Defining a Fabric Energy Efficiency Standard for zero carbon homes

Appendix C

Work Group 3 Lighting

The views and recommendations within this report are those of the Task Group and do not necessarily reflect the views of Government

Lighting

Introduction

This appendix should be read in conjunction with the main report entitled ‘Defining a Fabric Energy Efficiency Standard for zero carbon homes’.

It provides further information regarding the role of lighting in future zero carbon homes and summarises the Work Group’s discussions regarding the key innovations likely between now and 2016.

Please note – The Task Group concluded that lighting does not fall within the scope of the Fabric Energy Efficiency Standard.

However due to the need to balance heat loss through glazing with the positive benefits of maximising natural daylight during design the Task Group considered this an area that requires further investigation.

Therefore the valuable contribution that this Work Group made to the Task Group’s discussions has been included to provide a basis for future research and possible design guidance to support the Fabric Energy Efficiency Standard.

Work Group 3	Lighting
Scope of group discussions	The Lighting group discussed the main issues and boundaries for providing sufficient levels of natural lighting and energy efficient artificial lighting to occupants of 2016 dwellings. Energy efficiency and lighting quality were discussed hand in hand to ensure advice fell in line with current efficiency guidelines, technology development and lighting & health research. The Task Group decision to limit the Fabric Energy Efficiency Standard scope to passive measures meant that this Work Group's activities were drawn to a close comparatively early within the project. However the members considered it an important opportunity to explore and present the range of lighting related issues that will ultimately need consideration via other areas of regulation. For natural light, current daylight factor recommendations (percentage sky availability values) for specific room types were discussed in accordance with the established figures adopted within current UK BS8206-2 2008 and CIBSE/SLL documentation. These figures help determine minimum window/skylight sizes for areas and ensure rooms benefit from satisfactory levels of natural light. With the added benefit of good natural light helping to reduce artificial lighting energy requirements. Taking these daylight factor requirements and providing a tool to assist window design was an area discussed in detail. For artificial lighting the current European legislation for lamp efficiencies/ staged phasing out of lamp types, Part-L efficiency guidelines, and timescale of developed and emerging lamp technology performance were all essential parts of the discussion. Limiting practically the artificial lighting load demand on the households of 2016 was the primary task for the group whilst ensuring sufficient standards of lighting quality would not be precluded.

Area of natural and artificial lighting discussed for future regulation		
	Reasoning	**Possible unintended consequences?**
Minimum Daylight Factors for rooms.	In line with recommendations of BS8206-2 2008 and CIBSE/SLL guidance. Could be used to aid window/skylight sizing and design calculations. Increased natural light can help reduce artificial lighting requirements and thus reduce energy usage. Natural light is of optimum quality for health and wellbeing. A tool to assist in window sizing was discussed as being highly beneficial.	Natural Daylight recommendations may point to larger window sizes that may be incompatible with building fabric recommendations
Minimum Efficiencies for Artificial Lighting.	In line with efficiency minimum standards given within Part-L documents. Using luminous efficiency (efficacy) for lamp and lighting fixture. Not just lamp output, but taking into account any losses associated with the optics of the luminaire and control gear.	May prohibit some cheaper lighting fixtures/lamps and incur overall slightly higher lighting equipment costs.
Maximum Installed Loads for Artificial Lighting.	Provided to ensure there is a sensible energy usage limit applied to lighting installations for room /area types. Provides a limit to ensure there is no unnecessary over-application of lighting fixtures, (albeit intrinsically within the efficiency requirements), to room types	Builders, designers and installers may look to install lighting right up to the recommended maximum limit rather than look for minimum energy-usage applications
Light Quality for Artificial Lighting	Both the colour temperature of lamps (colour tone) and the colour rendering (light quality and ability to render all natural colours accurately) are essential to ensure there is a minimum level of artificial lighting quality for lighting and wellbeing achieved.	Setting the quality benchmark too high may exclude many lamp types and/or more economic lighting fixtures and lamps. Setting it too low may lead to long-term health and wellbeing issues.

Area of natural and artificial lighting discussed for future regulation		
	Reasoning	**Possible unintended consequences?**
Dimming/Controls	Use of automated and manual controls for lighting were discussed to assess the maximum practical benefits that could be gained for increased energy saving. Ensuring the majority of internal lighting fixtures/lamps can be dimmed by simple means will offer real energy saving benefits over simple on/off switching.	May exclude some lamp technologies that are either unable to be dimmed or complicated to dim. Adds some additional initial cost onto the lighting installation.
Brightness and Glare	Fittings today need to have glare control and the more powerful efficient lamps and lighting that will be available in 2016 will potentially result in unacceptable levels of glare and visible brightness if left unchecked. This can be both hazardous and unhealthy.	Brightness limits may require slightly deeper lighting fixtures and/or more complex reflectors to control the light. May impact into ceiling and wall depth requirements a little.
Future Lamp Sources and Technology	There is a rapid change in lamp technology being experienced at present. This is led by both European legislation to reduce lighting energy consumption and by breakthroughs in performance of new types of lamp technologies. Some lamp sources such as GLS/tungsten will be near completely banned, where as newer lamp sources such as CFL, LED and OLED are developing fast. With efficiency and quality limits required, understanding where these lamps will be in 2016 is essential to ensure the levels set will be sensible and achievable.	By 2016 the Timelines/roadmaps for these new lamp technologies' performance may have been exceeded or possibly not reached. Recommendations must therefore be slightly conservative but in line with current trends.
Avoidance of Unnecessary Wasted Light and Pollution from External Lighting	In line with current national guidance from the ILE Notes for Avoidance for Obtrusive Light, external lighting levels and brightness limits should be adhered to as well as compliance with installation and design practices. Controls should be used where applicable to ensure no external lighting can be operated in daylight hours and only when needed during night-time hours.	Controls must be provided in a suitable manner for the type and task of any external lighting.

Metrics discussed		
Type	**Pros**	**Cons**
Daylight. Minimum daylight factors to be applied to various room types.	Complies with BS8206-2 2008 In line with CIBSE/SLL guidance. Reduces need for artificial lighting. Optimum quality of light. Could be used to aid window/skylight sizing and design calculations.	May result in larger window sizes than ideal for building fabric recommendations. Larger windows add more building cost.
Minimum Luminaire (light fixture) efficiencies.	In line with Part-L documents. In line with staged European Legislation on the phasing out of inefficient lamp types. Sets high energy efficiency benchmark for all lighting. Using industry standard luminous efficiency (efficacy) Not just lamp output, but taking into account any losses associated with the optics of the luminaire and control gear. Limits set for both internal and external lighting fixtures. Ensures efficient lamp types are used. Ensures efficient lighting fixtures are used. Ensures efficient control gear is used.	Depending on where the minimum level is set, it will exclude a proportion of cheaper less efficient light fixtures and lamps.

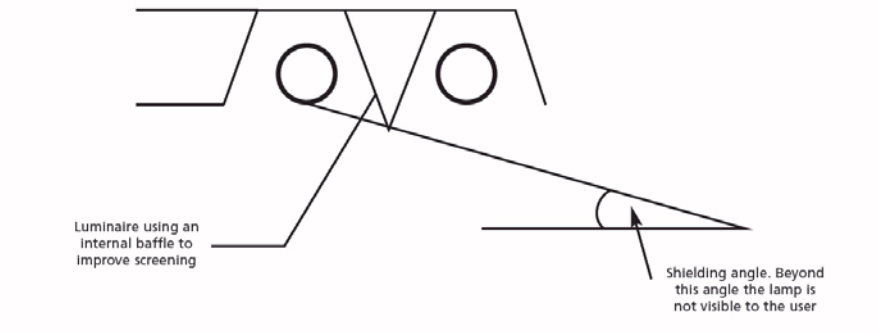
Metrics discussed		
Type	**Pros**	**Cons**
Internal Lighting. Maximum Lighting Loads	Provided to ensure there is a sensible energy usage limit (cap) applied to the lighting installations for every room. Ensures there are no over applications of energy-efficient fittings resulting in an overall unnecessarily inefficient lighting installation. Avoids excessive space and fabric heat-gain from lighting installations. Assists in lighting load assessments and calculations. Helps avoid the use of higher wattage fixtures for use in spaces that do not require that level of lighting.	A metric not undertaken in Part-L documentation as yet. Additional design consideration and/or check. May restrict more elaborate lighting designs and installations on, for example, higher-end dwellings
Lamps: Colour Temperature Recommendations and Minimum Colour Rendering.	Ensures sensible limits are in place for all lamps to produce good quality light. Uses lighting industry standard value for correlated colour temperature. Uses lighting industry standard value for Colour Rendering Index. In line with CIBSE/SLL Guidance and best practice. Ensures correct band of warm colour of artificial light is selected. Ensures all lamps are of sufficient rendering quality to enable surfaces and colours to be lit and rendered properly. Ensures skin tones remain natural. Will avoid poor quality lamps from being installed. Addresses any lighting health and wellbeing concerns for some emerging technology lamps	Will prevent some cheaper lamp types being used.

Metrics discussed		
Type	**Pros**	**Cons**
Internal Lighting Dimming and Controls	Practically all new technology light sources and fixtures will be compatible with dimmers and lamp-life unaffected by dimming or switching. Energy losses through dimming equipment are minimal, therefore dimming provides real additional energy saving. Either simple dimmer switches or more complicated scene-plates could be used. Occupants have control over their environment and energy usage. Future proofing the dwelling. Occupancy sensors to switch fittings for some low-use rooms such as garages, utility rooms etc. would avoid lights left on unnecessarily.	Additional cost to provide dimmer switches, dimming plates or sensors. A break in the culture of building dwellings with minimal lighting controls built in rather than ready to upgrade post occupation.
External Lighting Controls	Passive movement sensors and daylight linked controls ensure external lighting only comes on when required and will be inhibited when not needed. Ensures all external lighting is inhibited throughout daylight hours Labelled manual override switches can be provided where applicable for additional occupant control.	Additional cost for sensors/switches on external lighting circuits.

Metrics discussed		
Type	**Pros**	**Cons**
Brightness and Glare Limits.	In line with CIBSE/SLL Guidance. External lighting in line with CIBSE/SLL and ILE Guidance. Avoids any potential discomfort or disability glare issues. Reduces eye strain and improves lighting quality of dwellings. Sets brightness cap on visible lamp sources and luminaire components. Ensures correct lighting distribution is achievable. Provides minimum shielding angles for shielding of lamps within light fixtures. For external lighting, ensures compliance with light pollution avoidance and brightness guidance.	Some fittings will tend to be deeper to comply as lamps may need to be recessed further. Limiting angles do not apply to adjustable (pan and/or tilt) fittings.

Work Group preferred metrics		
Area	**Metric**	**Reason**
Minimum Daylight Factor for Bedrooms	**1**(%)	Standard from BS8206-2 2008
Minimum Daylight Factor for Living Rooms	**1.5**(%)	Standard from BS8206-2 2008
Minimum Daylight Factor for Kitchens	**2**(%)	Standard from BS8206-2 2008
To understand more how this issue may influence your future designs please see the Daylight Factor Calculator which can be downloaded from the Zero Carbon Hub Website at www.zerocarbonhub.org Note. Where one room serves more than one purpose, the minimum average daylight factor should be that for the room type with the highest value. For example, for a space which contains a living room and a kitchen the minimum average daylight factor should be **2**%.		
Efficiency Requirement for Internal Lighting	All lighting fixtures must have an overall Efficacy greater than or equal to **65lm/W** (Luminaire Lumens per Watt) which includes any losses from the control gear and the Light Output Ratio (LOR) of the luminaire.	In line with Part-L requirements and 3-year amendment predictions. Appropriate for lamp and gear technology development to 2016. Suitable for dwelling lighting design requirements.
Maximum Internal Lighting Load	Total installed lighting equipment should not exceed **10Wm^2**	To set a sensible limit to avoid over application of unnecessary lighting.
Efficiency Requirement for External Lighting	All lighting fixtures must have an overall Efficacy greater than or equal to **45lm/W** (Luminaire Lumens per Watt) which includes any losses from the control gear and the Light Output Ratio (LOR) of the luminaire.	In line with Part-L requirements and 3-year amendment predictions. Appropriate for external IP-rated fittings and lamp and gear technology development to 2016. Suitable for dwelling external lighting design requirements.

Work Group preferred metrics		
Area	**Metric**	**Reason**
Colour Quality Internal Lighting	All lamps to have a correlated colour temperature of between **2700 and 3100Kelvin(K)** All lamps to have a Colour Rendering Index (CRI) rating of **1A (89 or greater)**	Appropriate for lamp and gear technology development to 2016. Suitable for dwelling lighting design requirements. Minimum requirements for lighting quality
Colour Quality External Lighting	All lamps to have a correlated colour temperature of between **2700 and 4000Kelvin(K)** All lamps to have a Colour Rendering Index (CRI) rating of **1B (80-89)**	Appropriate for lamp and gear technology development to 2016. Suitable for dwelling external lighting design requirements. Minimum requirements for lighting quality and security
Internal Lighting Control Requirements	All internal lighting fixtures (lamps and gear) for use within **Living Rooms, Dining Rooms, Bedrooms, Kitchens Hallways & Stairs** must be suitable for dimming by means of both domestic dimmers and simple scene-setting control plates	To ensure maximum additional energy savings from user control
External Lighting Control Requirements	All external lighting fixtures or circuits must be fitted with suitable automatic switching control to ensure light fixtures are always inhibited during the hours of daylight. In additional, suitable passive movement sensors and/or labelled manual switches to be provided as required	To ensure minimum energy wastage or misuse.

Work Group preferred metrics		
Area	**Metric**	**Reason**
Internal Lighting Brightness and Glare	Brightness limit for ambient (diffuse) light fixtures or any visible components of directional fixtures complying with criteria below - **5000 cdm^2 from all visible angles.** Limiting-angle for shielding of fixtures with open visible lamps (unless the fixture is adjustable in tilt and pan). Shielding angle **minimum 30-degrees.**	In line with CIBSE/SLL Guidance. Avoids any potential discomfort or disability glare issues.
		
External Lighting Brightness and Glare	All external lighting levels should be in line with the current national guidance from the ILE Guidance Notes for Obtrusive Light, which gives the following summarised levels.	In line with CIBSE/SLL and ILE Guidance.

ENVIRONMENTAL ZONES:

It is recommended that Local Planning Authorities specify the following environmental zones for exterior lighting control within their Development Plans.

Category Examples

E1: Intrinsically dark landscapes National Parks, Areas of Outstanding Natural Beauty, etc

E2: Low district brightness areas Rural, small village, or relatively dark urban locations

E3: Medium district brightness areas Small town centres or urban locations

E4: High district brightness areas Town/city centres with high levels of night-time activity.

Where an area to be lit lies on the boundary of two zones the obtrusive light limitation values used should be those applicable to the most rigorous zone.

DESIGN GUIDANCE

The following limitations may be supplemented or replaced by a LPA's own planning guidance for exterior lighting installations. As lighting design is not as simple as it may seem, you are advised to consult and/or work with a professional lighting designer before installing any exterior lighting.

Table 1 – Obtrusive Light Limitations for Exterior Lighting Installations

Environmental Zone	Sky Glow ULR [Max %] (1)	Light Trespass (into Windows) Ev [Lux] (2)		Source Intensity I [kcd] (3)		Building Luminance Pre-curfew (4)
		Pre- curfew	Post- curfew	Pre- curfew	Post- curfew	Average, L [cd/m2]
E1	0	2	1*	2.5	0	0
E2	2.5	5	1	7.5	0.5	5
E3	5.0	10	2	10	1.0	10
E4	15.0	25	5	25	2.5	25

ULR = **Upward Light Ratio of the Installation** is the maximum permitted percentage of luminaire flux for the total installation that goes directly into the sky.

Ev = **Vertical Illuminance in Lux** and is measured flat on the glazing at the centre of the window

I = **Light Intensity in Cd**

L = **Luminance in Cd/m2**

Curfew = **The time after which stricter requirements (for the control of obtrusive light) will apply**; often a condition of use of lighting applied by the local planning authority. If not otherwise stated _ 23.00hrs is suggested.

***** = From Public road lighting installations only

(1) Upward Light Ratio – Some lighting schemes will require the deliberate and careful use of upward light – e.g. ground recessed luminaires, ground mounted floodlights, festive lighting – to which these limits cannot apply. However, care should always be taken to minimise any upward waste light by the proper application of suitably directional luminaires and light controlling attachments.

(2) Light Trespass (into Windows) – These values are suggested maxima and need to take account of existing light trespass at the point of measurement. In the case of road lighting on public highways where building facades are adjacent to the lit highway, these levels may not be obtainable. In such cases where a specific complaint has been received, the Highway Authority should endeavour to reduce the light trespass into the window down to the after curfew value by fitting a shield, replacing the luminaire, or by varying the lighting level.

(3) Source Intensity – This applies to each source in the potentially obtrusive direction, outside of the area being lit. The figures given are for general guidance only and for some sports lighting applications with limited mounting heights, may be difficult to achieve.

(4) Building Luminance – This should be limited to avoid over lighting, and related to the general district brightness. In this reference building luminance is applicable to buildings directly illuminated as a night-time feature as against the illumination of a building caused by spill light from adjacent luminaires or luminaires fixed to the building but used to light an adjacent area.

Future Thinking

The Work Group members, all from different areas of the industry, brought many years of experience to the table. After much discussion there were a number of clear targets identified for the lighting to meet to achieve maximum energy efficiency for Zero Carbon Homes in 2016. These notes are a summary of their views:

Maximizing the use of available natural light was agreed as one of the major energy efficient ways of bringing light into a dwelling. Not only does it reduce the reliance on artificial lighting, but the quality of natural light is second to none. Established standards for minimum daylight (factor) levels for different room types are in place and the recommendations reiterated as a design standard for the various dwelling room types. Indeed, it was agreed to provide some form of window design guide to aid compliance with minimum daylight factors and this has been provided on the Zero Carbon Hub website.

The requirements for setting standards for energy efficiency for the artificial lighting caused most debate. The current Part L requirements and proposed revisions go some way in setting minimum efficiency levels for lighting in dwellings, but for looking ahead to 2016 it was important to explore all the possible additional metrics that could be assessed as achievable and beneficial. Much research was undertaken on lamp technology development timescales and alternate lamp comparisons.

Further discussion covered the often ignored issue of lighting quality. In recent years many of the newer energy efficient lamps that have come into the marketplace have not always been met with enthusiasm. Issues such as size, colour quality, high cost, warm-up time, flicker and lack of dimming capability has resulted in many people shying away from them and staying with less efficient but cheaper and more flexible lamps such as tungsten. However, many of the problematic issues found with early low energy lamps have now gradually been addressed and many more good quality and efficient options are available now and in the years to come.

The group wanted to ensure that the best possible balance of energy efficiency, cost effectiveness and lighting quality was detailed in the recommendations for the 2016 Zero Carbon Homes. We have endeavoured to set targets, recommendations and metrics which are achievable and realistic, but also ultimately capable of long term carbon reductions for 2016 and beyond.

Lamp Development

The last few years has seen a dramatic change of direction in the development of energy efficient lighting technology. Partly a reaction to the European Directives on the phasing out of less energy efficient lamps, the first phase of which came into force in 2009, but also due to a number of breakthroughs in new lamp sources.

There are five main characteristics of lamps which are key to their success and these are:

- Energy Efficiency
- Longevity
- Flexibility
- Quality of Light
- Cost

Current low-energy lamps such as CFLs, when compared to traditional GLS, are far better on the first characteristic, moderately good on the second, but fall short on the last three, the cost only coming down significantly after they became subsidised. They continue to be developed and improved, but they are very

close to reaching the ceiling of their possible development.

LED technology development has all but taken over in the world's largest lamp producers and this has been due to a number of key breakthroughs which hitherto had held LEDs back. Heat dissipation issues had stopped the lamps from increasing in power substantially and the quality of the light white LEDs produced was poor, even compared to CFLs. This has fast been addressed and even today there are LED lamps rapidly hitting the marketplace which already exceed the capabilities of CFLs in most applications on everything except cost. However the cost too is dropping fast and in a very short period of time they will take a primary foothold in commercial and domestic lighting.

The envisaged efficiencies LEDs will reach will be over three times higher than any other light source and lamp-life already around 10-15 times higher than CFL. Colour rendering is already high, they can be dimmed, they are relatively small, instant start, flicker-free and they are environmentally safe.

In addition other new technologies such as OLED (Organic LED) are being developed which will potentially revolutionise ambient lighting alongside LEDs, as a material only a few millimetres thick, eventually flexible, see-through and which will be capable of being bonded onto surfaces and produce high-levels of light output.

GLS/tungsten	Present Levels	Short Term <3 years	Mid-Term 3-5 years	Long-Term 5-8 years	Max Limit
Efficacy(lm/w)	12	Gradually being phased out under European Law	Gradually being phased out under European Law	Gradually being phased out under European Law	12
Rated Life	1000hrs				1000hrs
Estimated price	£0.50				-
Colour Rendering	1A - 100				1A - 100
Colour Temperature(s)	2700k				2700k

Halogen	Present Levels	Short Term <3 years	Mid-Term 3-5 years	Long-Term 5-8 years	Max Limit
Efficacy(lm/w)	20	30	Gradually being phased out under European Law	Gradually being phased out under European Law	30
Rated Life	2000-3000hrs	3000-5000hrs			3000-5000hrs
Estimated price	£1.00	£2.00			-
Colour Rendering	1A - 100	1A - 100			1A - 100
Colour Temperature(s)	2900-3100k	2900-3100k			2900-3100k

CFL	Present Levels	Short Term <3 years	Mid-Term 3-5 years	Long-Term 5-8 years	Max Limit
Efficacy(lm/w)	55-60	65-75	No further advance. Performance limits reached	No further advance. Performance limits reached	65-75
Rated Life	7000-9000hrs	9000-15000hrs			9000-15000hrs
Estimated price	£0.50- £1.50*	£0.50- £1.50*			-
Colour Rendering	1B - 82-85	1B - 82-85			1B - 82-85
Colour Temperature(s)	2700-4000k	2700-4000k			2700-4000k

* Government Subsidies Applicable

LED	Present Levels	Short Term <3 years	Mid-Term 3-5 years	Long-Term 5-8 years	Estimated limit
Efficacy(lm/w)	30-50	70-100	100-125	125-150	>200
Rated Life	45000hrs	45000hrs	45000hrs	45000hrs	>100,000hrs
Estimated price	£20-25	£7-15**	£5-10**	£3-7**	-
Colour Rendering	1B - 75-85	1B - 80-89	1A - 89-95	1A - 89-95	1A - >95
Colour Temperature(s)	3000/4000k	3000/4000k	3000/4000k	3000/4000k	3000/4000k

** Government Subsidies Likely

Industry Standardisation of performance criteria and measurement expected in next 3 years

OLED	Present Levels	Short Term <3 years	Mid-Term 3-5 years	Long-Term 5-8 years	Estimated limit
Efficacy(lm/w)	15	50	90	120	>150
Rated Life	5000hrs	15000hrs	20000hrs	30000hrs	>50000hrs
Estimated price (per 100cm-2)	£250.00	£75.00	£35.00	£15.00	-
Colour Rendering	1C - 65-70	1B - 75-85	1B - 80-89	1A - 89-95	1A - >95
Colour Temperature(s)	3000/4000k	2700-6500k	2700-6500k	2700-6500k	2700-6500k
Size	100cm-2	400cm-2 #	900cm-2 x	1600cm-2 +	unlimited

\# Colour-tunable, x Colour-tunable & transparent, + Colour-tunable, transparent & flexible

Industry Standardisation of performance criteria and measurement expected in next 3 year s

Microwave ***	Present Levels	Short Term <3 years	Mid-Term 3-5 years	Long-Term 5-8 years	Estimated limit
Efficacy(lm/w)	Not currently available	65-80	No data available	No data available	No data available
Rated Life		No data			
Estimated price		No data			
Colour Rendering		1A - 95-97			
Colour Temperature(s)		2400-4800k			

*** US development with little information known of exact performance expectations

As part of the research the table above was constructed to provide as much detail as possible on all the major characteristics of the various lamp options available today and those projected for the future.

Information Requirements

Due to the unprecedented pace of lamp development, whilst every effort has been made to research the estimated performance characteristics and technology improvements, the timescales may alter and it is important to keep informed. With this in mind it is suggested that the recommendations and metrics be reviewed every three years and revisions made where required.