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Level(s) indicator 4.3: Lighting and Visual Comfort

User manual: introductory briefing, instructions and guidance

(Publication version 1.1)

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Title

Level(s) indicator 4.3: Lighting and Visual Comfort user manual: introductory briefing, instructions and guidance (Publication version 1.1)

Abstract

Developed as a common EU framework of core indicators for assessing the sustainability of office and residential buildings, Level(s) can be applied from the very earliest stages of conceptual design through to the projected end of life of the building. As well as environmental performance, which is the main focus, it also enables other important related performance aspects to be assessed using indicators and tools for health and comfort, life cycle cost and potential future risks to performance.

Level(s) aims to provide a common language of sustainability for buildings. This common language should enable actions to be taken at building level that can make a clear contribution to broader European environmental policy objectives. It is structured as follows:

1. Macro-objectives: An overarching set of 6 macro-objectives for the Level(s) framework that contribute to EU and Member State policy objectives in areas such as energy, material use, waste management, water and indoor air quality.

2. Core Indicators: A set of 16 common indicators, together with a simplified Life Cycle Assessment (LCA) methodology, that can be used to measure the performance of buildings and their contribution to each macro-objective.

In addition, the Level(s) framework aims to promote life cycle thinking. It guides users from an initial focus on individual aspects of building performance towards a more holistic perspective, with the aim of wider European use of Life Cycle Assessment (LCA) and Life Cycle Cost Assessment (LCCA) methods.

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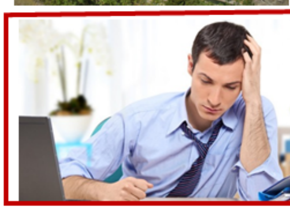

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Figure 1. The Level(s) document structure

How this indicator user manual works

Level(s) is a framework of core indicators of sustainability that can be applied to building projects in order to report on and improve their performance. The supporting documentation has been designed to be accessible to all the actors that may be involved in this process.

If you are new to the assessment of building sustainability, we recommend reading the **first part of the Level(s) user manual**. This will provide you with an introduction to the basic concepts behind Level(s) and how you can apply it to a building project.

If you haven't yet set up your building project to use Level(s), including completing the project plan and the building description, then we recommend reading the **second part of the Level(s) user manual**.

This indicator user manual forms part of the third part of the Level(s) user manual where you will find instructions on how to use the indicators themselves. It is designed to help you apply your chosen indicator to a building project. It will help you to do this in the following way:

- **Introductory briefing:** This section provides an overview of the indicator, including:
  - ✓ why you may wish to measure performance with it,
  - ✓ what it measures,
  - ✓ at which stages in a project it can be used,
  - ✓ the unit of measurement, and
  - ✓ the relevant calculation method and reference standards.
- **Instructions on how to use the indicators at each level**: This section provides:
  - ✓ step by step instructions for each level,
  - ✓ what is needed to make an assessment,
  - ✓ a design concept checklist (at Level 1), and
  - ✓ the reporting formats.

  The instructions often refer to the guidance and further information section, which can be found after the instructions.
- **Guidance and further information for using the indicator**: This section provides more background information and guidance to support you in following specific steps in the instructions, including the design concepts introduced at Level 1 and the practical steps to calculate or measure performance at Levels 2 and 3. They are all cross-referenced to specific instruction steps at either level 1, 2 or 3.

This indicator user manual is structured so that once you are familiar with using the indicator and you know how to work with it, you may no longer need to refer to the guidance and background information, but only work directly with the instructions at the level of your choice.

Introductory briefing

Note for users: This indicator only has instructions and guidance for using the indicator at **Level 1** at this moment. For those who wish to work at **Level 2 and 3,** it provides some initial information about possible units of calculation and measurement, as well as reference standards that could be used.

Why measure performance with this indicator?

The availability and quality of light are important factors in the design of healthy and comfortable homes and workspaces. Millions of Europeans spend approximately 90% of their time indoors (WHO, 2014)[1]. Comfort can be understood both in terms of the light needed to carry out tasks but also in terms of what the human body requires and desires and, where there is an excess of light, can tolerate.

Studies have shown the importance of increased access to daylight and views on overall wellbeing [2], as well as the increased satisfaction that comes with personalised control of lighting and shading[3,4]. The quality and composition of light can also influence circadian rhythms (the sleeping and waking cycles of the human body) and depending on the composition of the light to which people are exposed, a person's health and wellbeing can be affected [5]. For all of these reasons, a properly designed environment that considers the interaction of daylight, views, and electric light is beneficial to both the occupants and the owners.

From an operational cost perspective, a recent study suggests that the salaries of the occupants of offices are the most expensive annual cost per square meter, accounting for 90% of costs, while rent and maintenance are 9%, and energy is just 1%[6]. Consequently, the optimisation of operating costs is closely linked to optimising the productivity and wellbeing of commercial building occupants.

The aim of this indicator is foremost to provide the means to improve and optimise lighting and visual comfort conditions, while also considering the positive influence that natural lighting can have, as referred to in the Energy Performance of Buildings Directive[7].

What does it measure?

The starting point for considering lighting in a building is the availability and quality of light. This can be understood in terms of a combination of installed electric lighting systems and the penetration of natural light into a building:

- **Electric luminaire quality**: The design and specification of electric lighting can be used to ensure that there is both sufficient quantity and quality of light for the type of building. The colour quality and temperature of luminaires are also important aspects that can potentially attenuate vision and affect concentration.
- **Daylighting of internal spaces**: The plan depth of an office or home will dictate how much of the floor area can be illuminated with natural light. The geometry of the building form will also affect both the penetration of daylight and the ability for occupants to maintain a clear view to the exterior environment.

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[1] WHO, 2014. World Health Organisation (2014) Combined or Multiple Exposure to Health Stressors in Indoor Built Environments

[2] Farley, K. M., & Veitch, J. A. (2001). A room with a view: A review of the effects of windows on work and well-being

[3] Boyce, P. R., Veitch, J. A., Newsham, G. R., Jones, C. C., Heerwagen, J., Myer, M., & Hunter, C. M. (2006). Occupant use of switching and dimming controls in offices. Lighting Research & Technology, 38(4), p. 358-376

[4] Newsham, G., Veitch, J., Arsenault, C., & Duval, C. (2004, July). Effect of dimming control on office worker satisfaction and performance. Proceedings of the IESNA Annual Conference, p. 19-41.

[5] Well standard v2, Light criteria, https://v2.wellcertified.com/v2.1/en/light

[6] World Green Building Council, *Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building*, September 2014.

[7] Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. OJ L 156, 19.6.2018, p.75-91.

- **Discomfort from glare**: Without careful design, unwanted glare from both electric and natural light can make the internal environment uncomfortable and, potentially, result in more energy use than predicted. So, whilst a building design may achieve an ideal plan depth and Daylighting Factor for work or living spaces, this may result in unwanted glare and thermal gain.

A further aspect relates to the degree of control that end-users have over their living or working environment, including the extent to which automatic systems can be overridden to allow for a reaction to a change in conditions (for example, a sudden increase in glare) and the personalisation of comfort conditions.

At what stage of a project?

The stages at which an assessment can be made reflect the three 'levels'. Only Level 1 is currently available, but the intention for Levels 2 and 3 is also outlined for future reference.

Level	Activities related to the use of indicator 4.3
1. Conceptual design (following design principles)	✓ At the <u>conceptual design</u> stage, the influence of building form and orientation on the daylighting performance can be considered as well as the supplementary electric lighting systems that will be necessary to provide the required illumination.
2. Detailed design and construction (based on calculations, simulations and drawings)	✓ *<u>Detailed design and construction:</u> Prior to commencement of works on site and during the detailed design stage, more accurate lighting plans as well as sequences of operations for lighting controls can be made to ensure that the lighting system is capable of meeting the required lighting needs. Calculations will be made and verified by simulations.*
3. As-built and in-use (based on commissioning, visual inspection and meter readings)	✓ *<u>As-built and in-use:</u> The last stage should include a walk-through pre-occupation of the work/living spaces with in-situ measurements to identify and address any performance gaps and to ensure that the commissioned luminaires and systems meet the design criteria. A post-occupancy evaluation could be considered in order to understand the occupant impressions of the lighting conditions and installations.*

Units of measurement

The focus of this version of the indicator is on addressing the four main lighting and visual comfort design aspects. So whilst there are several different measurements that can be used, separately or in conjunction, the choice of unit or units of measurement is currently left open to professional judgement. In some cases the unit is binary, reflecting whether a function is provided or not. Table 1 lists metrics that can be considered as important for the assessment of the quality of lighting provision.

Table 1. Units of measurement of the quality of lighting

Quality aspect	Level 1 - Concept Design Stage	*Levels 2 & 3 - Detailed Design & In-Use Stages*	*Units*
1. Daylight: Maximising the useful contribution & minimising negative impacts on visual comfort	External view requirements	*Horizontal Sight Angle*	*deg*
		Outside Distance of the View	*M*
		Layers Seen	*No. layers*
	Daylight control and glare	*Daylight Glare (Direct / Indirect / Diffuse)*	
	Daylight sufficiency	*Complementary Electric Light*	
	Daylight distribution	*Variation of Distribution*	
2. Light Levels & Distribution: For visual comfort	Light levels	*Task Illuminance*	*Lux*
		Luminance	*Candela*
		Surface reflectance, shape and colour	*% reflectance*
		Melanopic irradiance / equivalent daylight illuminance	
	Light distribution	*Visual hierarchy*	
		Luminance Distribution	
		Brightness Contrast	

		Glare from electric lighting	
		Illuminance Uniformity	%
3. Control: Automated and personalised control for visual comfort	Personal control (time / activity / preference)	Intensity	Y/N
		Colour Properties (incl. CCT, Saturation, Hue, CRI)	Y/N
	Automation (time / activity / system integration)	Pre-Programmed Cycle over time	Y/N
		Pre-Programmed Scenes	Y/N
4. Light Source Quality: For electric light sources	Colour	Colour Rendering	
		Colour Consistency	
		Correlated Colour Temperature	K
		Spectral Power Distribution	
	Temporal light artefacts	Flicker	Pst
		Stroboscopic Effects	SVM
	Tuneable lighting	E.g. - Melanopic Irradiance, Equivalent daylight illuminance	Y/N

System boundary

The indicator is clearly related to the B6 stage (operational energy use) of the building life cycle, as per EN 15978. The material footprint of any associated windows, shading devices, light fittings and controls/sensors would fall under stages A1-A5 (production and construction). Specific provision is also made for reporting on building parts under Level(s) indicator 2.1 (Bill of quantities, materials and lifespans).

However, the main purpose of indicator 4.3 is to focus attention on occupant health and comfort based on scientific knowledge of lighting and visual effects on the human body. In order to quantitatively or qualitatively assess any beneficial effects for the actual occupants, feedback would need to be obtained from them.

Scope

This indicator should consider the importance of architectural aspects including building location, orientation, glazing design, solar shading design, plan depth, surface finishes and other architectural elements that can affect natural light penetration such as atria and light wells. The indicator also considers the design, performance specifications and functionality of the installed electric lighting systems.

Calculation method and reference standards

The calculations carried out when assessing the provision of electric light in a space are mostly defined in EN 12464-1 (Light and lighting. Lighting of workplaces. Indoor workplaces) and EN 17037 (Daylight in buildings). These standards are complemented by the design requirements for the indoor environment in EN 16798-1.

Instructions on how to use the indicator at each level

Note: this indicator is currently only specified with instructions for users at Level 1.

Instructions for Level 1

L1.1. The purpose of level 1

The focus of Level 1, at the concept design stage, is to support architects and other early stage influencers in understanding and prioritising the most important aspects of lighting and visual comfort to focus attention on. This in turn will help them in making the right decisions when setting requirements and specifications. These requirements and specifications should facilitate the later detailed architectural and engineering design that is supportive of occupant health and comfort during visual tasks and activities.

L1.2. Step-by step instructions

These instructions should be read in conjunction with the accompanying guidance and supporting information which is provided from page 12 onwards.

1. Consult the checklist of lighting and visual comfort design concepts under L1.4 and read the background descriptions in the Level 1 technical guidance
2. Within the design team, review and identify how the design concepts can be introduced into the design process.
3. Once the design concept is finalised with the client, record the lighting design concepts that were taken into account using the L1 reporting format.

L1.3. Who should be involved and when?

At the concept stage, the main actors could include the concept architect, the building owner / investor, representatives for the occupier and the relevant building planning authorities.

Later in the project, additional stakeholders would be likely to include design engineers, lighting, interior designers, the main building contractor, electrical contractor, specialist sub-contractors and the building occupiers

L1.4. Checklist of relevant design concepts

It is necessary to be aware of the design concepts and the related factors that influence the planned provision of artificial and natural light in a space. Each concept informs what is required to ensure that the right decisions are made at concept design stage and in order to achieve better outcomes at later stages:

Level 1 design concept	Brief description
1. Maximising the useful contribution of daylight	This aspect can be influenced by a number of architectural design decisions/concepts. Metrics for assessment would include daylight factor, sunlight exposure, spatial daylight autonomy and the use of automated shading. Potential trade-offs from excessive daylighting (e.g. glare, increased cooling energy) should also be considered as well as the design integration of shading devices.
2. Ensure that light levels and distribution are appropriate	Paying particular attention with this aspect to working planes for the visual tasks of the occupier. This should take into account both artificial and natural light as well as diffusion. Metrics should include task illuminance and colour rendering index.
3. Ability of occupants to tailor the lighting to their individual needs.	This aspect should include control over individual lighting levels and colour temperature (via manual or programmable controls for on/off and dimming).
4. Suitable quality of electric light fittings	This aspect should be defined by, for example, light efficacy, durability etc., whilst still minimising use phase electricity consumption

L1.5. Reporting format

To complete the reporting format for Level 1 you should answer yes or no for each of the design concepts that you have addressed and then provide brief descriptions of the measures or decisions taken for each one.

Examples of how the concepts can be addressed and reported on are filled out in the reporting format below.

Lighting and visual comfort design concept	**Has it been addressed?** *(yes/no)*	**How has it been addressed during the building design process?** *(provide a brief description)*
1. Daylight - Maximise the useful contribution of daylight and minimise negative impacts on visual comfort	*Yes*	*The building is in a built-up area surrounded on two sides by other high buildings in close proximity. The risk of excessive solar gain is negligible. Therefore, window design, orientation and building depth have been considered to ensure maximum use of the available daylight and views.*
2. Light levels and distribution for visual comfort	*Yes*	*Provision has been made that the electric lighting installation will be capable of meeting the illuminance requirements at desk-height assuming the absence of daylight (i.e. window blinds closed or night-time shifts).* *To account for the potential contribution of daytime to illuminance needs, the electric lighting can be dimmed to in the range of 10-100% of full light output.*
3. Automated and personalised control for visual comfort	*Yes*	*Full manual control for lighting in individual offices is foreseen (on/off and for dimming) with automatic switch-off at set times when the office is expected to be unoccupied.* *In cases of large offices, separate dimming levels are foreseen for the light fittings that illuminate the half of the office closest to the window and those that light the half of the office furthest from the window.*
4. Light source quality (for electric light sources)	*Yes*	*Luminaires with a minimum luminaire efficacy of 120 lm/W, a Correlated Colour temperature of ≤3500K and a Colour Rendering Index of >80 will be specified.*

Guidance and further information for using the indicator

For using level 1

In this section of the guidance, additional background guidance and explanations are provided for two key concepts introduced in the Level 1 energy design concept checklist, namely:

- L1.4. Checklist design concept 1a: Daylight: maximising its useful contribution
- L1.4. Checklist design concept 1b: Daylight: minimising its negative impact
- L1.4. Checklist design concept 2: Light levels and distribution for visual comfort
- L1.4. Checklist design concept 3: Optimised and personalised control for visual comfort
- L1.4. Checklist design concept 4: Light source quality for electric light sources

L1.4. Checklist design concept 1a: Daylight: maximising its useful contribution

There are many factors that affect the amount of useful daylight that enters into a building. These factors include the building massing (depth, orientation, fenestration, size/location), the type of window, as well as the orientation of the building on the building site. It is critical at the earliest of design stages to ensure the building maximises the amount of useful daylight available in the space by passive methods.

<u>*Metrics:*</u>

There are a few methods to understand the amount of daylight that is able to enter a building. The "*daylight factor*" is the traditional metric, which compares the illuminance level of daylight in an unobstructed field to that of the illuminance at a defined point inside the room. This is done using simulation software under uniform sky conditions. You then divide the interior illuminance level by the exterior level to get the fraction of light that is capable of making it to the inside of the space. The thresholds and targets for a building can be found in Tables A1 and A3 of EN 17037 for both the Minimum Daylight Factor as well as the Median Daylight Factor.

Although the daylight factor is a useful metric, it fails to characterise the building over annual climate conditions. The daylight penetration into a building can be simulated dynamically with Typical Meteorological Year (TMY) data, using a file that contains annual meteorological year data at hourly intervals, that is representative of the building location. A metric called Spatial Daylight Autonomy (SDA) can be used to understand the sufficiency of daylight for a space. Details on the calculation can be found in the IES LM-83-12 document [8], which describes the simulation procedures. This calculation requires the modelling of the manual or automated shading devices in the space.

It is important to also consider the view out as part of the daylight quality. People appreciate a view to the outdoors, including the landscape, sky, and other exterior surroundings. The EN 17037 standard contains table A5, which is used to define horizontal sight angles, outside distance of the view, as well as the number of layers seen in the view.

<u>*Design Considerations:*</u>

Once the internal spaces have been modelled and the calculations completed for each of the metrics, future design revisions can be compared against one another. There are always more things to consider than just the amount of daylight that is able to make its way into the building, but these metrics will help inform on the sufficiency of the daylight in the building.

If the design team decides that more daylight is required in the space, they could consider increasing the size of the window-to-wall ratio (WWR). The WWR is the area of window divided by the total exterior wall area for a particular space. Adjusting the height of the windows may also change the depth of daylight penetration into the space but, depending on the season, time and daylight component, it may also have the consequence of increasing solar gain, thereby creating a risk of overheating and a need for mechanical cooling.

[8] Published by the Illuminating Engineering Society of North America [IESNA] and made available by ANSI

There are many design decisions that influence the light entering the apertures of the building, and these decisions are often split amongst the entire design team and, as already illustrated, linked to other design decisions. It is therefore important to have thorough communication between design team members early in conceptual design.

L1.4. Checklist design concept 1b: Daylight: minimising its negative impact

Although daylight is a high quality light source to include in the lighting design of the building, there are some potential negative impacts that should be mitigated. These negatives include glare, overheating due to excessive solar thermal gains and subsequent increased cooling energy costs. These can be considered during the conceptual design stage as these are again affected by the building orientation, massing and glazing.

Metrics:

Communication with the entire design team is extremely important at this stage of design. Incorrect or poorly considered decisions at this point are very hard to readdress and will likely require more effort to design around, rather than simply making the change at the beginning. Moreover, the thermal load on the building is affected by many factors in the building envelope, but this has to be balanced against the positives of the daylight and views that the occupants desire.

Though occupants will desire a view to the outside, direct and reflected glare can be distracting and cause discomfort. Daylight Glare Probability (DGP) is one metric that attempts to describe the likelihood that glare will be present in a given view from an occupant position in a building. Tables E2-E5 in EN17037 detail the control of DGP based on the shades employed on the building. This helps determine the value of incorporating shading into the design.

It is important to note that this degree of control relates to the physical properties of the materials in the shading, not necessarily that the shade will be deployed in the right place at the right time. It is well understood that occupants require support to use shading devices correctly, with the result being that they very often fail to perform as intended by the designer. For this reason, the design team should consider the use of automation to ensure that the shades adjust to their optimum positions as the sun constantly changes its position in the sky, without requiring user interaction.

Design Considerations:

Orientation of the building is very important. A west facing exposure tends to increase the solar heat gain at the time that the building is already at its peak for thermal load. Having a long southern exposure and short east/west exposure can be one way to minimise the solar heat gain in the afternoon. Typically, a shallower floor plate allows for deeper daylight penetration (see figure 2) but this will need to be balanced in thermal modelling against the increased surface area to volume ratio. A shallower floor plate will increase the daylight sufficiency across the space and allows for a better view. Many design options can be considered before simply reducing the window area.

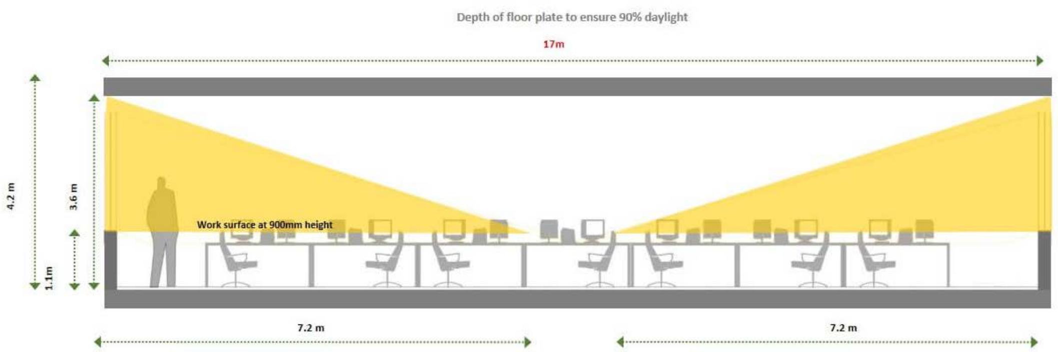

Figure 2. Indicative cross section of an office floor plate illustrating daylight penetration

The arrangement of the glazed area is another important consideration. For example, the use of clerestories[9] - windows located above the field of view - in addition to the normal view window can introduce indirect lighting. The view window can still be a high-quality glazing unit, but transparent for the view at eye level. The clerestory allows for a more efficient glazing unit which can be translucent, because a view is not necessary from the window at that height on the wall and glare will not be as big an issue. This provides the added benefit of increasing the daylight, while reducing the solar gain in the building. The use of automated shading devices can also help reject the solar heat gain when it is not wanted, but still allow a view for the occupants.

L1.4. Checklist design concept 2: Light levels and distribution for visual comfort

The objective of the electric lighting installation is to either completely substitute, or to supplement and enhance the daylight contribution to the space, by ensuring that light of sufficient quantity and quality is properly distributed so as to allow visual tasks relevant to the type of space to be carried out in a healthy and comfortable way.

Metrics:

At the concept design stage, the principal quantity and quality metrics for consideration by relevant stakeholders relate to:

- Light levels
- Distribution of light
- Contrast rendering

Each of these are briefly described in the sections below.

Light levels metrics:

The electric lighting installation needs to provide a sufficient quantity of light to allow visual tasks to be performed both whilst supplementing natural daylight provision and when electric light is the only option available. In addition to lighting for tasks, the quantity of light required may also be affected by a desire to provide light for non-visual effects, particularly circadian lighting. Circadian lighting is especially relevant in workspaces where night shifts are commonplace and in residential buildings, especially bedroom lighting. Furthermore, in bedrooms, the impact of exposure to intrusive light at night may be an important aspect and require certain shading elements to be considered.

Learn more about:

What is circadian lighting and how can it influence our health?

The human body's daily sleep/wake cycle – referred to as circadian rhythms - are to a great extent dictated by biochemical reactions triggered by our exposure to light. The spectral properties, intensity, distribution and time of light provision are factors that are therefore believed to play significant roles in stimulating or indeed suppressing the body's natural circadian system. Lighting designs that incorporate this are known by several popular names including Circadian Lighting design and Integrative Lighting design.

Multiple new possible metrics for this have been developed and are gaining attention, including Equivalent Melanopic Lux and Equivalent Daylight Illuminance. It should be understood though that whilst knowledge of circadian rhythms has a fundamental grounding in the science, the application to lighting is still ongoing and consensus has not yet been reached. Nonetheless, it seems prudent that some awareness of the concept and likely contributory factors is obtained and considered when conceptualising a lighting installation today.

Light distribution metrics:

[9] The technical definition of this term is: high wall sections that contain windows above eye level.

As well as providing sufficient light for visual tasks, the distribution of the light provided in the space needs to be considered. At concept design stage, it is important for the design team to consider that the installation needs to allow a good degree of distribution throughout the space to accommodate for multiple potential needs when occupied, as well as for the potential that these needs are likely to be constantly changing, thereby requiring the adjustment of the distribution.

Contrast rendering metrics:

During the concept design stage, it is important to consider the luminance ratios (contrast) that will be used as design criteria. The ratios should be considered for both the task and the background (e.g. Desk: Wall). This can also be considered for nearby surfaces in the field of view of an occupant. While luminance ratios can be used to direct an occupant towards something in a space, it is important to ensure people are comfortable in a working environment.

L1.4. Checklist design concept 3: Optimised and personalised control for visual comfort

The value of optimised and personal control, depending on individual occupant needs at any point in time, should be considered at concept design stage to ensure any desired requirements can be met in the completed building.

The amount, distribution and spectral qualities of lighting that are required from a lighting installation vary considerably according to multiple factors. These include the tasks that are being carried out at any point in time, as well as the visual acuity and preferences of the individuals in the space at the time. Traditionally, lighting design has attempted to accommodate this by providing for the worst-case scenario, inevitably leading to unnecessarily high light levels across the entire space at all times and with limited visual comfort. Of course, this also has a material effect on increasing the power consumption of the lighting installation.

As well as saving energy, personalisation and optimisation via lighting controls can help ensure that only the right light, in the right quantity, at the right time and in the right place is provided. Light levels can be changed automatically through pre-programmed '*scenes*' that can themselves be triggered by external factors like prevailing natural daylight conditions or by manual override by the occupants, depending on their particular needs or preferences at the time. Making the right choices at concept design stage can help ensure that this is provided for in the completed building.

Metrics:

The metric at concept design stage essentially relates to having an understanding of the degree and type of control that is appropriate for the building in order that allowance is made for more detailed design and installation later in the project.

L1.4. Checklist design concept 4: Light source quality for electric light sources

The quantity and quality of light output from an electric lighting installation depends fundamentally on the quality of the light generated by the light source itself. The lamp and/or luminaire in which the light source(s) are installed will also have some influence on the quality and quantity of light output.

The development of LED lighting has revolutionised the lighting sector. With digital circuits, LED technology is highly amenable to dimming control. Many different possible distributions of light output are possible, due to the flexibility in arranging the assembly of the diodes onto LED modules. Furthermore, the spectral output (in terms of correlated colour temperature) of light from diodes can be varied across a wide range (from 2000K with amber LED to >5000K) to suit client needs, whereas traditional light sources are much more limited in these aspects.

Although LED lighting is generally considered to be energy efficient (in terms of lumens generated per Watt of electricity consumed), there is a significant range of performance within these products and care needs to be taken whether efficacies (lm/W) apply to the light source, the lamp or the luminaire that is being purchased. Selection should therefore be made with reference to the sources of information provides by manufacturers as required under EU Energy Labelling and Ecodesign requirements [10]. Some efficacy will be lost when mounted in the luminaire due to some light being trapped in the luminaire. The location of the light source within the luminaire and the opacity of the material therefore require consideration.

At the concept design stage, it is sufficient for stakeholders to be aware of the likely needs of the occupants in the space, and to ensure that suitable provision is made in the project plan for light sources that are able to generate light with appropriate colour properties. The light should be sufficiently free of so-called '*temporal light artefacts*' (flicker and stroboscopic effects) and be tuneable in its spectral output and intensity according to the needs of the occupants in the space and with appropriate colour.

[10] Energy labelling and ecodesign requirements that apply to lighting products. https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/lighting_en