Environmental performance of external roller blinds in the UK

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Fixed external shading devices, such as louvers, are widely used to combat solar gains that can lead to excessive overheating. External roller blinds are retractable shading devices formed of horizontal slats that roll up into a casing above a window opening. They are a well-developed technology with distinct advantages over fixed external shading devices. External roller blinds, although commonly used in mainland Europe, are rarities in the UK.

This paper reports on an on-going applied research project investigating the thermal and environmental performance of external roller blinds in the UK. This work contains a summary of studies carried out; an in-situ demonstration of concept study; a computer thermal simulation and an assessment of life cycle environmental impact. The results show that external roller blinds have the potential to improve the thermal performance of a building and reduce associated operational energy consumption by 15% annually. The blinds control excessive solar gains and reduce the requirement for cooling. In cold weather they reduce heat loss and the requirement for heating. The environmental impact assessment revealed that a blind in operation can compensate its lifecycle emissions in less than six months.

Alonso Marshall Associates (AMA) are working on a shorter Knowledge Transfer Partnership (KTP) with the University of Brighton to support the launch of external blinds in the UK. AMA provides professional services to the construction industry with much of their work aiming to reduce the carbon emissions of buildings.

Keywords: external roller blinds, shading device, solar control, heat loss reduction, thermal performance, computer modelling, environmental impact, Knowledge Transfer Partnership

1. Introduction

One of the most common causes of overheating in buildings is excessive solar gains though windows. Controlling solar gains is a key consideration in maintaining indoor comfort and implementing low energy building design. Solar gains can be limited with effective shading; shading can reduce overheating, regulate swings in temperature and reduce the building cooling load. In comparison to mechanical cooling, shading is energy efficient and more cost effective way to control overheating (CIBSE, 2006; Littlefair, 2002; 2006). Effective shading is an integral part of a sustainable building and should be considered from early design stages of new buildings and for retrofit of existing buildings.

This paper reports on an on-going applied research project on the impact of integrating external roller blinds as a sustainability measure to buildings in the UK. External roller blinds are discussed as a potential low carbon technology, the theory for their use is reviewed and their function is outlined. The findings and conclusions of the first three stages of a research programme focusing on a retrofit office building installation are summarised, these are; an experimental study, a computer thermal simulation and an environmental impact assessment.

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Much of this work has been undertaken during a Knowledge Transfer Partnership (KTP) project formed between Alonso Marshal Associates (AMA) and the University of Brighton. KTP is a Technology Strategy Board funded programme helping businesses improve through interaction with academic institution and subsequent transfer of knowledge, technology and skills (KTP, 2013).

The immediate outcome of the partnership has been the launch of Enviroblinds Ltd, an external roller blind specialist company in the UK. External roller blinds are an area of on-going research and beyond the KTP project.

1.1 Background

Level of solar gain in a space is established by the amount of solar radiation transmitted by and absorbed within the glazing system; the higher the gain the greater the increase in temperature (CIBSE, 2006). External shading is more effective than internal shading in reducing overheating as most of the heat in solar radiation is prevented from reaching a building surface. External shading can reduce solar heat input by 80% to 90% (Wuffinghoff, 1999). Detailed design, in particular of fixed shading systems, is required to ensure heating and lighting demand is not increased by blocking out useful daylight and winter passive heat gain (Littlefair 2002; 2006). The need for shading is not the same throughout the year; variation comes from seasonal requirements, daily weather and building occupant needs. Therefore, moveable devices that can respond to the climate and user needs are preferred.

1.2 Quantifying performance

Three different performance indicators are used in this research; shading performance, amount of heat loss and greenhouse gas emissions. In order to allow comparison with other systems a method of quantifying is outlined.

1.2.1 Quantifying shading

On a clear summer day, an unshaded window in the UK can admit 3kWh/m^2/day (Littlefair, 1999). To reduce overheating, a shading device should have a low total *solar transmittance,* or *g-value*, the fraction of incoming solar radiation. It includes radiation that is transmitted directly through the window and radiation that is absorbed by the glazing; and then re-radiated, convected or conducted into the room. The *effective solar transmittance*, or effective g-value g_{eff}, allows for the effects of radiation coming in from different angles, throughout a sunny day and also accounting the extra impact of a shading device, Figure 1 (CIBSE, 2006). If possible, the g_{eff}*-value* should be low in the summer to reduce excessive solar heat gain and high in the winter to take advantage of passive heat gain.

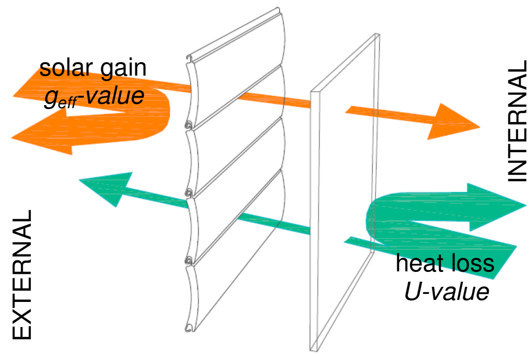


Figure 1. Solar gain and heat loss through external blind and window

1.2.2 Quantifying heat loss

External blinds provide additional insulation due to the air enclosed between the window and the blind. The degree of insulation depends on the level of enclosure, the effective entrapment by top and bottom seals and side channels (CIBSE, 2006). The thermal transmittance of a window with closed external blind, or heat loss, is expressed as *U-value*. The smaller the U-value the better, as less heat is transferred through the component.

1.2.3 Quantifying greenhouse gas emissions

Embodied greenhouse gas (GHG) emissions can be calculated by measuring the energy used in the manufacturing processes and transport and applying published conversion factors.

Table 1. Conversion factors for greenhouse gas emissions, kgCO$_{2e}$/kWh (Defra 2011)

Natural gas	Grid electricity		Transport	
	UK	Spain	Road	Sea
0.224	0.48462	0.32588	0.25897	0.00411

2. Performance and function of external roller blinds

External roller blinds are retractable shading devices that are widely used in continental Europe. They provide solar control and reduce heat gains by blocking solar radiation externally. In a down position the blind increases thermal resistance, resulting from both the blind itself and the additional air layer enclosed between the window and the blind.

The thermal impact of various fixed external shading devices has been studied (Littlefair 2006, Stack et al 2000); focus often being on reducing summer overheating without blocking out useful daylight. Performance indicators are established for generic static shading devices as shown in Table 2. However, these performance indicators, in terms of *effective solar transmittances* (g_{eff}), are not appropriate for external roller blinds. Dynamic shading coefficients that relate blind position, external climatic condition and time and day of the year are currently being developed as a part of the KTP.

In wintertime, due to the supplementary thermal resistance in a closed position external roller blinds can reduce heat loss through windows at night. Generic external shading devices, Table 2, do not affect the window system *U-value*; they do not reduce the rate of heat loss in cold weather. External roller blinds improve the window *U-value,* depending on the blind material and the system air tightness, Table 3.

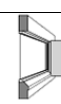
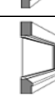
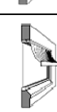
Table 3. Improvement to U-value by external roller blinds (ES-SO, 2009)

Glazing	Window U-value	Improvement
3- pane	0.8 W/m^2K	7-17%
2- pane	2.1 W/m^2K	16-35%
1- pane	> 3.0 W/m^2K	20-44%

When fully extended the blinds improve the acoustic performance of a window system, they provide privacy, act as a security measure and protect against wind and water. When fully extended the access to natural light and ventilation can be restricted.

The current UK market place for external roller blinds is mainly for security applications. Anecdotal evidence indicates that the public perception of the system is as a security product and their thermal impact is not realised. Establishing the system thermal performance is a key consideration for wider UK applications.

Table 2. Functionality of generic shading devices (Littlefair 2006, Stack et al 2000)

Shading device	Description	Performance g_{eff} *	Recommended orientation (UK)	Illustration
Fins	Vertical projections fixed at the sides of window openings	0.35	North	
Louvres vertical	Framed assemblies of vertical slats, fixed or adjustable angle	0.31	Northeast, northwest	
Overhangs	Horizontal devices fixed above window openings	0.27	South, southeast southwest	
Reveals	The sides to window openings, window heads and sills	0.35 (0.2 x width) 0.16 (0.5 x width)	South, north	
Louvres horizontal	Framed assemblies of horizontal slats, fixed or adjustable angle	0.21 (no tilt) 0.15 (45° tilt)	South, southeast, southwest	
Awnings	Retractable fabric-on-frame projections above window openings	0.13	Any	

*South facing low emissivity double-glazed window with *g* value of 0.68

2.1 External roller blind systems

There are two main system types: retrofit and compact, Figure 2. The retrofit system has the blind mechanism fixed to the exterior of the building with access to all components externally. The compact system has the blind as part of the window system, housed in a lintel box, with internal access to all components. With the compact system careful construction detailing is required to comply with the UK Building Regulations and to limit cold bridging. The KTP has focused on producing these details due to lack of existing manufacturer installation drawings.

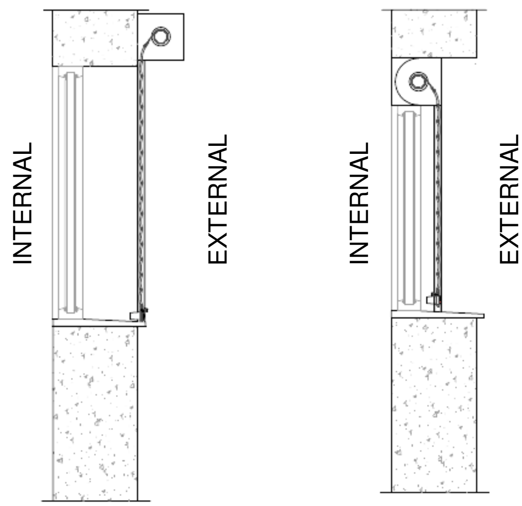


Figure 2. Section through external blind installation: retrofit (left), compact (right)

The slats that form the blind are double skin aluminium with polyurethane foam insulation, Figure 3. The thermal capacity of the slat is determined by its thickness and the density of the polyurethane foam. Slats are available in a range of sizes

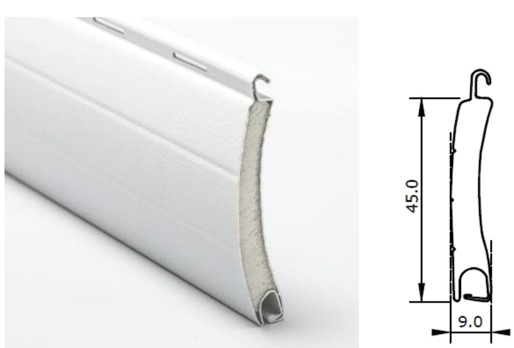


Figure 3. Detail of polyurethane foam filled aluminium slat

The blinds are commonly used with tilt and turn windows that open inwards or windows that slide open. Operating system is either manual belt driven or motorised. Motorised blinds can be automated via a building management system, or by local control using wireless handheld device or wall mounted switch.

3. Demonstration of concept study

A study was conducted with the aim to determine the shading effect of an external roller blind. The study was carried out at the University of Brighton in August 2011. A southwest facing room was partitioned into three compartments: entrance area, control room and test room, Figure 4. Control room and test room had the total floor area of 16.5m^2 each, 3.5m high.

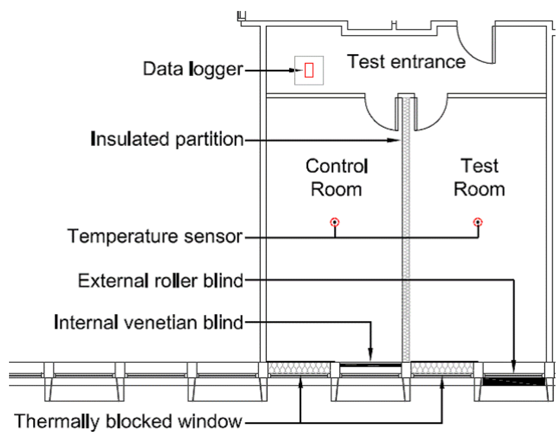


Figure 4. Floor plan of concept study

Each room had two windows with boxed type projection fins, one of which was blocked and thermally insulated. The remaining window was installed with either an internal venetian blind or an external roller blind. Blind positions were set manually at midday to an internal daylight level of 300 lux to achieve visual comfort in offices (CIBSE, 2006). This set the external roller blind 650mm open from the base. Rooms were unoccupied, windows remained closed, the lights were switched off and no equipment was present. The mean radiant temperature was recorded at five-minute intervals. Local meteorological data (Weather Underground, 2011) of external air temperature was collated.

3.1 Concept study results

Temperature data was simplified to hourly mean values and organised to daytime (8am to

6pm) and night time (6pm to 8am) to represent office occupation hours. The results (Ylitalo et al 2012) summarised in Table 4, show that the mean daytime temperature difference between the rooms was 1.8℃, maximum difference 3.5℃ and minimum difference 0.4℃.

Table 4. A summary of the concept study daytime temperature data

	Mean radiant temperature(℃)			External air temp (℃)
	Test room	Control room	Room differ.	
Mean	20.4	22.2	1.8	17.3
Max	22.5	24.7	3.5	23.0
Min	18.6	20.0	0.4	12.0

The analysis of temperature frequency in rooms revealed that the temperature range in test room is more uniform and levels out at a lower temperature with peaks closer to the trend indicating that the external roller blind is regulating the level of solar gain.

4. Computer thermal modelling and simulation

Dynamic thermal simulation was carried out using IES Virtual Environment software to predict the impact of an external roller blind on cooling and heating loads. The simulation parameters are based on the concept study setup. The existing building is not considered to be thermally efficient to current standards, external walls have a U-value of 1.06W/m^{2}K and the single glazed windows have U-value 5.56W/m^{2}K (Ip et al 2013).

4.1 Simulation results

The results show different emissions profiles for test room and control room, Figure 5.

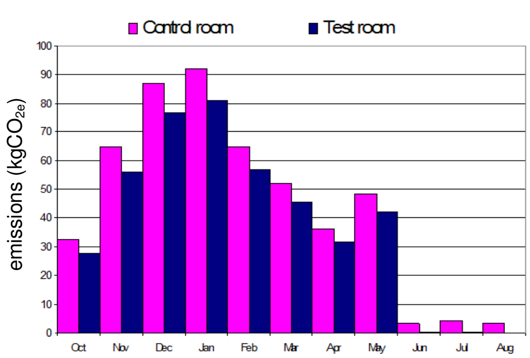


Figure 5. Predicted monthly emissions

Monthly consumption has been converted from energy (kWh) to greenhouse gas emissions (kgCO_2e). Majority of annual energy consumption is for heating energy, the room with external roller blind has 13% lower requirement. The summertime results show a lower requirement for cooling energy in the test room with the external roller blind. Test room cooling requirement is not significant enough to justify the installation of an active cooling system. Under the concept study conditions and with the use of external roller blinds annual emissions can be reduced by 15% or 68kgCO_{2e}.

5. Environmental impact of the external roller blind

The environmental impact of the external roller blind is established by an indicative life cycle assessment (LCA). The LCA consisting of four phases; goal and scope defining; life cycle inventory; life cycle impact assessment and interpretation (ISO 2012).

5.1 Goal and scope definition

The goal of the LCA is to establish the life cycle greenhouse gas emissions of one functional unit of an external roller blind. The processes and emissions are established for the life cycle of a blind that is the same size and specification as used in the demonstration of concept study.

One functional unit is taken as external roller blind sized to fit demonstration of concept study window; 1.3m wide x 2.3m high (surface 2.99m^2). Any part of the blind that contributes less than 2% to the total quantity of the blind, such as coatings, fixings and small components of the operating mechanism, are out of the scope. Blind lifespan is 25 years.

This assessment includes the manufacturing of the blind from aluminium ingot, with assumed recycled content of 33% (Hammond and Jones 2011). The transport of ingot to manufacturer is excluded. The mechanical processes of aluminium roll forming, coating, manufacturing and associated transport between factories are included. Transport to site is included, based on 30kg weight of one functional unit and packaging. Return journeys and maintenance of vehicles are not considered. The site installation of the blind and maintenance are out of scope as are other end of life management process beyond the recycling of aluminium and steel. Figure 6 is the processes within the scope, items excluded are shown in dashed outline.

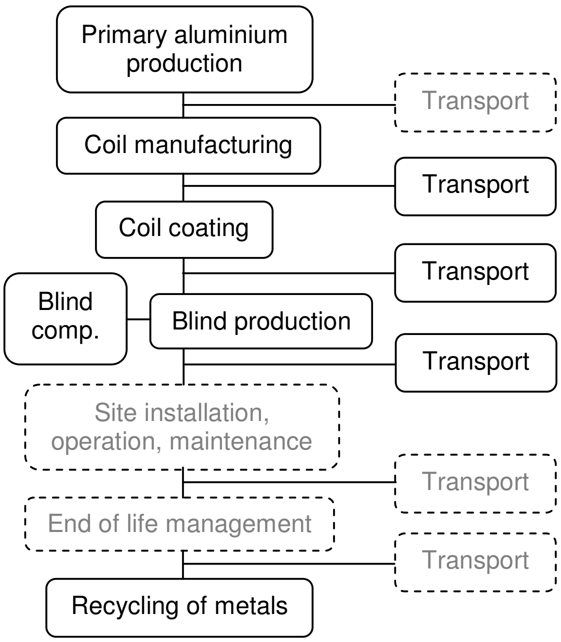


Figure 6. Life cycle processes

5.2 Inventory of life cycle processes

A summary of processes (Ip et al 2013);

Aluminium production – The main material of the blinds is aluminium. The production process starts by surface mining of bauxite that is refined to alumina, which is smelted to aluminium. Ingot is provided for manufacture of end-use products.

Coil manufacturing – The primary aluminium ingot is combined with recycled aluminium and manganese to form an alloy that is cast to form a continuous strip. Hot and cold rolling mills are used to reduce the thickness of strip as required. Tension levelling line improves the precision flatness of the strip. Aluminium coil is cut to required width in the slitting process. Die cast and extruded components are manufactured.

Transport – Raw aluminium components are transported to coating factory, 300km by road.

Coil coating – The raw aluminium coils are linked to form a continuous band to allow coating. A pre-treatment layer is applied, followed by a three layered lacquering process of coating and curing in a furnace. Die cast and extruded components are coated similarly.

Transport – Coated aluminium is transported to blind manufacturer, 250km by road.

Roller blind production - The coated coil is roll formed by machine to produce the curtain slats. The polyurethane foam insulation is injected during the forming process. Slats are cut to size at the end of the line. The casing is roll formed in sections. Other components are sourced and the blind is assembled. The final product is packaged and ready to be transported to site.

Transport – The blind in this study is transported from Valencia in Spain to Brighton in England, 1900km by road and 120km by sea.

Installation, operation and maintenance - The blind is manually operated with no associated operational energy. Annual cleaning and maintenance is required. Replacement of some components is required, namely the belt. These processes are excluded of the assessment.

End of life management – 95% of the aluminium content is recycled, 80% of steel is recycled. Other end of life management is excluded.

5.3 Impact assessment

The total life cycle impact of the processes is 37.54kgCO_{2e}, Figure 7.

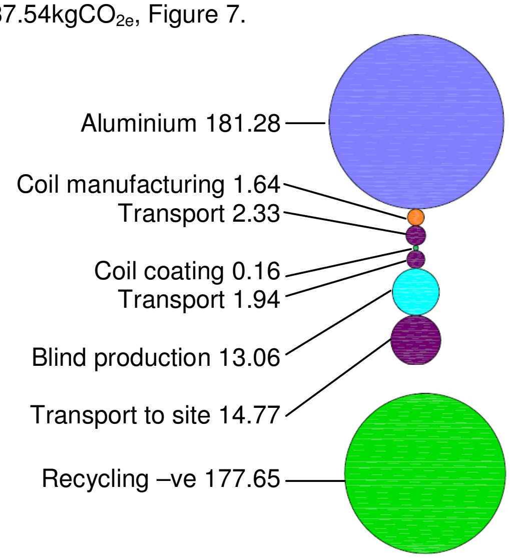


Figure 7. LCA processes and emissions quantities (kgCO_2e)

Greenhouse gas conversion factors are applied to process energy consumption to achieve the emissions. As predicated by the simulation, detailed in Section 4, an annual emissions saving of 68.29kgCO_{2e} is expected. Therefore, within the boundary of the assumptions and limitations, the saving of greenhouse gases while the blind is in operation will compensate its life cycle emissions in less than six months, which are mainly due to production of aluminium and transport, Figure 7.

If end of life management is not taken into consideration and the blind is not recycled, the life cycle emission becomes 215.19kgCO_{2e}, approximately three years operational saving would be required to cover the life cycle emissions.

6. Discussion of results

There is a growing demand for strategies to combat excessive solar gains in buildings. This work, reporting on three parts of study, provides a summary on the performance of external roller blinds as a low carbon shading device.

The concept study set out to demonstrate the thermal impact of external roller blinds. Results show improvement of thermal comfort in the test room with the external roller blind when compared with the control room. Daytime data analysis shows that maximum temperature difference between the rooms was 3.5ºC; mean temperature was reduced by 1.7ºC and temperature swing reduced by 3.2ºC. Therefore, it can be concluded that under the concept study conditions external roller blind has demonstrated potential to improve thermal comfort and reduce overheating.

The dynamic thermal analysis of annual energy consumption is a comprehensive study of both summer and winter performances taking into account the daily operation profiles of occupants and the operations of the roller blind. The results indicated a 15% carbon reduction could be achieved. Proportion of heating energy was significantly higher than cooling energy and the results suggested the possibility of avoiding the requirement of comfort cooling with the use of external roller blind.

The life cycle analysis cannot be considered as comprehensive, but adequate to establish preliminary results in terms of the carbon payback. Minor items excluded in the study are likely to cause a slight increase in the embodied carbon, nevertheless within its 25 year lifespan the external roller blind will clearly result in significant greenhouse gas savings.

Transport related emissions are notable in the case of the blind. These emissions have the potential to be reduced by the choice of transport method. Transport by sea has significantly lower emissions than transport by road and should be considered where feasible.

7. Limitations

The concept study was limited in time and provided a snapshot of the blind operation only. Further monitoring of blind installation to collect real time summer and winter operation data is planned. The simulation is based on fixed operation profile for the roller blind, the integration of dynamic shading coefficients being developed will enable closer to real-life simulation of the shading performance of the roller blind in response to the external climate. The LCA study is hampered by the lack of existing manufacturing data. The assumptions made have to be validated in the future studies when the data become available.

8. Further areas of study

One of the main aims of the KTP project is to establish dynamic shading coefficient for the external bind to allow comparison with other shading devices. The work in this paper forms a basis to achieving this aim.

Further monitoring of the blind in situ is to be carried out once a suitable installation is established. In particular real time data on the winter performance of the blind is of interest.

Technical detail of the blind is being further detailed to enable Building Regulations compliance in terms of reduction of cold bridging and U-value of the roller casing of new build installations. Materials selections are considered for next generation of the external roller blinds.

Detailed life cycle impact assessment will be carried out with *SimaPro* Life Cycle Assessment software. The assessment will include detailed analysis of all blind components to establish its Global Warming Potential over 100 years. Furthermore an ISO-standardised Environmental Product

Declaration will be established for the external roller blinds.

On-going IES simulation study is being carried out to establish the performance of the dynamic external roller blind for different orientations. A typical air conditioned office building was modelled and with nine zones with different orientations, including a central core, Figure 8. The impact on heating, cooling and lighting annual energy demand is compared to an option with no blinds.

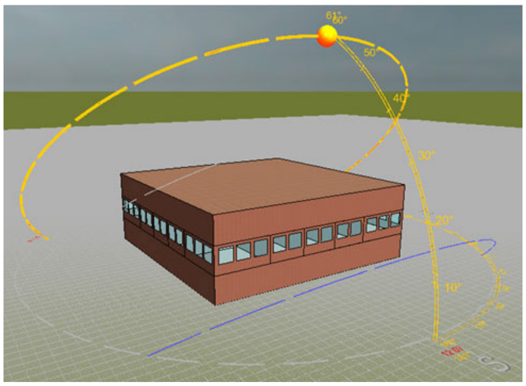


Figure 8. IES model of typical air conditioned building

The indicative results show that the dynamic blind has an impact on the building heating and cooling energy requirement. The heating and cooling are set to be on during the hours of occupation. Total energy consumption and associated emissions are reduced with the use of the blind on all building orientations. When the building is unoccupied and the heating and cooling systems are not on, the temperature maximums and minimums predicted for the external roller blind case are closer to comfort temperature. These results further confirm the impact of the blind as a low carbon technology.

9. Conclusion

External roller blinds are movable external shading devices with potential to improve the thermal performance and sustainability of buildings in the UK climate. An experimental trial concluded that summertime internal temperatures, temperature peaks and temperature swing could be reduced with use of external roller blind. Computer simulation predictions corroborate the results of the experiment that external roller blind can be used to reduce, or in some cases, avoid the requirement for active cooling.

Life cycle analysis of greenhouse gas emissions of a functional unit representing the roller blind used in the concept study, taking into account the key materials and processes throughout its life cycle, show that a six months payback time for the life cycle greenhouse gas emissions or three years if the metallic components were not recycled. The findings so far indicated there is significant potential of using external roller blinds to reduce the operational and life cycle carbon emissions of buildings in the United Kingdom.

The on-going research continues to develop the dynamic performance of the roller blinds that can work in conjunction with interior lighting and thermal systems of the building as well as responding to the external climatic conditions and other functional requirements of the building facade.

The study has provided encouraging results to prove the thermal performance of the blinds, in the UK and allow the establishment of UK marketplace.

Table 5. Predicted temperatures and emissions for different orientations

Orientation	No blind			External roller blind		
	Max °C	Min °C	$kgCO_2/m^2$	Max °C	Min °C	$kgCO_2/m^2$
E	29.9	14.3	111.7	23.1	16.3	96.4
N	25.4	13.9	101.9	23.1	16.3	96.4
NE	30.5	9.6	95.5	23.3	14.1	75.0
NW	31.5	9.5	91.7	23.3	14.2	74.9
S	29.4	15.1	107.1	23.1	16.3	95.9
SE	33.2	11.7	103.8	23.3	14.1	74.5
SW	33.4	11.7	100.0	23.4	14.2	74.3
W	29.7	14.2	107.5	23.1	16.3	96.1

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