, and compared the cost-effectiveness of a range of measures. The energy analysis of a semi-detached Passivhaus carried out in the Passivhaus Planning Package (PHPP) saw increased frequency of overheating for all of the different locations assumed – Glasgow, Leicester and Portsmouth – over the timescale of the simulations (present until 2080). The overheating frequency would rise from 0.0% to 5.2-8.2% in Glasgow; from 0.8% to 11-13.8% in Leicester and from 5.5% to 23.0-27.2% in Portsmouth. External shading emerged as the most cost effective measure to reduce the frequency of overheating. In the case of the Leicester Passivhaus it decreased from 11-13.8% to 3.9-8.2%.

Measuring performance

Different methodologies and tools can be used for the prediction of overheating risk (ZCH, 2015e). DSM provides a detailed means of capturing the dynamic relationships between the external and internal environment, however the complexity and level of expertise required should be taken into account. A simplified methodology is provided by PHPP.

Box Key Terms

Solar spectrum and greenhouse effect

The spectral solar irradiance varies in relation to the wavelength range – the solar spectrum at sea level ranges from 280 nm in the ultraviolet wavelength to 2,500 nm in the infrared (outside this range the solar irradiance is negligible) (Beck et al., 2010):

- Ultraviolet: 280-380 nm – invisible to the human eye and responsible for ageing, changing and damaging our skin and objects around us. Shading can act as an additional layer of protection to ultraviolet radiation and the associated negative effects on perishable contents such as furnishings within art displays. Specific products of solar shading have been developed working in partnership with the National Trust and other heritage organisations for similar applications.
- Visible: 380-780 nm– perceived by the human eye as visible light.
- Short wave infrared: 780-2,500 nm – solar radiation in the infrared range to which glass is permeable.

Not in the solar spectrum, long wave infrared, spanning from 5,000 to 25,000 nm (peaking at about 10,000 nm), is the thermal infrared radiation emitted by all objects, to which glass is not permeable.

When solar energy entering a room through the glass is absorbed by the internal objects, it changes wavelength from short-wave to long-wave infrared radiation. As glass is transparent to short wave but not long wave radiation, the resultant thermal radiation cannot escape through the window, triggering a greenhouse effect.

Overheating

Overheating is not uniquely defined and diverging definitions are available depending on the context. ZCH (2015f) refers to two key types of thresholds:

- Evidence-based thresholds, in which different metrics have been introduced on the basis of different variables specific to the sector of interest;
- Comfort-based and indoor health-related thresholds, with the latter less well developed due partly to the complex relationships underpinning the linkage between indoor environment and health.

An integrated multi-disciplinary approach to overheating is still missing to date.

g-value

Also called solar heat gain coefficient or solar factor, it describes the glass total solar energy transmittance (primary and secondary) on a 0 to 1 scale (1 being completely transmittant). The lower the g-value, the lower the solar gain.

g_{tot}

Ratio of solar transmittance through solar protected glazing (glass + solar shading device package). The lower the g_{tot}, the lower the solar gain.

nZEB

Nearly ZEBs have been introduced by the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) to indicate buildings with a very low energy consumption in part covered by renewable means achieving cost optimal level of energy performance throughout the estimated economic lifecycle.

Case study review

This section of the report focuses on two high profile buildings chosen to illustrate successful implementation of solar shading devices. We examine two tall buildings: the US New York Times Building and the Shard near London Bridge.

These buildings illustrate how advanced, integrated design of solar shading can bring together improved visual comfort, heat control, and automation. Both buildings were designed by Italian architect Renzo Piano and both use the MechoSystem's control system for the automatic blinds, tracking the sun and adjusting blinds differently according to the time of year, the position of the sun, and the intensity of solar radiation.

Conclusions

Properly specified shading systems can:

- reduce need for mechanical cooling
- reduce heating demand by allowing passive solar gain and improving insulation
- improve control of lighting and save electricity for lighting
- control glare and improve occupants' comfort
- allow more glazing, better views and link to outside

Renzo Piano's Shard building next to London Bridge shows how smart shading and integrated design can make buildings more transparent without causing unacceptable glare or solar gain.

NATIONAL ENERGY FOUNDATION

New York Times Building (completed 2007)

Architect	Renzo Piano

Project details

Location	*New York*	Building Owner	*New York Times*
Use	*Office*	Total Floor Area	*143,000m²*
Type	*New construction*	Project Costs	*$850m*
Year of Construction	*2007*	Standard	*Unknown*

Project Strategy

Building Fabric	52-storey tower with steel frame and double-skin curtain walling and ceramic rods on east, west & south facades.
Shading	Curtain wall system, double-pane, spectrally selective shading, with horizontal ceramic rods attached to façade and automated blinds inside.
HVAC&R	Uses cogeneration to generate electricity, heating and cooling. Underfloor air distribution to give ventilation, with air intake on 28th floor
Lighting & Daylighting	Sought to maximise daylight & views, without glare and with minimal direct solar radiation.

Setting


Building


Performance

Energy	24% saving	Modelled, compared to ASHRAE baseline
Heating	50% saving	Modelled, compared to ASHRAE baseline
Lighting	56% saving	Modelled, compared to ASHRAE baseline

Visual Comfort

MechoShade uses solar screen blinds, with 3% openness and visible transmission (t_{vis}) of 6% (preserving some visual connection with outside).

Lighting system has a computer chip in every luminaire to adjust lighting according to occupancy, dimming lights as necessary.

50-60% of lighting energy on west-facing windows was saved, 25-40% on SW and NW-facing windows.

Automation

Automated roller blinds are controlled using sky-monitoring equipment to lower blinds on clear days and raise them on cloudy days. It also takes account of how high the sun is in the sky: (high sun = lower blinds- just enough to block sunlight entering building).

This system is known as SolarTrac, also from the US company MechoSystems. It uses three roof-mounted sensors to monitor the sun angle and conditions in real time.

Heat Control

The ceramic rods made from aluminium silicate reduce the solar gains in summer as well as reflect the light into the building. The external rods are positioned to preserve views out of the building at sitting and standing level, and they work in tandem with the double-skin curtain walling and internal roller blinds to reduce solar gain.
Designers built a mock-up of a part of the building as a nine-month experiment before constructing the main building.


Roller blinds & ceramic rods work together

NATIONAL ENERGY FOUNDATION

The Shard (completed 2012)

Architect	Renzo Piano

Project details

Location	*London Bridge, London*	Building Owner	*Sellar Property Group/State of Qatar*
Use	*Office/retail/residential/hotel*	Total Floor Area	*110,000m²*
Type	*New construction*	Project Costs	*£435m (contract costs only)*
Year of Construction	*2012*	Standard	*BREEAM 'Excellent'*

Project Strategy

Building Fabric	Tallest building in Europe, at 310m and 95 storeys. Triple-skin glazed modules on a steel frame with concrete core.
Shading	Motorised roller blinds in a double skin facade, controlled automatically, based on gains & sun position.
HVAC&R	Mixed uses in the building are perfect for combined heat & power. Very challenging services risers, assembled off site.
Lighting & Daylighting	Sought to maximise daylight & views, without glare and with minimal direct solar radiation.

Setting

Building

Performance

CO_2	28.2	$kgCO_2\ m^2$/year (modelled)
Airtightness	5	$m^3/h.m^2$ @50 Pa

Visual Comfort

Blinds in the external glazing cavity are open weave fabric roller blinds. Using blinds to reduce the solar gain means that glass can be more transparent (low-iron glass), improving daylighting and making the building lighter.

Winter gardens have opening vents to give a stronger link to outside.

Bespoke ceilings have Perspex sheets with diffuse light from LEDs above.

Automation

Similar to the New York Times Building, intelligent blinds track the position and intensity of the sun so that the blinds are used as and when needed.

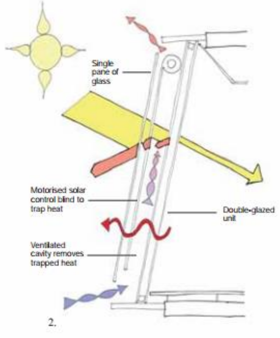
The controls lower blinds when solar radiation reaches 200 W/m^2, but this could be reduced to 180 W/m^2 to comply with more demanding Part L 2010.

Heat Control

Single glazed outside, with a second skin comprising a motorised solar control blind, then a ventilated cavity and finally another double-glazed unit on the internal side of the glazing module.

The blinds also help to reduce solar gain so they reduce the cooling load and save plant and riser space – a key concern for tall buildings with limited floor space and high rentals.

The Building Regulations Approved Document L2A requires a maximum g-value of 0.68 in summer. The Shard achieves 0.12 with blinds down.



Ventilated cavity & auto-blinds keep down gains

NATIONAL ENERGY FOUNDATION

03 QUANTIFYING THE IMPACT

A cost-benefit analysis (CBA) of representative internal and external shading systems against a subset of alternative space cooling strategies – window films, treated glass and fan coil systems – is presented in Table 5.

The CBA has two main objectives. Firstly, to shed light on the heterogeneous leverages triggered by optimally used shading, overcoming the myth of reduced glare and overheating as the only benefits of solar shading. Secondly, to evidence that there is no single product that is de facto the best one, given the variety of elements in the equation – a CBA on a building by building basis would be needed. In contrast, the intention of this exercise was to advocate the need to understand the key variables that come into play when specifying solar shading and to urge an adoption of holistic approach to achieve optimal design.

There is not an a-priori ideal product. Optimal shading varies depending upon the particular needs of the building.

Although the CBA scope was not to rank the cost effectiveness of competing products on the market, their relative performance was qualified against specified yardsticks of: thermal, visual and functional performance; user controllability and responsiveness to varying conditions (weather and occupants); installation, durability and service life; maintenance requirements; aesthetics ('aspirational' aspect and status symbol); cost; operational energy savings and carbon dioxide reduction. The aspects that informed the CBA are outlined below.

Criteria	Solar shading systems (LBNL and BuildingGreen, 2013)	Applied films (LBNL and BuildingGreen, 2013	Tinted glass (CIBSE, 2006; Littlefair, 2002b; TargetZero, 2011; GGF, 2013)	Fan Coil systems (CIBSE, 2008)
Thermal Performance				
Thermal insulation	V	V	V	
Airtightness	V	V	V	
Solar gain control	V	V	V	
Winter comfort	V	V	V	
Summer comfort	V	V	V	V
Condensation prevention	V	V	V	
Ventilation	V	V	V	V
Visual Performance				
Outdoor view	V	V	V	
Visible transmission	V	V	V	
Daylighting control	V	V	V	
Glare control	V	V	V	
Privacy	V	V	V	
Functional Performance				
Window protection	V	V	V	
Egress	V	V	V	
Security	V	V	V	
Control of noise	V	V	V	V
Acoustic absorption	V	V	V	
Controllability and responsiveness	V	V	V	
Operational Performance				
Installation	V	V	V	V
Durability and service life	V	V	V	V
Maintenance	V	V	V	V
Aesthetics	V	V	V	V
Cost	V	V	V	V
Energy / CO_2 savings	V	V	V	V

Evaluating the performance (thermal, visual, functional and operational) of solar shading systems and applied films was informed by the 'Window Covering & Attachments' portal developed by Lawrence Berkeley National Laboratory (LBNL) and BuildingGreen Inc. (2013), with the support of the US Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) and the Building Technologies programme.

The portal is designed into two key modules, a qualitative selection tool ('Help Me Choose' and 'Compare Coverings') and a set of quantitative fact sheets covering different configurations ('Understanding Window Coverings'), intended to provide unbiased guidance on the relative performance of efficient window covering technologies.

The aesthetic of the different configurations was separately assessed in relation to the degree at which 'aspirational' aspect and status symbol were deemed key issues driving the choice of a system.

The capital costs of the systems were retrieved from the Ecodesign of Window Products proposal (Sack et al., 2014), the SPON'S Price Book (Langdon, 2008) or via market research, and are detailed in Appendix A. The estimate price might not reflect the actual market price in the UK given the range of set prices.

The operational energy savings and CO_2 reduction from four generic shading variables (internal / external and fixed / adjusted) were assessed for an office building via DSM in the EnergyPlus environment, a well-established energy analysis and thermal load simulation engine developed by the US Department of Energy[1]. EnergyPlus allows advanced fenestration calculations including controllable window shades, complex shades, blinds and screens, via layer-by-layer heat balances that allow proper simulation of solar energy absorbed by window panes. Solar shading is modelled using up-to-date algorithms and methods to determine thermal performance of shading devices in line with ISO 15099 standard calculation procedures. This is in contrast to other leading mainstream whole-building dynamic simulation packages that currently fail to adhere to internationally recognised engineering methods set out by EN / ISO standards to model shading[2]. Other software compliant with ISO 15099 includes SSF ESBO, the Swedish Solar Shading Organisation's solar shading calculation software,

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.

[1] Originally written in Fortran and recently reconstructed in C++ architecture, EnergyPlus is a whole building energy simulation software that inherits many of its characteristics from BLAST (Building Loads Analysis and System Thermodynamics) and DOE–2, two energy and load simulation tools released in the late 1970s and early 1980s. At the core of EnergyPlus is a modular structure that simplifies upgrades and additions of features and links without affecting all parts of simulation code and algorithms, achieving reactiveness to advances in the field of building energy analysis and thermal load calculations. EnergyPlus aims to emulate reality in the way buildings respond to environmental factors and the HVAC systems meet the building thermal loads by fully coupling building envelopes, systems and plants. The interactions between the thermal zones and the environment / HVAC systems are simulated sub-hourly at user-definable time steps.

[2] The problem is actually fairly complex and has a variety of repercussions. Untangling its historical roots was out of the scope of this study. One of the problems, tracing back to past Part L revisions, when building energy modelling was still in its infancy, appears to have been the introduction of a relatively crude allowance to weight the user's interactions with adjustable shading, which might have contributed to a distorted market, ultimately biasing the industry's perception against adjustable shading.

and Parasol, an energy simulation tool developed by Lund University for comparing different glazing and shading devices. EnergyPlus was the designated software to carry out this exercise.

The reference building is a shading-free highly-glazed private office space halfway through the south façade of a small office building in London. The office has only one south-facing external wall, with one window (0.80 window to wall ratio), specified according to BS EN 14501:2005 benchmark glazing C. The office is equipped with four-pipe fan-coil system fed by hot / chilled water from a natural gas boiler / electric chiller respectively. The key geometric, construction and environmental modelling inputs are listed in Appendix B; the operating schedules of setpoints, occupancy density, equipment, lighting intensity and ventilation flow rates in Appendix C.

The process of preparing the report has highlighted an underassessment of shading in some building modelling and there are further studies required by the shading and software industries to ensure that all of the benefits of shading are adequately considered in building modelling.

The shading variants modelled are internal and external screen fabrics on a roller blind, referred to as SSI1 and SSE1, and venetian blinds with slats tilting at all angles from fully open to fully closed, referred to as SSI2 and SSE2. The key characteristics of performance in the solar and visible spectrum are reported in Table 3. The full energy modelling inputs are detailed in Appendix D for SSI1 / SSE1 and Appendix E for SSI2 and SSE2. Both designated shading options are typical of what is regularly specified in terms of screen / slat fabrics and colours – white / pearl and grey / white for the internal and external roller shades (3% and 5% openness factor), white slats for the venetian blinds. Neither is a particularly high performing specification in respect to reduction in space heating/cooling energy use.

Table 3: Key coefficients of solar transmittance (τ_S), reflectance (ρ_S), absorptance (α_S) and visible transmission (τ_V), reflection (ρ_V), and absorption (α_V), and emissivity (ε) of the four shading variables modelled.

Shading	Type	Position	τ_S	ρ_S	α_S	τ_V	ρ_V	α_V	ε
SSI1	Roller shade	Internal	0.17	0.56	0.26	0.16	0.63	0.21	0.90
SSI2	Blind	Internal	0.11	0.54	0.35	0.12	0.61	0.27	0.90
SSE1	Roller shade	External	0.09	0.41	0.50	0.08	0.43	0.49	0.90
SSE2	Blind	External	0.00	0.72	0.28	0.00	0.81	0.19	0.90

Although they are sensitive to the assumptions behind the energy models, and the 'typical' International Weather for Energy Calculations (IWEC) weather files used, the simulations quantified total energy savings for all of the shading variables. The considerable savings in energy use for space cooling offset a space heating energy penalty from reduced solar gains in winter, being the baseline space cooling loads predominant (Figure 4). As shown in Table 4, the total energy end use is reduced by 5% for SSI2 (-£1.4 per m^2); 12% for SSI1 (-£3.2 m^{-2}); 37% for SSE2 (-£10.0 m^{-2}) and 40% for SSE1 (-£11.2 m^{-2}). The operational carbon dioxide emissions are reduced by 5.9-13.5 $kgCO_2$ per m^2 for internal shading and 42.8-47.3 $kgCO_2m^{-2}$ for external shading (Figure 5). The breakdown into the different uses is detailed in Appendix F. The nominal capacities of the HVAC&R space cooling equipment (cooling tower and cooling coils) is 9% lower for SSI1; 56% lower for SSE2 and 62% lower for SSE1 (Appendix G and Appendix H). Accordingly, significant savings can be achieved both in terms of investment and running costs.

Dynamic energy simulations correlated the use of shading with total energy savings for all of the shading variables. Although subject to the assumptions made, savings from 7% to 16% have been estimated for the internal shading, and 30-33% for external shading.

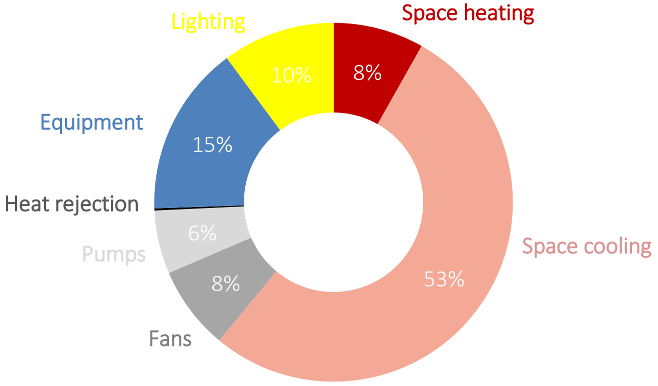


Figure 4: Shading-free baseline energy use breakdown.

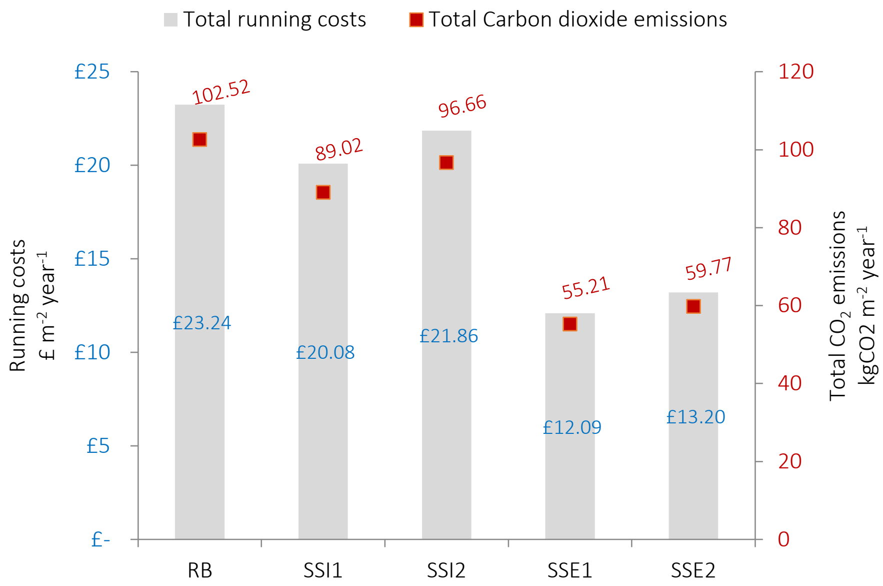


Figure 5: Total operational running cost and CO_2 savings per internal (SSI1) and external (SSE1) shade; internal (SSI2) and external (SSE2) blinds against a shading-free reference building (RB).

Table 4: Percentage savings against the shading-free baseline by shading variable: energy end-use for HVAC&R; total (including equipment and lighting) end-use / primary energy, carbon dioxide emissions and running costs.

	HVAC&R energy end use						Totals			
Shading	Space heating	Space cooling	Fans	Circulation pumps	Heat rejection	Total HVACC&R	Total energy end use	Total primary energy [i]	Total CO_2 emissions [ii]	Total running costs [iii]
SSI1	+15%	-21%	-10%	-20%	-20%	-16%	**-12%**	**-13%**	**-13%**	**-14%**
SSI2	+9%	-10%	0%	-8%	-10%	-7%	**-5%**	**-6%**	**-6%**	**-6%**
SSE1	+77%	-71%	-64%	-75%	-65%	-54%	**-40%**	**-46%**	**-46%**	**-48%**
SSE2	+59%	-63%	-58%	-68%	-57%	-50%	**-37%**	**-42%**	**-42%**	**-43%**

[i] Primary energy factor – 1.22 (natural gas); 3.07 (electricity) [Source: SAP2012].
[ii] Carbon intensity factor – 0.216 $kgCO_2kWh_{th}^{-1}$ (natural gas); 0.519 $kgCO_2kWh_{el}^{-1}$ (electricity) [Source: SAP2012].
[iii] Energy tariff –£0.029 kWh_{th}^{-1} (natural gas); £0.119 kWh_{el}^{-1} (electricity) [Source: DECC's prices of fuels purchased by small energy intensive non-domestic consumers in the United Kingdom over 2014 Quarter 4 (including the Climate Change Levy)]

When the DSM findings are combined together with the rest of the CBA matrix, there is evidence that shading can bring in a variety of benefits not captured in quantitative energy use / CO_2 terms, concerning the thermal, visual and functional sphere. Furthermore, a diversified market offer means that the needs of different building types can be met – this underlines the importance for designers and specifiers of understanding the relative advantages and disadvantages of different configurations.

Table 5: Cost-Benefit Analysis – internal and external shading and alternative products for space cooling.

System	Thermal Performance	Visual Performance	Functional Performance	Controllability & Responsiveness Mo - Motorised S – Sensor Ma- Manual	Installation Difficult to easy	Durability and Service Life	Maintenance High Medium Low	Aesthetic Leverage High Medium Low	Cost £ m^{-2}	Indicative % Energy Savings [Carbon dioxide emissions savings]	Indicative Running Cost Savings per m^2
Internal Shading											
Drapes & Curtains	Low High	Low High	Low High	Mo / S / Ma	Difficult Easy	Low High	Low	High	£40-79		
Louvered Shade	Low High	Low High	Low High	Mo / S / Ma	Difficult Easy	Low High	Low	High	£32-99		
Roller Shade	Low High	Low High	Low High	Mo / S / Ma	Difficult Easy	Low High	Low	High	£32	SSI1: -12% [-13%][i] SSI2: -5% [-6%][i]	SSI1: £3.2[i] SSI2: £1.4[i]
Panel Shade (solar screens)	Low High	Low High	Low High	None / Mo	Difficult Easy	Low High	Low	Low	£105-422		
Cellular Shade	Low High	Low High	Low High	Mo / S / Ma	Difficult Easy	Low High	Low	Low / Medium	£79-158		
External Shading											
Roller Blinds and Shutters	Low High	Low High	Low High	Mo / S / Ma	Difficult Easy	Low High	Medium	High	£71-111		
Fixed Horizontal Shading (brise soleil, awnings)	Low High	Low High	Low High	None	Difficult Easy	Low High	High	Low / High	£300-400	SSE1: -40% [-46%][i] SSE2: -37% [-42%][i]	SSE1: £11.2[i] SSE2: £10.0[i]
Retractable Awnings	Low High	Low High	Low High	Mo / S / Ma	Difficult Easy	Low High	Medium	Low / Medium	£133		
Alternative products											
Applied Films	Low High	Low High	Low High	None	Difficult Easy	Low High	Low	Low	£29-45	-3% [-3%][ii]	£0.7[ii]
Tinted glass	Low High	Low High	Low High	None	Difficult Easy	Low High	Low	High	£300-430	-18% [-20%][iii]	£4.9[iii]
Mechanical air conditioning	Low High	N.a.	Low High	Mo / S / Ma	Difficult Easy	15 years (prEN 15459:2006)	Medium	Low	£50-60	Baseline	Baseline

[i] The energy modelling concentrates primarily on heat rejection. If the heat retention properties of solar shading in relation to the night-time insulation (shading closed overnight) were taken into account in winter, the savings would have been higher.

[ii] Modelling based on a window film applied internally.

[iii] Modelling based on coating in position three and 3 mm bronze external pane.

04 LOOKING TO THE FUTURE

This section provides a legislative review around the solar shading requirements of key EU countries that could inform a revision of the current UK regulatory approach to solar shading, and it goes on to offer a joint strategic vision / business case / action plan to address the barriers facing the UK solar shading industry.

Legislative review

This short review draws out the key points relating to shading devices and energy use in buildings from legislation in different parts of Europe. It begins with summaries of mandatory controls in countries held to be leaders in providing incentives for solar shading in buildings. Then it considers the UK context, and finally offers recommendations for how we could potentially incorporate ideas from other countries in our own Building Regulations.

Six countries around Europe are held to have building regulations that help support effective use of shading devices:

- Austria
- Belgium
- France
- Italy
- Norway, and
- Poland.

These six have also addressed the new guidelines for shading set out in the recast EPBD.

In Austria it is a regulatory requirement to calculate cooling needs for non-residential buildings, along with the idea of 'cooling need from solar radiation'. There is also a limit on the area of glass surfaces in buildings, and a ban on mechanical cooling for homes.

Austria restricts glazing areas, but the limit can be by-passed by using solar shading.

Solar shading is not mandatory in Austria, but it is the solution to avoiding smaller glazed areas and large areas of thermal mass. Automation of shading devices is also recommended.

In Belgium, power distributors give discounts to private homes using external solar shading. There is also a lower rate of VAT on external shutters, blinds and pergolas (6%, against the normal rate of VAT of 21%).

Belgium applies a low rate of VAT on external shading.

In France, the RT2012 ('Reglementation Thermique') which requires residential buildings to have primary energy demand below 50 kWh/m^2, emphasises solar shading[3]. This came into force in 2013, and the intention is for new residential buildings to be 'energy positive' (i.e. generating more energy than they use) from 2020.

France emphasises solar shading as a way to achieve high energy performing buildings.

In Italy external solar shading is mandatory for some applications. There are also tax breaks worth 65% of

[3] http://www.french-property.com/news/build_renovation_france/energy_standard_rt2012/

the total cost (known as 'Ecobonus 65'), as a deduction in income tax, spread over 10 years, for supplying and installing external blinds and shutters (such as awnings, louvered blinds, pergola awnings) for new installations. The tax breaks also apply to replacing existing shading that is, independent from windows being replaced, as long as they do not face north. This incentive is part of the main tax break for energy retrofits of existing domestic and non-domestic buildings, so long as they are mechanically heated.

In Italy there are income tax incentives for installing solar shading.

Shading that is eligible for the Italian tax breaks must be in line with Standard UNI EN 13659 'Shutters: Performance requirements including safety' and UNI EN 13561 'External blinds and awnings: Performance requirements including safety', for external blinds.

There are no constraints in terms of operation (both manual and automated systems are permitted), materials, thermal performance (e.g., g_{tot}) or the minimum number of units (1 is fine).

Although Norway is not part of the European Union, it has implemented the Energy Performance of Buildings Directive (EPBD). There is a requirement for at least 40% of a building's net energy demand to come from renewable energy carriers apart from electricity or fossil fuels. Regarding shading, the g_{tot} must be less than 0.1 for non-domestic buildings with cooling, which effectively forces the use of shading. Window areas are also restricted to no more than 24% of the floor area, which affects both cooling and heating loads.

Norway legislated a minimum g_{tot} of 0.1 for all mechanically cooled non-domestic buildings.

The Norwegian energy performance calculations also assume an artificially low summer set-point (22°C) if mechanical cooling is installed, which penalises cooling and encourages passive measures of cutting down on overheating, including shading. The legislation also prohibits modelled non-domestic buildings from exceeding 26°C for more than 50 hours a year (Schild, 2009).

In Danish legislation energy use for mechanical cooling is multiplied by 2.5 in the energy balance calculation (accounting for electrical generation and distribution losses), which sends a strong signal to reduce energy use for cooling such as with the help of effective shading.

In Denmark the high conversion factor applied to mechanical cooling is a deterrent to excessive solar gain.

The Danish Building Regulations 10 (BR10) state that buildings must have total annual energy use per m^2 below fixed thresholds that will fall by 2020 to 20 kWh m^{-2} for dwellings and 25 kWh m^{-2} for other buildings.[4]

UK context

The Building Regulations for England and Wales have included an explicit requirement to limit heat gains to buildings since 2006. This means assessing designs of naturally ventilated buildings to ensure that they do not suffer from overheating in summer.

Part L of the Building Regulations (on 'Conservation of fuel and power') says that non-domestic buildings must either limit solar and internal heat gains, or otherwise show that they will not overheat. Developers can show they are limiting gains by demonstrating the total internal gain will not be

[4] http://www.paroc.dk/knowhow/building-regulations/danish-building-regulations-in-accordance-to-br-10?sc_lang=en

more than 35 W per m^2 on peak summer days (which may include shading to reduce solar gain). Alternatively, they can show that the building does not exceed an agreed threshold for more than a reasonable number of occupied hours each year (these differ according to the activities in the building).

Turning to housing, Part L says that developers should again limit 'excessive' solar gains (using window size and orientation, solar protection including shading, ventilation and thermal mass. Appendix P of SAP, the Standard Assessment Procedure for dwellings, gives designers a tool to calculate the likelihood of overheating, but this offers limited options for showing the effect of shading.

For both domestic and non-domestic buildings, the main limitation with the UK Building Regulations is one of enforcement: local authorities and Building Control Officers have very limited resources, and avoiding health and safety problems has a higher priority in their decisions than energy efficiency or overheating concerns.

In contrast to other countries, the UK lacks both subsidies and tax breaks incentivising the take-up of solar shading.

There are no subsidies or tax breaks available for solar shading devices on buildings in the UK.

Conclusions and recommendations

There are requirements for solar control in the UK Building Regulations, in relation to:

- Criterion 3 of Approved Document Part L2A (non-domestic buildings of new construction), 'Limiting the Effect of Heat Gains in Summer', which sets out "to reduce the need for air conditioning or reduce the installed capacity of any air conditioning system".
- Criterion 3a of Approved Document Part L1A, 'Limiting the Effect of Heat Gains in Summer' (new construction homes), which refers to tackling the effects of solar gain in summer "by an effective combination of window size and orientation, solar protection through shading and other solar control measures".
- SAP also includes an overheating risk assessment, based on simple monthly averaged values, that allows designers or specifiers to consider shading as part of the calculation of overheating risk.

Although the UK Building Regulations refer to solar shading, compliance checks are patchy.

Incentives for incorporating these devices to reduce heat loss and/or glare are absent however.

A missing link in the UK context, however, is the ability to enforce what is already written into legislation. Building Control Officers seldom have time to assess the plans and buildings in detail, and their main priority is health and safety.

Better enforcement of UK Building Regulations is as important as the Regulations themselves.

The UK Government could also learn from experience in Austria and Belgium, and introduce reduced VAT for shading appliances, and possibly new allowances for corporation tax and income tax (like Italy) that allow firms and individuals to offset capital costs against their tax liabilities.

Alternatively (or in addition) the Government could favour shading in Building Regulations compliance models: perhaps assuming lower internal summer temperatures (like Norway), or apply a multiplier to mechanical cooling energy (like Denmark).

Reduced VAT and tax deductions would shore up the uptake of shading.

The Italian approach of mandating solar shading for certain building types is probably too heavy-handed for the UK, where market-based solutions are preferred.

It would also be beneficial to prove the case for solar shading having an impact on heat loss and therefore bringing some savings on heating energy. Evidence on such savings would be very helpful.

The Italian tax breaks for shading could be rolled out in the UK and could be improved further with more granular requirements in terms of thermal parameters as eligibility criteria, and whole glazing unit to be taken into account rather than the shading element alone.

In summary, solar shading Industry could:

- Assemble robust evidence about the energy and carbon-saving potential of shading devices.
- Examine ways of making the qualitative benefits of solar shading (including reduced glare, health and productivity benefits) clearer to building designers and those procuring buildings.

The UK Government could:

- Introduce tax-breaks on devices shading products to encourage uptake, including reduced VAT rates and/or allowing claims against income and corporation tax. Concerns exist with regard to the use of VAT as a leverage – there is no evidence that a reduced VAT would change the consumer's purchasing behaviour.
- Consider positive discrimination for blinds and shutters in models used for Building Control.
- Consider simpler limits on $kWhm^{-2}$, like those in Denmark, which would be easier for Building Control to enforce, and could ratchet down over time.

Strategic vision

A number of key barriers prevent us from achieving the potential of solar shading in the UK building sector.

- Devaluing benefits – solar shading perceived as an optional window dressing instead of a dynamic solar control and daylight management concept (ES-SO, 2014).
- Sub-optimal performance – below best-practice design, specification, installation.
- Under-exploited retrofit market – value engineering insufficiently informed due to difficulties in quantifying the business case for solar shading.
- Ill-informed occupant behaviour – the way users interact with solar shading is unpredictable and complex and does not necessarily aid the most efficient outcome.
- Lack of leadership – the industry voice still appears weak compared to other lobbies operating in the construction sector (e.g., HVAC, glass, lighting).

Although the industry already owns the means to address many of the barriers currently faced, the business case for stakeholders to act is blurred.

These barriers are both internal and external to the industry, involving different stages and factors – product development, manufacture and supply (manufacturers and suppliers), design development and specification (designers / specifiers), installation (installers), management and aftercare (Facility Managers / Investors); in-use (domestic /non-domestic users), the regulatory framework (Government), professional accreditation (Trade associations) and opinion forming (influencers).

The good news is that the industry already owns the countermeasures to tackle most of these barriers. A whole life-holistic approach, combined with improved skills, training and lobbying, and alignment with the EPBD recast, which specifically refers to enhanced indoor climate and cost-effectiveness in its mission statement, would hand in hand contribute towards achieving leadership (a loud and firm voice) in the construction sector.

Different stakeholders are needed to act against each barrier and the barriers themselves are affected by a number of externalities likely to arise in the future (such as stricter regulations, rising energy prices, further climate change, technology advances, and increased digitalisation).

Each barrier has been separately framed in the following data sheets, and the business case and actions detailed for relevant stakeholders to address them.

The key actions are then summed up in a joint action plan/strategic vision over the short and long term for the optimal uptake of shading systems in UK buildings (Table 6).

Recognition

Barrier	
	In the UK, solar shading is perceived as an optional window dressing, a soft furnishing rather than a dynamic working tool capable of delivering quantifiable benefits. The business and scientifically backed knowledge is poorly understood across the board by regulation bodies, building professionals and also consumers. The Industry itself is not fully aware of its potential. One of the reasons being the lack of a design steer – even good practice provisions can sometimes be perceived as devaluing shading and misleading specification systems data. For instance, the current Ska Rating allocates few credits for the use of shading – some are for recycled contents, some for recyclability potential along with a simplified steer on light shading performance (RICS, 2013). The rating system of voluntary green building schemes such as the Building Research Establishment Environmental Assessment Methodology (BREEAM) is also questionable when it comes to the relative value of shading. With regard to construction specification systems, the National Building Specification relegate shading to a general fixture/fitting (as coat pegs and floor mats) misleading its potential purpose and overall perception by specifiers / building professionals.

Stakeholder	Business Case	Action
Building professionals (manufacturers, suppliers; designers, specifiers; installers / surveyors)	Deliver an improved end-product, reduce litigation, increase market profile and turnover.	○ Identify training needs and upgrade skills.
Government	Optimally used shading is instrumental in achieving the Government's low carbon building and overheating mitigation targets. Reduced air conditioning would lessen the loads on electrical supply i.e. the risks of blackouts.	○ Provide as part of the future Part L revision process: - Refer to g_{tot} - Shading as a pre-requisite of air-conditioning. - Detailed anti-overheating requirements rather than an averaged allowance. - Locally accurate climate datasets, including estimate of future temperature patterns over the estimated building lifecycle. - Emphasis on BIM and DSM. ○ Revise regulation body to emphasise aspects such as visual amenity and occupant satisfaction in addition to energy efficiency backstops. ○ Incorporate more specific shading requirements in Part K, Part F, Part E Approved Documents. ○ Recognise shading as key thermal element of the building envelope in the construction specification database. ○ Review construction specifications to include whole-life performance requirements.
Trade associations	Raise the industry's profile and reputation consolidating a leadership position in the marketplace by capitalising upon the existing potentials.	○ Collate robust body of evidence to demonstrate weaknesses in design compliance tools / Part L approach. Justify the business and scientific case for the building regulations for the government (across the board). ○ Learn and disseminate lessons on overheating from Innovate UK's BPE Programme. ○ Raise the standard bar for the shading industry to perform at its best. ○ Raise awareness internally and externally across key opinion makers (e.g., CIBSE, BRE, etc.). ○ Work with CIBSE to the production of a Solar Shading Guide in addition to the existing TM37 Design for Improved Solar Shading Control. ○ Lobby on mainstream certification schemes and NBS. ○ Commission an independent overheating tool à la BuildDesk. ○ Work alongside with the Government to promote the European Solar Shading Database (ES-SDA), a solar shading Product Construction Database (PCDB).
Influencers	Unlock shading potential contribution to enhance the UK built environment.	○ Revise good practice guidelines / voluntary certification systems to better reflect the impact of shading in terms of comfort, overheating mitigation, productivity & wellbeing of the occupant. Promotion of exemplary case studies and champions.

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Performance

Barrier	
	Sub-optimal performance of shading can be triggered by the combination of different factors accrued throughout the entire process, from inception and briefing down to in-use and maintenance. Common causes are listed below o Sub-optimal manufacture. Product development below best practice / technical potential owing to shortage of skills within the industry. o Sub-optimal design. Reductionist approach to building design, shading is treated as a stand-alone element rather than a holistic component of the whole building system. Inaccurate compliance design tools and energy modelling software such as SAP and SBEM based on averaged climate datasets can misrepresent the impact of shading being unable to compute performance of shades at realistic levels. Leading influencers are to a certain extent still biased by not up-to-date research (last century papers) with marginal reference to EU guidelines. o Sub-optimal specification. Lack of skills and not up-to-date knowledge of products. A potential conflict of interest is also apparent in the way building services professionals are paid proportionally to the magnitude of the services specified. This indirectly acts as a deterrent against the adoption of solutions that, like shading, are not part of the building services but contribute to reduce their size i.e. the value. As a result, there is a general lack of training on the benefits of shading across building services professionals, and the modelling software are not shading friendly. o Sub-optimal installation. Shading relegated to an afterthought to mitigate sub-optimal design and specification. Illustrative cases are conservatory companies selling extensions that become ovens and consumers having to buy shading to make them liveable. Installation procedures below good practice due to lack of skills and training. o Sub-optimal operation. In the absence of planned / preventive maintenance measures in place, the maintenance regime is typically limited to corrective measures or is entirely ignored.

Stakeholder	Business Case	Action
Manufacturers and suppliers	Higher quality standards improve reputation and, ultimately, result in larger market share and reduced complaints.	o Ramp-up R&D investments, take advantage of EU- and UK-funding programmes to support and encourage research and innovation in product development, e.g. Framework Programmes for Research and Technological Development and Innovate UK funding competitions, consider working in consortia and with academia. o Aim at third-party assessment of the organisation quality and environmental management systems (e.g. ISO 9001, ISO 14001). o Formalise and implement a rigorous continuous professional development (CPD) plan for employees. o Partnering with providers of building management systems (BMS) to optimise shading interaction with lighting, ventilating and space cooling services. Efforts to lowering costs and increase availability of controls / sensors as short term objective. o Improve design and interface of controls to make them simpler to understand and use for better acceptance by the user.
Designers and specifiers	Effective projects for clients trigger higher market demand and reduce litigation.	o Holistic approach to building design. Integrate shading from the project onset in new construction design / existing building refurbishments with other building system components (glazing, HVAC, lights). Adoption of whole-life-cycle thinking. o Refer to construction material energy efficiency labelling systems such as the forthcoming Ecodesign of Energy Related Products Directive 2009/125/EC (due to be launched in 2018). o Critically use design compliance tools (SAP, SBEM) in light of their limitations only for building regulation compliance. Rely upon DSM to inform the actual design. o Upgrade to building information modelling (BIM) to be able to carry links / data enabling different shading materials to be modelled against different sizes & location of windows along with various glazing, calculating and visibly demonstrating light quantities and penetration (adjusted for time of day/year) and heat gain / loss. o Conform to the requirements for shading of EN standards. o Understanding of climate data sets and how these impact on the calculations and might change in the future because of climate change. o Aim at cost optimal levels of energy performance throughout the economic service life of the building in line with EPBD methodology. o Sensitise the client on the trade-off capital / operational cost associated with high standard building design.

Stakeholder	Business Case	Action
Installers / surveyors	Satisfied clients, higher likelihood of repeat business.	○ Formalise and implement CPD. ○ Identify and promote best practice. ○ Whole building approach – understand how shading interacts with the rest of the building prior to installation. ○ Offer post-installation support and set up helpline service throughout the liability period. ○ Increased awareness around the business case for solar shading.
Facility managers and investors	Reduce operational costs. Keep occupants happy and productive. Raise the value of the property.	○ Instruct occupant on the reasons for which shading has been installed (not window dressing), optimal use of shading at handover / induction. Incorporate guidelines in user information pack (user guides and operation manual). ○ Follow-up issues as they arise. ○ Appoint maintenance team, define a systematic maintenance plan, schedule and keep track of preventive maintenance measures in place. ○ Raise awareness on the reasons for using solar shading effectively via the User Manual. ○ Approach buildings as assets. Understand the cost-effectiveness of solar shading as an investment, not a revenue cost.
Domestic / non-domestic users	Feel at ease with the environment, reduce energy costs, improve comfort.	○ Adopt energy conscious behaviour by understanding the reasons for using solar shading effectively.
Trade associations	Showcase best practice, contribute towards government commitment to reduce environmental impact of buildings and improve the quality of the built environment.	○ Push to recognise shading as part of the building services package, revising the fee of building services engineers to cover the shading systems specified. Work with CIBSE to produce a Solar Shading Guide in addition to the existing Technical Memorandum 37 Design for Improved Solar Shading Control. ○ Assist sales people / surveyors and installers to pitch the business case for intelligent shading leveraging in particular on the energy savings. ○ Support switch to a whole building approach, inspire third-party certified performance rating systems for combined shading-glazing unit on par with the scheme developed by the German solar trade association ITRS with the German laboratory ift Rosenheim. ○ Alignment with EPBD recast and awareness raising on EN 15459 global cost methodology and associated parameters of calculation e.g. whole-life cost (capital + running incl. maintenance, replacement and disposal), energy price evolution, reference buildings. ○ Identify and promote best practice. ○ Template User Manual outlining the reasons for using solar shading effectively. ○ Promote energy performance indicators.

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Retrofit

Barrier	
	Under-exploited retrofit market opportunities. Existing buildings will have a predominant market share of the future building stock; high solar energy transmittance glazing (single- and uncoated- double glazing) amount to approximately 2 billion units across the EU (ES-SO, 2014); renovation rates are growing from 1% to 2-3% a year (Dolmans, 2011), it is unclear how the shading industry can turn the renovation market into a tangible business. The business case for shading is, to a certain extent, blurred. Pinpointing the parameters and performance that justify a certain price is not straightforward. Although the EPBD recast refers to shading as a priority passive measure to reduce energy intensive space cooling, the associated saving potential needs to be demonstrated on a building by building basis. Social benefits are difficult to express and there is not a standardised assessment method to quantify returns in terms of, for instance, glare, productivity, comfort, well-being or aesthetics. Sub-optimal installation practices and poor understanding of the whole window system performance, before (glazing unit) and after (glazing unit + shading) are further critical aspects to take into account when shading is fitted into existing buildings.

Stakeholder	Business Case	Action
Manufacturers and suppliers	Potentially higher turnover from a less saturated market.	o Understand technical performance, use consistent technical performance data to EN standard o Focus on bespoke products for variable window types. o Innovate on - Visual appearance to minimise visual impact into existing buildings. - Improve design and interface of controls to make them simpler to understand and use for better acceptance by the user. - Optimal interaction with existing façade systems, e.g. external wall insulation systems. - System adaptability (catering for future scenarios). - Maintenance-free systems, self-cleaning materials. - Integration with renewables (from passive to energy-positive systems). o Work in partnership with BMS providers for shading to be integrated with existing BMS. o Explore synergies with Internet of Things (IoT). o Extend warranties to raise consumer confidence. o Apply EN shading standards
Designers and specifiers	Provide clients with better solutions that address problems that are more widespread. Compliance with regulation.	o Thinking forward, design buildings that can be retrospectively provided throughout their service life with solar shading to tackle overheating. o Focus on whole life-cycle performance, benchmark against Reference Buildings to pinpoint where cost optimality lies. o Enhance instructions with more granularity. o Prevent shading from being uncritically value engineered out at later stages. o CPD on retrofit related aspects.
Installers / surveyors	Increased market share – less saturated market. Gain competitive advantage against competitors anticipating regulatory requirements / minimising regulatory risk.	o CPD on retrofit related aspects. o Whole building approach – understand how shading interacts with the rest of the building prior to installation. o Offer post-installation support and set up helpline service throughout the liability period. o Extend warranties to raise consumer confidence.
Facility managers and investors	Improve quality (health and comfort) and value (equity) of their assets.	o Appoint accredited installers. o Third-party review product design and installation practices against best practices. o Follow Soft-landings approach.

		o Identify and implement preventive maintenance actions throughout the building service life.
Government	Unlock the greater energy saving potential in the building sector. Contribute to wider objectives of increased productivity and business efficiency in the UK. Line up with EU requirements of reduced air conditioning via passive measures.	o Revise building regulations to recognise shading as a pre-requisite to air-conditioning systems, and complex shading. o Recognition under future retrofit programmes. o Tax breaks schemes for energy-saving technologies to include shading (e.g. Enhanced Capital Allowance). o Take on board EU requirements of reduced space cooling, revise design compliance tools to more accurately predict overheating in light of rising temperatures (climate change) and apply EN shading standards. o Review the National Policy Planning Framework to steer on the uptake of solar shading under specific conditions. o Do not scrap solar shading in deregulation agenda. o Produce a clear roadmap detailing the government’s intentions and associated time plan to upgrade the existing building stock for the industry to manage and optimise its resources accordingly.
Trade associations	Involve more firms and people from the market they represent.	o Comprehend purchase-decision factors and steer the industry to capitalise upon them. o Work with academia to develop scientific robust yardsticks / rules of thumb to quantify softer benefits (e.g., productivity, comfort, aesthetics, biophilia) in a shared way and convey the business case to the government. o Investigate working opportunities with novel whole house refurbishment approaches such as Energiesprong (pioneered in the Netherlands and currently in the process of getting introduced in the UK market).
Influencers	Contribute towards low carbon economy vision and smart cities.	o Identify and promote best practice.

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Occupant behaviour

Barrier	
	The impact of ill-informed occupant behaviour can prevent shading from unlocking its full potential and reducing its benefits. The effects of occupants not only relate to manually operated shading but also impact on automatic systems that can be overridden via manual by-pass. The variable drivers underpinning occupant behaviour are unpredictable, depend on individual preferences (e.g. subjective comfort thresholds, higher/lower degree of adaptability to external conditions), and dependent on the context (environmental, cultural etc.). Understanding how these variables can be governed is thus complex, and in many cases they end up being neglected. A problem often correlated is the lack of a handover induction for the end user on how to correctly operate the shading. In addition, without aftercare in place, issues occurring during the occupancy phase can persist indefinitely, at a cost in terms of both occupant dissatisfaction and suboptimal performance.

Stakeholder	Business Case	Action
Designers and specifiers	More satisfied clients, better reputation.	○ Human-centric design and specifications. ○ Better understanding of the critical aspects of automation systems and how they might fail to deliver upon intentions, in particular interactions with manual overrides. ○ Learn from the Innovate UK's BPE programme which key issues are more likely to be experienced during occupancy and how these can be avoided upstream through conscious design / specification decisions.
Facility managers, investors	More comfortable environment, with maximised outside views and daylight levels, has a return on the user's productivity and wellbeing – staff related costs are predominant in buildings such as offices. Users are happier and the value of the property goes up, raising the visibility of the project as a success story.	○ Monitor and understand how occupants interact with shading via surveys and questionnaires combined with sensors data (e.g. indoor air temperature, luminance levels) to find out if shading is optimally operated; and rectify as needed. ○ Arrange systematic handover to occupants with key project organisations involved (e.g., design team and M&E engineers) and instruct on shading rationale and related best practice. ○ Educate users to not conceive shading as window dressing. ○ Include instructions on shading optimal operation and maintenance regime in user guides and operation manual. ○ Put in place awareness raising initiatives, arrange contests amid owned buildings to showcase and award best-practice e.g., low energy consumption.
Government	The Government will not put its energy efficiency and CO_2 reduction targets in the building sector in practice until occupants are considered a key element of the equation.	○ Allocate funds to support research in the area of energy-related occupant behaviour in buildings and quantitative social research.
Trade associations	Responsibility to make sure that the products delivered by the industry are understood by consumers and perform as intention.	○ Learn and disseminate findings from Building User Satisfaction surveys conducted throughout the Innovate UK's BPE programme to critically understand what factors trigger positive or negative response from occupants in relation to the indoor environment. ○ Learn and disseminate findings from IEA-EBC Annex 66 'Definition and Simulation of Occupant Behavior in Buildings'. ○ Work with academia to characterise most common profiles of occupants with respect to solar shading use and define how shading can be optimised accordingly via DSM / in-field studies. Use of findings from DSM to build open domain datasets (operation schedules) that better inform DSM software such as EnergyPlus. ○ Disseminate best practice guidance to occupants tailored to building types.
Influencers	Advocate conscious behaviour with the twofold intention of improving quality of life of people and reducing energy use and costs, contributing to the triple bottom line of the sustainable development paradigm.	○ Identify and promote best practice, champions, case studies.

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Leadership

Barrier	
	The UK shading industry is lobbying less effectively compared to other industries such as insulation, glass and glazing, and building services. At the core is a disjointed industry voice that has not fully capitalised upon the available opportunities. Whilst the message has been successfully sent across the EU, the UK framework remains mostly unreceptive. Although the EPBD recast identified passive solar systems and solar protection as key priorities to enhance the thermal performance of buildings during the summer period and reduce the use of mechanical cooling against the backdrop of rising temperatures, growing energy prices, and increasing power shortages, UK building regulations still refer to solar shading only marginally and give a simplistic steer on mitigating overheating.

Stakeholder	Business Case	Action
Manufacturers and suppliers	Reinforce presence in the marketplace, maximise market opportunities and turnover.	o Commitment to quality. Aim at third-party assessment of the organisation quality and environmental management systems (e.g. ISO 9001, ISO 14001). o Formalise and implement a rigorous CPD plan for employees. o Continue to innovate.
Installers / surveyors	Reinforce presence in the marketplace, maximise market opportunities and turnover.	o Identify and implement best practice. o Optimise installations in relation to effects on the whole building performance. o Put CPD in place.
Trade associations	Take a lead and raise the profile of the industry.	o Identify and promote best practice, champions, and case studies. o Act as a single point of contact with the government of a collective and united industry voice working across the solar shading supply chain. o Work in partnership with UK / EU governments to the establishment of a more supportive regulatory landscape that fully unlocks the potentials of shading in relation to improving the efficiency of the UK building stock and raise the productivity of the workforce contributing to the more prosperous nation' envisioned by the Conservative government in July 2015. o Intensify dialogue with EU and international solar shading trade associations as well as key influencers (e.g., BRE, Arup), learn from success stories. o Raise the bar of the membership requirements in particular with regard to CPD commitments, inspire the industry to be at the forefront for quality and innovation across the UK construction industry.

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Table 6: Action plan for shading systems in the UK with timescale to put the actions in place and short / long term strategic vision.

Barriers	Externalities Climate change Stricter Regulations Rising energy prices Technology progress Digitalisation	Actions	Stakeholders: Manufacturers /sup.	Designers / specifiers	Installers / surveyors	FMs / Investors	Users	Government	Trade associations	influencers	Time horizon: Short term 2020	Long Term 2020-2050	Vision
Devaluing	Climate change Stricter regulations Rising energy prices Technology progress	Identify training needs and upgrade skills	V	V	V								2020 – *A united industry raising awareness towards the recognition of solar shading as a cost-effective measure to enhance the energy behaviour of the building in summer and winter periods. Government technology roadmaps refer to dynamic shading systems as a milestone to achieve nZEBs, in line with the EPBD vision and using relevant EN standards. Consumers approach to the solar shading market is better informed and the industry itself is aware of the substantial role that shading can play against increasing overheating risk and higher institutional recognition.* 2050 –*Shading is acknowledged as a solar control and daylight management concept complementary to building design. Against the backdrop of the global warming threat, overheating emerges as a key mandatory requirement. A revised regulatory framework incorporate advance design compliance tools to dynamically compute the performance of the building as a whole throughout its service life, with the underlying climate datasets informed by temperature change forecasts over the short, medium and long term. The design of building services starts from the identification of the most convenient passive cooling techniques, whose uptake are encouraged via financial incentives to tackle increasing occurrence of power shortages. Solar shading is common practice, and there are different tools that evaluate its impact at the whole building level.*
		Incorporate more specific shading requirements in Part L, Part K, Part F, Part E Approved Documents						V					
		Part L to refer to g_{tot}						V					
		Part L to refer to shading as a pre-requisite of air-conditioning						V					
		Part L to provide detailed anti-overheating requirements rather than an averaged allowance						V					
		Part L to be informed by locally accurate climate datasets (present & future) over the building lifecycle						V					
		Part L to be informed by BIM and DSM						V					
		Emphasise beyond energy efficiency aspects such as visual amenity and occupant satisfaction						V					
		Recognise shading as key thermal element of the building envelope in construction specification database		V				V		V			
		Review construction specifications to include whole-life performance requirements		V				V					
		Collate robust body of evidence to demonstrate weaknesses in design compliance tools / Part L approach							V				
		Collate robust body of evidence to justify the business and scientific case for the regulations							V				
		Raise government awareness on the impact of shading, across the board							V				
		Learn overheating lessons from Innovate UK's BPE Programme		V					V				
		Raise the standard bar for the shading industry to perform at its best	V		V				V				
		Raise awareness internally and externally across key opinion makers (e.g., CIBSE, BRE etc.)							V				
		Work towards a CIBSE Solar Shading Guide in addition to existing TM37							V	V			
		Launch an independent overheating tool à la BuildDesk							V				
		Continue developing and promote ES-SDA (Solar Shading PCDB)						V	V				
		Lobby for better recognition of shading in good practice guidelines / mainstream certification schemes / NBS							V				
		Promotion of exemplary case studies and champions							V	V			
		Understand the reasons for using solar shading effectively – shading is not window dressing		V		V	V						
Suboptimal performance	Stricter regulations Technology progress Digitalisation (IoT, BIM...)	Ramp-up R&D investments working in consortia and with academia (e.g., Innovate UK, Horizon2020 calls)	V										2020 – *A solar shading supply chain committed to continuous professional development and updated skills, taking on the learning curve to champion in the area. Architects approach building design from a more holistic angle and start embracing shading from the early design stages. Shading is more integrated within the building construction narrative and is no more conceived as mere afterthought to rectify deficiencies in design. Preventive maintenance measures and global cost become the norm for facility and portfolio managers, driven by the effort to maximise the commercial value of their assets achieving cost optimality.* 2050 – *An industry at the forefront of R&D, innovation and skills in the UK construction sector. BBSA accredited professionals working across the supply chain have their quality management systems certified by independent third parties and partner with building professionals to fine-tune the use of shading in the context of the whole building. Aftercare, performance guarantee, liability periods are integrated within the package offered to consumers.* *The UK approach is internationally recognised as a model to aim at.*
		Recurring third-party assessment of the organisation quality and environmental management systems	V		V								
		Formalise and implement a rigorous CPD plan	V	V	V								
		Work with BMS providers to integrate shading with building services and increase the availability of controls	V			V							
		Holistic approach and whole-life thinking for building integrated shading systems	V	V	V			V					
		Specify against Ecodesign of Energy Related Products Directive 2009/125/EC (still at draft stage)		V				V					
		Use / demand of SAP / SBEM for building regulation compliance and DSM to inform the actual design		V		V		V					
		Use / demand of BIM to define the optimal shading configuration in relation to specific boundary conditions		V		V		V					
		Understand climate datasets, the impact on the calculations and changes in future climate scenarios		V				V					
		Aim at cost optimal levels of energy performance throughout the economic service life of the building(EPBD)		V		V		V		V			
		Sensitise the user on the trade-off capital / operational cost associated with high standard building design		V		V		V					
		Increased awareness around the business case for solar shading.		V	V	V	V						
		Assist sales people / surveyors and installers to pitch the business case for intelligent shading.							V				
		Raise awareness on the reasons for using solar shading effectively. Produce User Manuals.				V			V				
		Identify and promote best practice	V	V	V	V		V	V	V			
		Promote energy performance indicators.						V	V				
		Offer post-installation support and set up helpline service throughout the liability period			V				V				
		Systematic maintenance regime, schedule and keep track of preventive maintenance measures in place				V	V						
		Follow-up issues as they arise				V	V						
		Instruct occupant on use of shading at handover / induction, incorporate guidelines in user information pack	V	V		V							
		Understand the cost-effectiveness – solar shading is an investment, not a revenue cost				V							
		Adopt energy conscious behaviour					V						
		Incorporate shading in the building services package, revise fee of building services engineers		V					V				
		Third-party certified performance rating systems for combined shading-glazing unit						V	V				
		Familiarise with EPBD recast, EN 15459 global cost methodology, energy price evolution, reference buildings		V				V	V				
Unexploited retrofit market	Climate change Stricter regulations	Understand technical performance, use consistent technical performance data to EN standard	V										2020 – *Against the EU2020 objectives of pushing the renovation rate from 1.2% to 2-3% per year, the solar shading industry has been investing on R&D and upskilling to*
		Focus on bespoke products for variable window types	V							V			

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Barriers	Externalities Climate change Stricter Regulations Rising energy prices Technology progress Digitalisation	Actions	Stakeholders Manufacturers /sup.	Designers / specifiers	Installers / surveyors	FMs / Investors	Users	Government	Trade associations	influencers	Time horizon Short term 2020	Long Term 2020-2050	Vision
	Rising energy prices Technology progress Digitalisation (IoT, BIM…)	Innovate on visual appearance to minimise visual impact into existing buildings	V	V									*overcome the regulatory and non-regulatory (market) barriers facing the energy upgrade of buildings, including addressing fragmentation within the supply chain; inefficiencies, complexities, and uncertain environmental requirements in the renovation processes; and lack of performance guarantees. Innovative business models are explored and tested to maximise impact against market failures. Solar shading synergies with novel whole house approaches delivering fully integrated refurbishment packages to achieve nZEB standards at reduced delivery time and costs are refined to maximise deep renovation potentials. Generally, new construction building design is rethought to incorporate principles such as adaptability of the buildings to future adverse climate conditions, and at the same time a more conscious approach to whole-lifecycle design and specifications results in solar shading that is not value engineered out.* 2050 – *The solar shading industry has been able to develop the means to optimise shading selection based on a series of quantitatively robust metrics of performance (e.g., visual amenity, daylighting, overheating, comfort) whose assessment methodology is internationally shared across industry and academia. Shading uptake in retrofitted existing buildings increases to enhance the health and wellbeing of the occupants. In order to ramp-up retrofit and meet its legislated commitment to cut carbon dioxide emissions of 80% by 2050, the UK government has introduced financial mechanisms and instruments to shore up the energy performance upgrade of the existing building stock, where highest energy saving potentials are available, stimulating the market demand for energy efficient products. Technology development is seeing renewable integrated shading systems, marking the shift from passive to energy-generating solutions.*
		Innovate on optimal interaction with existing façade systems, e.g. external wall insulation systems	V		V								
		Innovate on system adaptability (catering for future scenarios)	V		V								
		Innovate on maintenance-free systems, self-cleaning materials	V										
		Innovate on integration with renewables (from passive to energy-positive systems)	V	V									
		Improve design and interface of controls for ease of use and better acceptance by the user.	V										
		Work in partnership with BMS providers for shading to be integrated with existing BMS	V	V	V								
		Explore synergies with Internet of Things (IoT)	V	V	V			V	V				
		Design buildings that can be retrospectively provided throughout their service life with solar shading		V									
		Focus on whole life-cycle performance, benchmark against Reference Buildings to pinpoint cost optimality		V		V		V	V				
		Enhance specifications with more granularity		V									
		Prevent shading from being uncritically value engineered out at later stages		V									
		CPD on retrofit related aspects		V	V	V							
		Whole building approach – understand how shading interacts with the rest of the building	V	V	V	V			V				
		Offer post-installation support and set up helpline service throughout the liability period			V								
		Extend warranties to raise consumer confidence	V		V								
		Appoint accredited installers				V							
		Third-party review product design and installation practices against best practices				V							
		Follow Soft-Landings approach				V							
		Identify and implement preventive maintenance actions throughout the building service life				V							
		Revise building regulations to recognise shading as a pre-requisite to air-conditioning and complex shading						V	V				
		Recognition under future retrofit programmes						V					
		Tax breaks schemes for energy-saving technologies to include shading (e.g. Enhanced Capital Allowance)						V					
		Apply EN standards for shading	V					V					
		Revise EN standards and compliance tools to predict more accurately current and future overheating risk		V				V					
		Review the National Policy Planning Framework to steer on the uptake of solar shading						V					
		Do not scrap solar shading in deregulation agenda						V					
		Clear road-mapping how and when the government intends to retrofit the existing building stock						V					
		Comprehend purchase-decision factors and steer the industry to capitalise on them							V				
		Develop with the academia scientific robust yardsticks / rules of thumb to quantify softer benefits							V				
		Investigate working opportunities with novel whole house refurbishment approaches such as Energiesprong	V						V				
		Identify and promote best practice							V	V			
Ill-informed occupant behaviour	Climate change Rising energy prices Technology progress Digitalisation (IoT, BIM…)	Human-centric design and specifications		V									2020 – *Consensus is reached in language and methodology to define and simulate occupant behaviour in a consistent and scientifically robust way. A common framework is established, underpinned by an ontology of different occupant behaviour models, including quantitative descriptions of building system-occupant behaviour interactions, and shared approach to quantitatively describe and assess the context-dependent psychological, physiological and economic factors determining occupant behaviour. Occupancy monitoring programme and data mining to improve knowledge are afoot.* 2050 – *Quantitative descriptions and profiles of occupants in relation to interactions with solar shading inform occupant behaviour models within building energy simulation tools as a steer to pinpoint optimal shading solutions on a building-by-buildingbasis. Controls systems fine tune shading operations according to learning algorithms. Data sharing via IoT feeds data back to architects, engineers, building operators for a constant refinement and upgrade of occupant models minimising performance gap.*
		Better understand reasons of potential performance gap in automation systems	V	V		V							
		Occupant-related learnings from the BPE programme, and mitigation measures at design / specification		V		V		V	V	V			
		Monitor occupants' interactions with shading – surveys + sensors data; rectify suboptimal behaviour				V							
		Systematic handover with key project organisations involved, instruct on shading-related best practice		V		V							
		Educate and instruct on shading optimal operation and maintenance regime in user guides and manual	V	V		V							
		Awareness raising, contests amid owned buildings to showcase and award best-practice				V							
		Fund research in the area of energy-related occupant behaviour in buildings and quantitative social research	V					V					
		Understand triggers of occupants' positive/negative response from BPE's Building User Satisfaction surveys	V	V					V				
		Learnings from IEA-EBC Annex 66 'Definition and Simulation of Occupant Behavior in Buildings'	V	V					V				
		Work with academia to characterise most common profiles of solar shading use via DSM / in-field studies		V					V				
		Disseminate solar shading best practice guidance to occupants tailored to building types		V					V				
Lack of leadership	Climate change Stricter regulations Rising energy prices Technology progress	Aim at third-party assessment of quality and environmental management systems	V										2020 – *The solar shading industry has been actively involved in the Part L revision process to ramp-up compliance and implementation of EPBD recast and making its voice heard in EU tables. BBSA continues working across the supply chain raising awareness around the industry potential, inspiring best-practice, and understanding how effective results can be ensured in practice.* 2050 – *A united industry that has been lobbying powerfully as a collective and united*
		Formalise and implement a rigorous CPD plan for employees	V										
		Continue to innovate	V										
		Identify and implement best practice			V								
		Optimise installations in relation to effects on the whole building performance			V								
		Identify and promote best practice, champions, and case studies			V				V				
		Act as a single point of contact with the government of a collective and united industry voice							V				

Barriers	Externalities	Actions	Stakeholders								Time horizon		Vision
	Climate change Stricter Regulations Rising energy prices Technology progress Digitalisation		Manufacturers /sup.	Designers / specifiers	Installers / surveyors	FMs / Investors	Users	Government	Trade associations	influencers	Short term 2020	Long Term 2020-2050	
		Work in partnership with governments to the establishment of a more supportive regulatory landscape							*V*				*voice and has taken a lead at UK and EU level.*
		Intensify dialogue with EU and international solar shading trade associations and key influencers (BRE, Arup)							*V*				
		Raise the bar of the membership requirements in particular with regard to CPD commitments							*V*				
		Inspire the industry to be at the forefront for quality and innovation across the UK construction industry							*V*				

Where Next

This Solar Shading Impact report aims to be envisioned as a 'dynamic' document and will be reviewed in May 2017 based on the feedback received from the readers in the interim.

Readers are invited to send comments, warts and all, on the report via the BBSA Shade it website. Comments will be reviewed and fed into a revised version of the report that will be made available in the public domain.

An area of particular focus will aim to reach a consensus around the laboratory test procedures on the basis of internationally recognised standards. Currently independent companies refer to research laboratories of their own choice and between themselves devise tests representative of the investigated performance. General consensus is sought on what tests are required and which parameters should companies be looking at.

In addition, the BBSA are looking for case studies that showcase the optimal use of shading with quantitative evidence of the benefits gained. A possible output of this could lead to the introduction of a new Architectural Competition (open to all countries) its shape being defined by the submissions received.

In terms of the next steps, the authors of the report consider upgrading solar shading modelling to international standards (EN / ISO) essential to making shading a mainstream energy efficiency measure as opposed to a decorative product. Modelling should be informed and supported by third-party certified performance indicators. The ES-SDA datasets, based on ISO compliant laboratory tests corroborated by a Peer Review Committee, would provide a more robust knowledge base compared to outdated references tracing back to the last century. This trajectory would line up with the steer coming from EU-driven projects such as QUALICHeCK (qualicheck-platform.eu), tasked with improving the reliability of building information, which is required to make the nZEB target not just rhetoric.

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Appendices

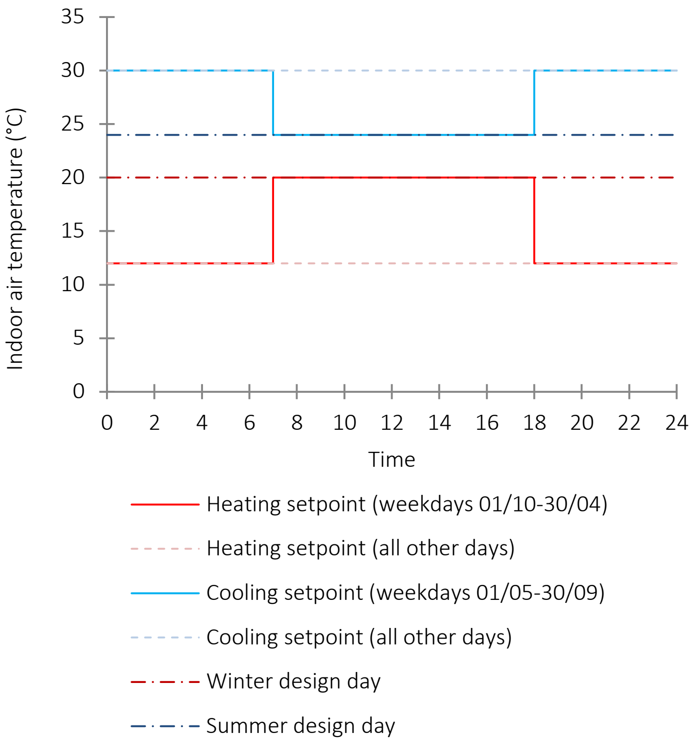
Appendix A – Representative prices per configuration adopted in the Cost-Benefit Analysis (assumed exchange rate 1€=£0.7880).

Criteria	Average price per m² € [£]	Baseline configuration	Reference
Internal shading			
Drapes & Curtains	€50-100 [£40-79]	Generic curtain	Market research
Louvered Shade	€40 [£32]	Internal venetian blind, manually operated	Sack et al., 2014
	€125 [£99]	Generic shutter	Sack et al., 2014
Roller Shade	€40 [£32]	Internal roller blind, manually operated	Sack et al., 2014
Panel Shade (solar screens)	€133 [£105]	Manual panel shutters	Sack et al., 2014
	€533 [£422]	Motorised panel shutters	Sack et al., 2014
Cellular Shade	€100-200 [£79-158]	Internal blinds	Assumed from €69-185 Ecodesign estimate for internal blinds
External shading			
Roller Blinds and Shutters	€90 [£71]	External roller blind	Sack et al., 2014
	€140 [£111]	External venetian blind	Sack et al., 2014
	€125 [£99]	Generic shutter	Sack et al., 2014
Fixed horizontal shading	€381-508 [£300-400]	Brise-soleil	Langdon, 2008
Retractable Awnings	€143 [£133]	Awning	Sack et al., 2014
Applied films	€37-57 [£29-45]	Standard solar control / spectrally selective film	Market research
Treated glass	€381-546 [£300-430]	Double / triple glazed soft-coat window	Market research
Fan coil systems	€63-76 [£50-60]	2 pipe fan coil for office building up to 3000 m²	Langdon, 2008

Appendix B – Dynamic simulation modelling inputs for the office baseline buildings.

Context	One private office, located halfway through the south façade of a small office building located in London. The office has only one south-facing external wall with one window. The adjacent environments were assumed adiabatic (no heat loss or gain in the system).
Geometry	
Floor area	15 m^2 (5x3m)
Floor-to-ceiling height	3.5m
Window	4.8x2.9m
Glazing to wall ratio	0.8
Construction (outside to inside)	
External wall	6mm lightweight metallic cladding; 50mm EPS insulation; lightweight 6mm metallic cladding – 0.45 $Wm^{-2}K^{-1}$
Ceiling / roof	3mm carpet; 50mm screed; 100mm polyurethane board; 100mm cast concrete; 3mm plaster – 0.22 $Wm^{-2}K^{-1}$
BS EN 14501:2005 Glazing C	4/16/4 double glazing, low-e in position 3 – U-value: 1.2 $Wm^{-2}K^{-1}$ | g-value: 0.59
External pane [internal pane]	Solar transmittance: 0.83 [0.58] Front side solar reflectance: 0.08 [0.30] Back side solar reflectance: 0.08 [0.24] Front side emissivity: 0.84 [0.05] Back side emissivity: 0.084 [0.84]
Internal partition	12.5mm plasterboard; 50mm cavity; 12.5mm plasterboard – 1.79 $Wm^{-2}K^{-1}$
Air infiltration	0.3 air changes per hour (ACH)
HVAC&R	
Space heating plant	Natural gas-fired boiler (η=0.65) with hydronic circuit ($t_{water,out}$= 81°C)
Space cooling plant	Electric chiller (ESEER=2.00) with chilled water ($t_{water,out}$= 6.67°C) and two-speed cooling tower
HVAC&R system	Four-pipe fan coil
Heating coil	Hot water heating coil ($t_{water,in}$=82.2°C; $t_{air,out}$=32.2°C)
Cooling coil	Chilled water cooling coil ($t_{water,in}$=24.14°C; $t_{air,out}$=14°C)
Fans	Constant volume fan (η=0.70)
Setpoint schedule	7 am to 6 pm during occupied periods
Heating setpoint [setback]	20°C [12°C] (working days) | [12°C] (non-working days)
Cooling setpoint [setback]	24°C [30°C] (working days) | [30°C] (non-working days)
Ventilation	3.25 l s^{-1} person (CIBSE, 2005)
Occupancy	
Occupant density	One occupant
Schedule	8am to 5pm with two half hour breaks in the morning and in the afternoon + one-hour lunchbreak during the working days. Assumed unoccupied over weekends and holidays (Appendix C).
Internal loads (CIBSE, 2016)	
Sensible occupant heat output [latent]	115 [70] W $person^{-1}$
Sensible equipment heat output	12 Wm^{-2}
Lighting power density	9 Wm^{-2}

Appendix C - Dynamic simulation modelling schedules for the office case study: (a) space heating and cooling setpoints; (b) occupancy; (c) equipment, (d) lighting; (e) ventilation.



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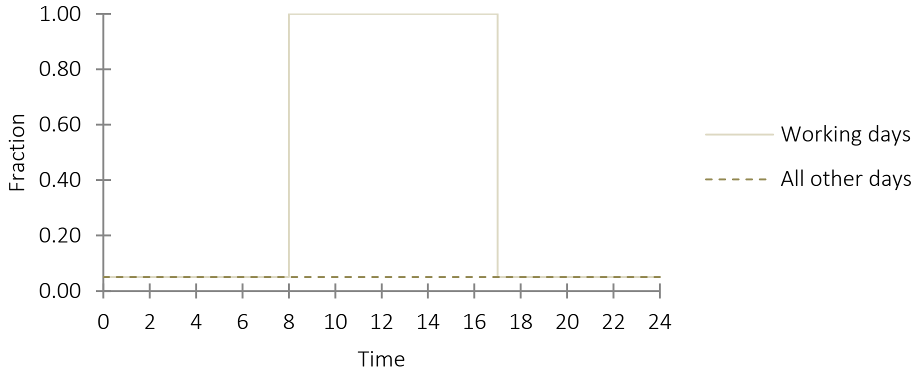

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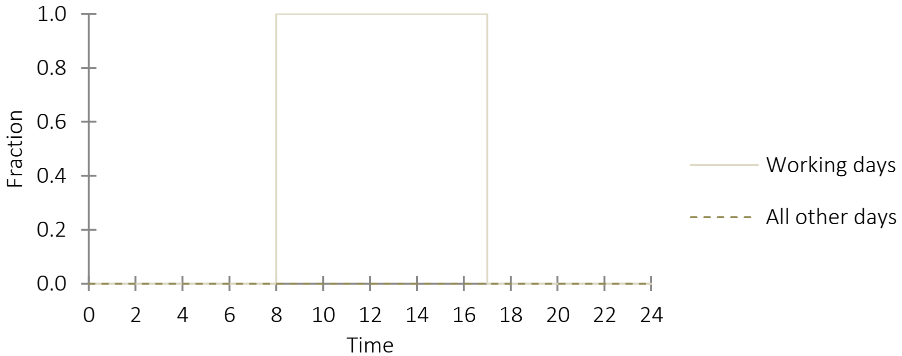

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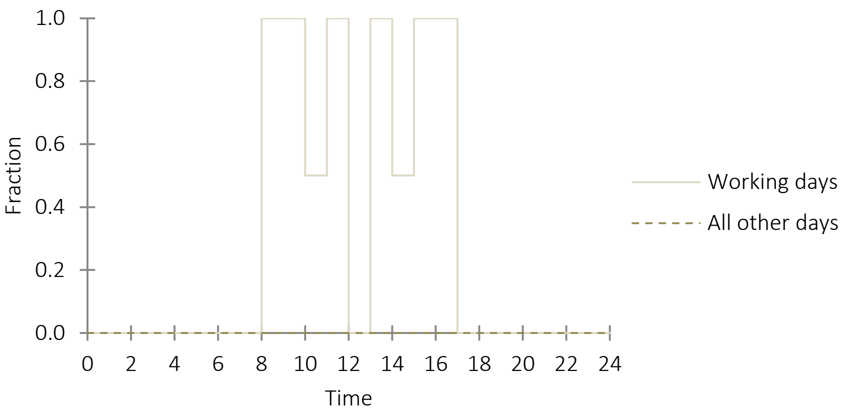

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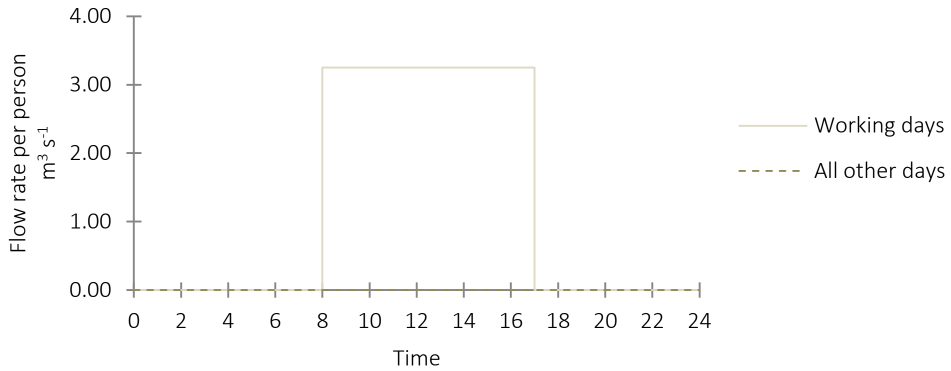

(e)

Appendix D - Dynamic simulation modelling shading inputs: internal (SSI1) and external (SSE1) shades.

Field	Unit of measure	SSI1	SSE1	Reference
Control	-	Beam + diffuse incident radiation > 400 Wm^{-2}	Beam + diffuse incident radiation > 400 Wm^{-2}	Assumed
Solar transmittance [i]	-	0.17	0.09	ES-SO benchmark shades
Solar reflectance [ii]	-	0.56	0.41	ES-SO benchmark shades
Visible transmission [i]	-	0.16	0.08	ES-SO benchmark shades
Visible reflection [ii]	-	0.63	0.43	ES-SO benchmark shades
ε_{eff}, effective thermal hemispherical emissivity [iii]	-	0.87	0.86	Manually calculated
T_{eff}, effective thermal transmittance [iv]	-	0.03	0.05	Manually calculated
Thickness	m	0.00048	0.00083	Product sheets
Conductivity	$W\ m^{-1}K^{-1}$	0.136	0.136	Inferred for PVC-coated fibreglass fabric
Distance from shade to adjacent glass	m	0.05	0.05	Assumed
Top opening multiplier [v]	m^2/m^2	0.6	0.6	Manually calculated
Bottom opening multiplier [vi]	m^2/m^2	0.6	0.6	Manually calculated
Left side opening multiplier [vii]	m^2/m^2	0.4	0.4	Manually calculated
Right side opening multiplier [viii]	m^2/m^2	0.4	0.4	Manually calculated
Shade fabric permeability to air flow [ix]	-	0.002	0.004	Manually calculated

[i] Assumed independent of angle of incidence.
[ii] Assumed same on both sides of shade and independent of angle of incidence.
[iii] Assumed same on both sides of shade. $\varepsilon_{eff} \approx \varepsilon$ (1-Openness Factor).
[iv] Assumed independent of angle of incidence. $T_{eff} \approx$ Openness Factor + T (1 -Openness Factor) $\approx$ Openness Factor [being for most materials T very close to zero].
[v] Effective area for air flow at the top of the shade divided by the horizontal area between glass and shade.
[vi] Effective area for air flow at the bottom of the shade divided by the horizontal area between glass and shade.
[vii] Effective area for air flow at the left side of the shade divided by the vertical area between glass and shade.
[viii] Effective area for air flow at the right side of the shade divided by the vertical area between glass and shade.
[ix] Shading openness factor divided by the shade area.

Appendix E: Dynamic simulation modelling shading inputs: internal (SSI2) and external (SSE2) blinds.

Field	Unit of measure	SSI2	SSE2	Reference
Shading control		Beam + diffuse incident radiation > 400 Wm^{-2}	Beam + diffuse incident radiation > 400 Wm^{-2}	Assumed
Slat orientation	Horizontal / vertical	Horizontal	Horizontal	Assumed
Slat width from edge to edge	m	0.025	0.025	Assumed
Slat separation (measured from central point)	m	0.01875	0.01875	Assumed
Slat thickness	m	0.008	0.008	Product sheet
Default slat angle between the glazing outward normal and the slat outward normal	deg	45	3	ES-SO benchmark shades
Minimum slat angle	deg	17.4	17.4	Assumed
Maximum slat angle	deg	162.6	162.6	Assumed
Slat angle control		Block beam solar[i]	Block beam solar[i]	Assumed
Slat conductivity	$W\,m^{-1}K^{-1}$	190	190	Inferred for generic aluminium
Slat beam solar transmittance[ii]	-	0.11	0	ES-SO benchmark shades
Front side slat beam solar reflectance[iii]	-	0.54	0.72	ES-SO benchmark shades
Back side slat beam solar reflectance[iii]	-	0.54	0.72	ES-SO benchmark shades
Slat diffuse solar transmittance	-	0.11	0	ES-SO benchmark shades
Front side slat diffuse solar reflectance	-	0.54	0.72	ES-SO benchmark shades
Back side slat diffuse solar reflectance	-	0.54	0.72	ES-SO benchmark shades
Slat beam visible transmission[iv]	-	0.12	0	ES-SO benchmark shades
Front side slat beam visible reflection[iii]	-	0.61	0.81	ES-SO benchmark shades
Back side slat beam visible reflection[iii]	-	0.61	0.81	ES-SO benchmark shades
Slat diffuse visible transmission	-	0.12	0	ES-SO benchmark shades
Front side slat diffuse visible reflection	-	0.61	0.81	ES-SO benchmark shades
Back side slat diffuse visible reflection	-	0.61	0.81	ES-SO benchmark shades
Slat infrared hemispherical transmittance	-	0.0	0.0	Assumed (typically zero for non-solid metals)
Front side slat infrared hemispherical emissivity	-	0.9	0.9	ES-SO benchmark shades
Back side slat infrared hemispherical emissivity	-	0.9	0.9	ES-SO benchmark shades
Blind to glass distance	m	0.05	0.05	Assumed
Blind top opening multiplier[v]	m^2/m^2	0.6	0.6	Manually calculated

Field	Unit of measure	SSI2	SSE2	Reference
Blind bottom opening multiplier[vi]	m^2/m^2	0.6	0.6	Manually calculated
Blind left-side opening multiplier[vii]	m^2/m^2	0.4	0.4	Manually calculated
Blind right-side opening multiplier[viii]	m^2/m^2	0.4	0.4	Manually calculated

[i] Control algorithm that varies the slat angle to block beam solar radiation causing possible unwanted glare according to the minimum / maximum slat angle. In absence of beam solar, the default slat angle is set.

[ii] Assumed independent of angle of incidence. The quota of transmitted beam radiation is assumed 100% diffuse i.e., translucent slats.

[iii] Assumed independent of angle of incidence i.e., with a matte finish.

[iv] Assumed independent of angle of incidence. The quota of transmitted visible radiation is assumed 100% diffuse i.e., translucent slats.

[v] Effective area for air flow at the top of the shade divided by the horizontal area between glass and shade.

[vi] Effective area for air flow at the bottom of the shade divided by the horizontal area between glass and shade.

[vii] Effective area for air flow at the left side of the shade divided by the vertical area between glass and shade.

[viii] Effective area for air flow at the right side of the shade divided by the vertical area between glass and shade.

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Appendix F: Annual energy breakdown, total primary energy, CO_2 emissions and running costs per m^2 per internal (SSI1) and external (SSE1) shade; internal (SSI2) and external (SSE2) blinds against a shading-free reference building (RB).

Category	Unit of measure	Actual [Difference against RB]							
		RB	SSI1	% variation	SSI2	% variation	SSE1	% variation	SSE2	% variation
Space heating	$kWh_{th}\ m^{-2}year^{-1}$	17.0	19.5 [+2.5]	+15%	18.5 [+1.5]	+9%	30.0 [+13.0]	+77%	27.0 [+10.0]	+59%
Space cooling	$kWh_{el}\ m^{-2}year^{-1}$	109.6	86.4 [-23.1]	-21%	98.7 [-10.9]	-10%	32.2 [-77.4]	-71%	40.4 [-69.2]	-63%
Fans	$kWh_{el}\ m^{-2}year^{-1}$	15.7	14.1 [-1.5]	-10%	15.7 [+0.1]	0%	5.6 [-10.0]	-64%	6.5 [-9.1]	-58%
Circulation pumps	$kWh_{el}\ m^{-2}year^{-1}$	11.8	9.5 [-2.3]	-20%	10.8 [-1.0]	-8%	3.0 [-8.8]	-75%	3.8 [-8.1]	-68%
Heat rejection	$kWh_{el}\ m^{-2}year^{-1}$	0.4	0.3 [-0.1]	-20%	0.4 [0.0]	-10%	0.1 [-0.3]	-65%	0.2 [-0.2]	-57%
Total HVAC&R end-use energy	$kWh\ m^{-2}year^{-1}$	**154.4**	**129.9 [-24.6]**	**-16%**	**144.1 [-10.4]**	**-7%**	**70.9 [-83.6]**	**-54%**	**77.9 [-76.5]**	**-50%**
Equipment	$kWh_{el}\ m^{-2}year^{-1}$	31.9	31.9 [-]	0%	31.9 [-]	0%	31.9 [-]	0%	31.9 [-]	0%
Lighting	$kWh_{el}\ m^{-2}year^{-1}$	21.1	21.1 [-]	0%	21.1 [-]	0%	21.1 [-]	0%	21.1 [-]	0%
Total end-use energy	$kWh\ m^{-2}year^{-1}$	**207.4**	**182.9 [-24.6]**	**-12%**	**197.1 [-10.4]**	**-5%**	**123.9 [-83.6]**	**-40%**	**130.9 [-76.5]**	**-37%**
Total primary energy[i]	$kWh_{pe}\ m^{-2}year^{-1}$	**605.5**	**525.4 [-80.0]**	**-13%**	**570.7 [-34.7]**	**-6%**	**324.8 [-280.6]**	**-46%**	**352.0 [-253.5]**	**-42%**
Total carbon dioxide emissions[ii]	$kgCO_2\ m^{-2}year^{-1}$	**102.5**	**89.0 [-13.5]**	**-13%**	**96.7 [-5.9]**	**-6%**	**55.2 [-47.3]**	**-46%**	**59.8 [-42.8]**	**-42%**
Total running energy costs[iii]	$£\ m^{-2}year^{-1}$	**£23.2**	**£20.1 [-£3.2]**	**-14%**	**£21.9 [-£1.4]**	**-6%**	**£12.1 [-£11.2]**	**-48%**	**£13.2 [-£10.0]**	**-43%**

[i] **Primary energy factor** – 1.22 (natural gas); 3.07 (electricity) [Source: SAP 2012].

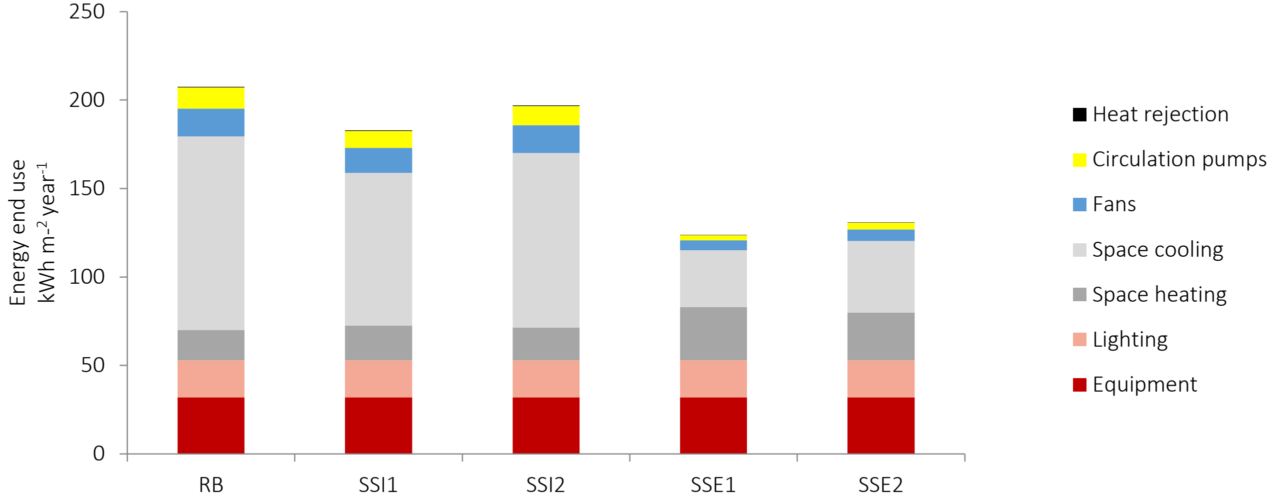
[ii] **Carbon intensity factor** – 0.216 $kgCO_2kWh_{th}^{-1}$ (natural gas); 0.519 $kgCO_2kWh_{el}^{-1}$ (electricity) [Source: SAP 2012].

[iii] **Energy tariff** – £0.029 kWh_{th}^{-1} (natural gas); £0.119 kWh_{el}^{-1} (electricity) [Source: DECC's Prices of fuels purchased by small energy intensive non-domestic consumers in the United Kingdom over 2014 Quarter 4 (including the Climate Change Levy)]

Appendix G: Total nominal capacities and fans' rated electric power of the HVAC&R components per internal (SSI1) and external (SSE1) shade; internal (SSI2) and external (SSE2) blinds against a shading-free reference building (RB).

HVAC&R component	Unit of measure	Nominal capacity [% variation]				
		RB	SSI1	SSI2	SSE1	SSE2
Boiler	W	785.9	785.9 [0%]	785.9 [0%]	785.9 [0%]	785.9 [0%]
Chiller	W	3188.9	2890.4 [-9%]	3196.7 [0%]	1220.6 [-62%]	1406.3 [-56%]
Cooling tower	W	3826.7	3468.4 [-9%]	3836.1 [0%]	1464.7 [-62%]	1687.5 [-56%]
Cooling coil	W	4299.3	3896.5 [-9%]	4311.8 [0%]	1626.2 [-62%]	1878.9 [-56%]
Heating coil	W	659.9	659.9 [0%]	659.9 [0%]	659.9 [0%]	659.9 [0%]
Fans rated electric power	W	26.7	24.1 [-10%]	26.8 [0%]	9.5 [-64%]	11.1 [-58%]

Appendix H: Energy modelling outputs per internal (SSI1) and external (SSE1) shade; internal (SSI2) and external (SSE2) blinds against a shading-free reference building (RB): (a) annual energy use breakdown per HVAC&R end-use, (b) total nominal capacity breakdown per HVAC&R component.



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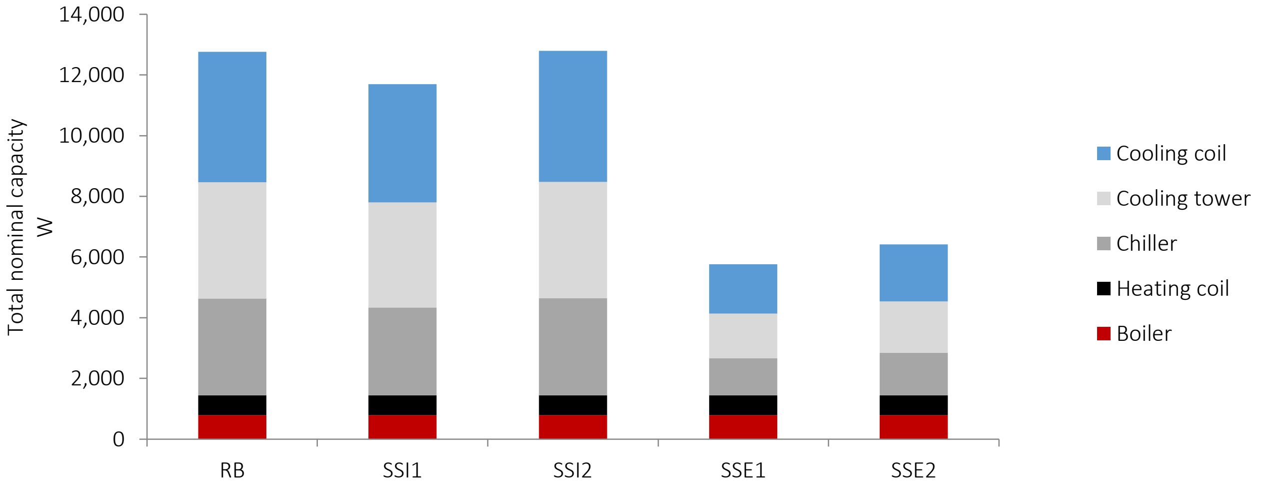

(b)

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