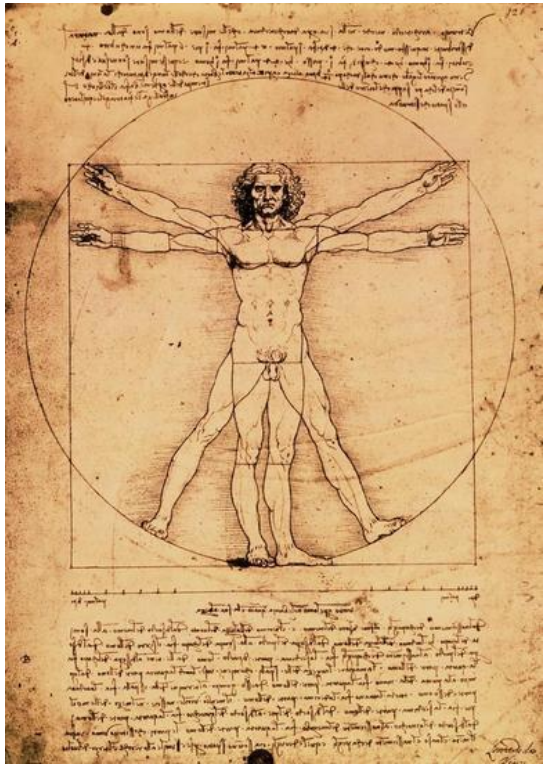
LIGHT

"New aspects of daylight design in European standard" / Jens Christoffersen, VELUX A/S
"Á jour with light: DS700 / Anne Bay, Danish Lighting Center

INNOBYG SPRING CONFERENCE 2014 - THE VALUE OF INDOOR CLIMATE

US DEFINITION OF INDOOR CLIMATE

- The Indoor Environmental Quality (IEQ) category in LEED* standards, one of the five environmental categories, was created to provide comfort, well-being, and productivity of occupants. The LEED IEQ category addresses design and construction guidelines especially:
  - indoor air quality (IAQ),
  - thermal quality
  - acoustics, and
  - **lighting quality**



***Leadership in Energy and Environmental Design** (**LEED**) is a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes and neighborhoods. Developed by the U.S. Green Building Council (USGBC)

DANISH BUILDING REGULATIONS (BR10)

- Thermal indoor climate
- Air quality
- Acoustical indoor climate
- **Lighting**

SOME CHALLENGES

- Why is lighting design not a high priority in indoor climate debate?
- Why does engineers only prioritise the fulfilment of standards in their planning?
- How do we raise awareness of the psycological and physiological consequences of poor lighting design?
- How do we make the best use of modern solutions (LED, glazing, sun shading, control and regulation)

FACTS & FIGURES

- Indoor daylight levels, illuminances, in the range of 100 to 2500 lux are likely to result in significant reduction of electrical lighting usage[1]
- Daylight is recognized to have the highest levels of light needed for the biological functions compared with typical electrical light sources[2]
- Daylighting has been associated with improved mood, enhanced morale, less fatigue, and reduced eyestrain[3]
- Daylight is the most energy-efficient means to deliver the light exposure, when it is available[4]

[1] J. Mardaljevic, Climate –Based Daylight Analysis for Residential Buildings – Impact of various window configurations, external obstructions, orientations and location on useful daylight illuminance, Institute of Energy And Sustainable Development, De Montfort University, 2008

[2] W.E.Hathaway, J.A. Hargreaves, G.W. Thomson et al., A study into the effects of light on children of elementary school age – a case of daylight robbery, Alberta Department of Education 1992

[3] C.L. Robbins, Daylighting Design and Analysis, New York: Van Nostand Reinhold Company, 1986

[4] Jennifer A. Veitch & Anca D. Galasiu, The Physiological and Psychological Effects of Windows, Daylight and View at Home: Review and Research Agenda, 2012

FACTS & FIGURES, LEARNING

- Learning in daylit environments results in more effective learning. Students in classrooms with the most window area or daylighting had 7-18% higher scores in tests than those with the least daylight[8]

- Learning in spaces with proper artificial light (high illuminance, high vertical luminance, maybe high colour temperature) improves scores (reading & math) considerably at wintertime[9a]

- Higher daytime light exposures result in more positive mood, less pain and smoother social interactions[9].

[8] L.Heschong, Daylighting and Human Performance, ASHRAE Journal, vol. 44, no.6, pp. 65-67, 2002

[9]Jennifer A. Veitch & Anca D. Galasiu, The Physiological and Psychological Effects of Windows, Daylight and View at Home: Review and Research Agenda, 2012

[9a]Tommy Govén et al., Influence of ambient light on the performance, mood, endocrine systems and other factors of School children, 2009

FACTS & FIGURES, HOMES

- Natural light is the single most important attribute in a home, with over 60% of respondents ranking it as important.[12]
- WHO's Large Analysis and Review of European Housing and Health Survey, covering eight cities across Europe, showed that individuals who report inadequate natural light in their homes have greater risk for depression and falls.[13]

[12]The Way We Live Now, RIBA and Ipsos MORI, 2012

[13]Brown, M. J., & Jacobs, D. E. (2011). Residential light and risk for depression and falls: Results from the LARES study of eight European cities. Public Health Reports, 126(Supplement 1), 131-140.

FACTS & FIGURES, SLEEP

- It is important with daily exposure to high amount of daylight, and complete darkness at night. Healthy light is inextricably linked to healthy darkness [18]

Insufficient sleep duration, difficulty maintaining sleep, and difficulty initiating sleep and early morning awakening are common problems that can be related to the lack of daylight exposure.

- The cost of insomnia to the US economy exceeds $30 billion (1994 USD). [19]

- Poor sleepers miss five more days of work per year than those with no sleep problems[20]

[18] The Physiological and Psychological Effects of Windows, Daylight, and View at Home: Review and Research Agenda (2012), J. A. Veitch & A. D. Galasiu, NRC-IRC Research Report RR-325, National Research Council of Canada Institute for Research in Construction, ON, Canada

[19] Chilcott and Shapiro, 1996

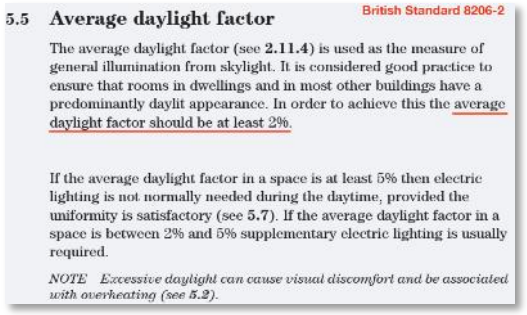
[16] Schweiter et al, 1992


International Daylight Legislation
and Recommendations

Daylight Requirements (Europe)

Daylighting requirements or recommendations in legislations is often limited, and tends to be related to three main types:

- *Requirements for window area in relation to room or facade area.*
- *Levels for daylighting by daylight factor (DF)*
- *Sunlight access in buildings*



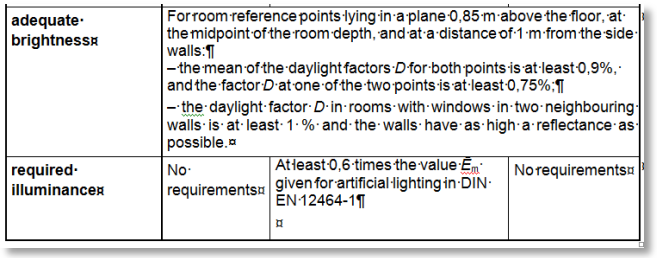
5.5 Average daylight factor British Standard 8206-2

The average daylight factor (see **2.11.4**) is used as the measure of general illumination from skylight. It is considered good practice to ensure that rooms in dwellings and in most other buildings have a predominantly daylit appearance. In order to achieve this the average daylight factor should be at least 2%.

If the average daylight factor in a space is at least 5% then electric lighting is not normally needed during the daytime, provided the uniformity is satisfactory (see **5.7**). If the average daylight factor in a space is between 2% and 5% supplementary electric lighting is usually required.

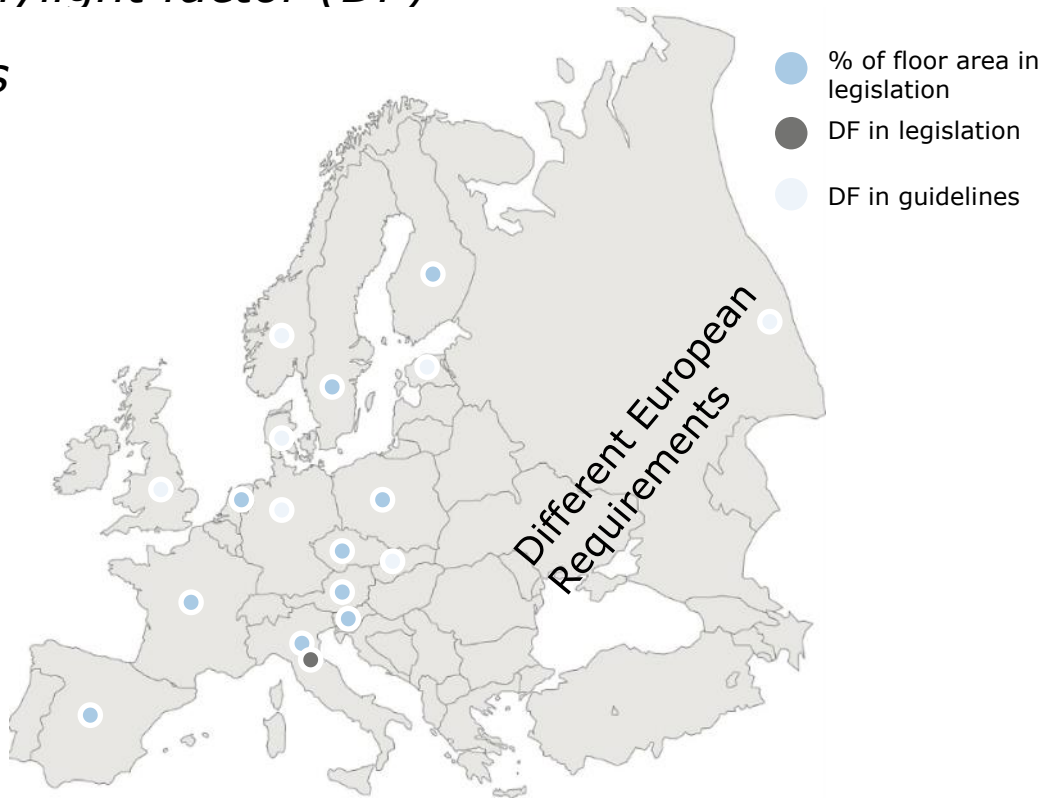
NOTE Excessive daylight can cause visual discomfort and be associated with overheating (see 5.2).

British Standard 8206-2



adequate brightness	For room reference points lying in a plane 0,85 m above the floor, at the midpoint of the room depth, and at a distance of 1 m from the side walls: – the mean of the daylight factors *D* for both points is at least 0,9%, and the factor *D* at one of the two points is at least 0,75%; – the daylight factor *D* in rooms with windows in two neighbouring walls is at least 1 % and the walls have as high a reflectance as possible.		
required illuminance	No requirements	At least 0,6 times the value $\bar{E}_m$ given for artificial lighting in DIN EN 12464-1	No requirements

Germany: DIN 5034-1

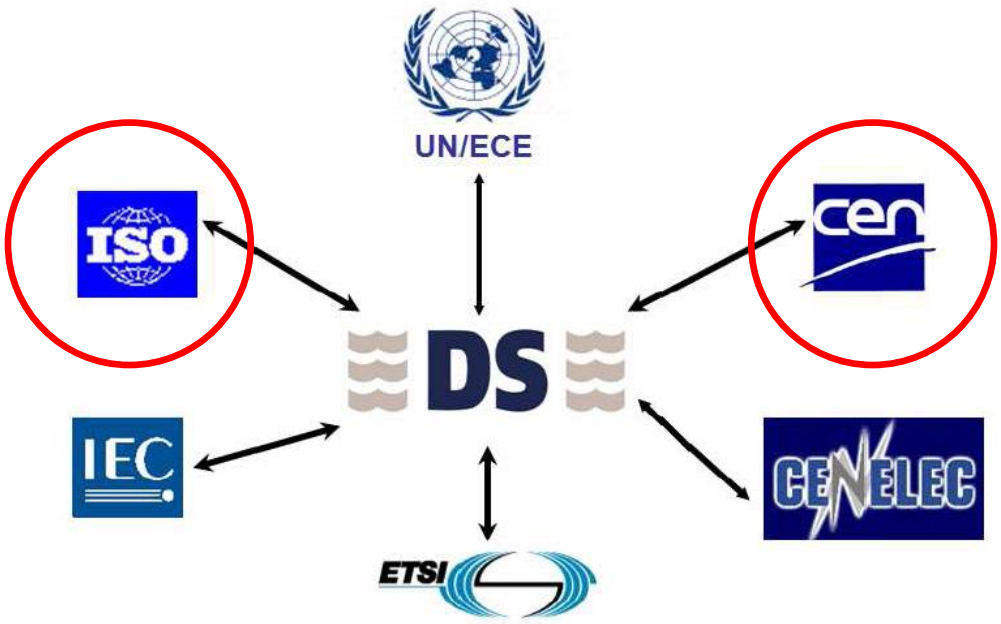


INTERNATIONAL STANDARDIZATION

- CEN European Committee for Standardization (CEN) is a European standardization body with 33 participating countries, including Denmark and the other 27 EU members

- International Organization for Standardization (ISO) s an international standardization organization that consists of representatives from various national standardization bodies.

- CIE - Commission Internationale de l'Eclairage (The International Commission on Illumination) is privately held organization that promotes worldwide cooperation and the exchange of information on all matters relating to the science and art of light and lighting, colour and vision, photobiology and image technology.



CEN / TC 169 WG 11
"Daylight"

Members:

Austria, Belgium, Czech Republic, Denmark, France, Germany, Italy, Slovakia, Slovenia, Sweden, The Netherlands, **UK**

linked to

CEN/TC 169 WG 2 Lighting of Workplaces

CEN/TC 169 WG 9 Energy Performance of Buildings

CEN/TC 169 WG 13 Non-Visual Effects of Light on Human Beings

Objectives:

Develop European Standard for "Daylight of Buildings"

EU Standard for Daylighting of Buildings

Daylight
Annex A,
Normative

View
Annex B,
Normative

Sunlight
Annex C,
Informative

Glare
Annex D,
Informative

Applies to all spaces: Workplaces and Dwellings

CEN/TC 169/WG 11 Daylight

Scope

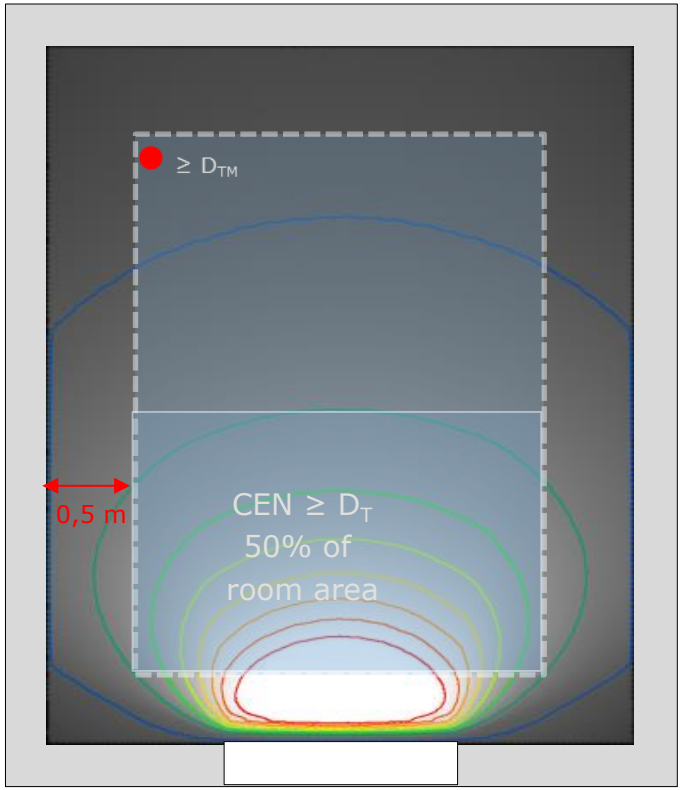
- Specify minimum recommendations for achieving an adequate subjective impression of lightness indoors, and for providing an adequate view out.
- Recommendations for the duration of sunshine exposure within habitable and occupied rooms.
- Give information on how to use daylighting to provide lighting within interiors, and how to limit glare.
- Defines metrics used for the evaluation of daylighting conditions and gives methods of calculation.

Target Daylight Factor

Daylight design should achieve a target daylight factor (D_T) across a fraction of the relevant floor area (i.e. 50%) for half of the daylight hours in the year. For a space predominantly lit by roof lights, then 90% of the points should meet this criterion.

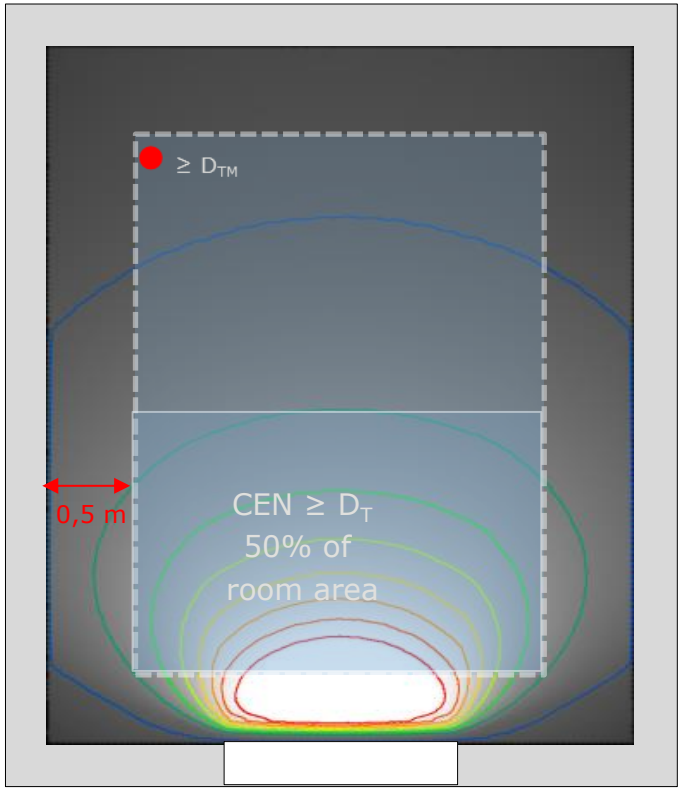
$$D_T = \frac{Internal}{External} = \frac{300 \cdot 100}{14.200} = 2{,}1\%$$

City	Internal lux	External lux	D_T %	D_{TM} %
Copenhagen	300	14.200	2,1%	0,7%
Paris	300	15.900	1,9%	0,6%
Rome	300	19.200	1,6%	0,5%

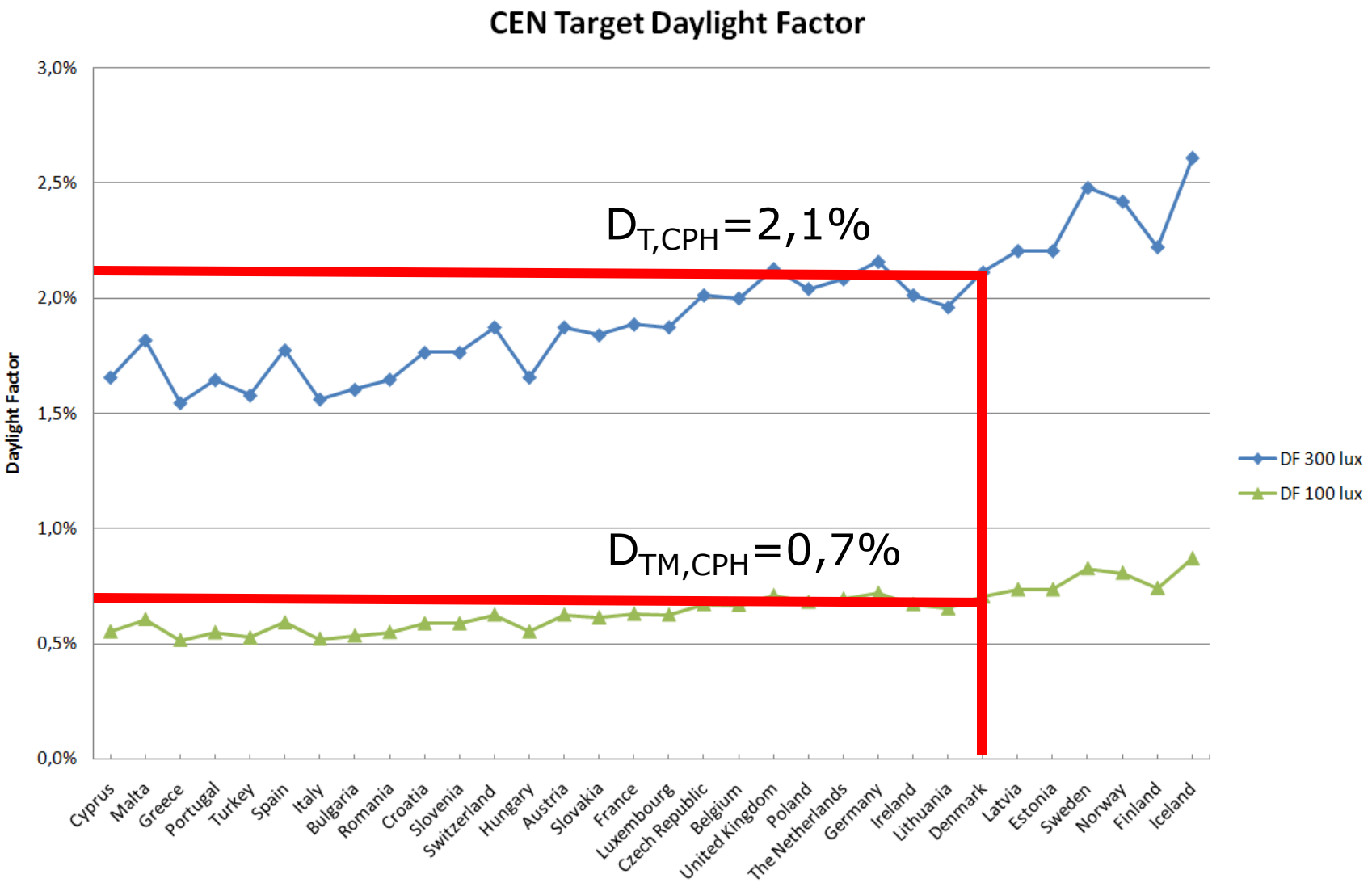


How to do it?

1. Design a space with one or more windows in the façade or roof
2. Properties of the space
   - external obstruction, glazing transmittance, thickness of walls and roofs, internal partition and surface reflectance etc.
3. Do the Daylight Calculations with an overcast sky
   - VELUX Daylight Visualizer, Dialux, Relux or others.
4. Count how many points have a value of the target daylight factor D_T or higher; and lowest value higher than D_{TM}.
5. If number of grid points higher than D_T is more than 50% and lowest value higher D_{TM} then daylight access according to the prEN Standard.
6. If not then e.g. enlarge the window, add windows, change glazing, reduce room depth ...

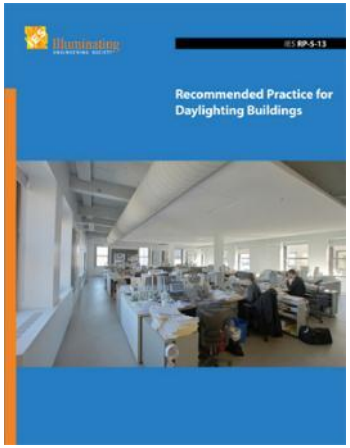


DF_{target} & $DF_{minimum\ target}$

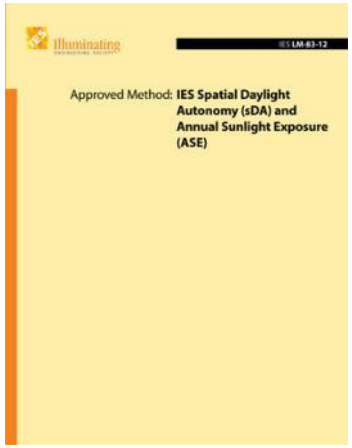


Daylight Recommendations (USA)

- The IES Daylight Metrics Group recognized the limitation in previous daylight requirements, and recommended that satisfying daylight requirement should consider daylighting design issues as:
  - direct and reflected sunlight
  - latitude
  - building orientation
  - time and date
  - climatic conditions



- IES Daylight Metric Group recommends climate-based annual daylight performance metrics such as:
  - Spatial Daylight Autonomy (sDA)
  - Annual Sunlight Exposure (ASE)

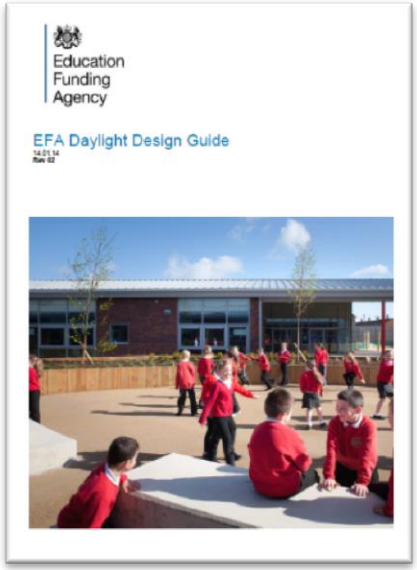


Daylight Recommendations (UK)

- In 2013 the Education Funding Authority (EFA) published the Facilities Output Specification for the new Priority Schools Building Programme (PSBP) and the Baseline design lighting strategy.

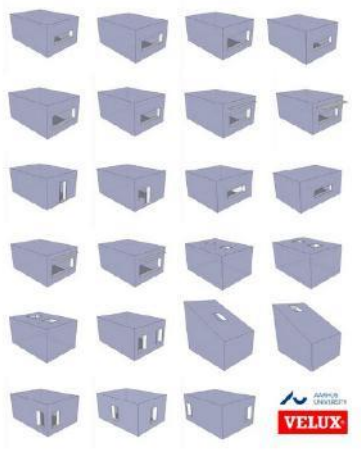
- The Baseline schools shall be designed using Climate Based Daylight Modelling (CBDM), taking into account the quality and quantity of sunlight and daylight.

  - UDI-a, between 100-3000 lx for 80% (average) of the calculation points within space for the occupied time.

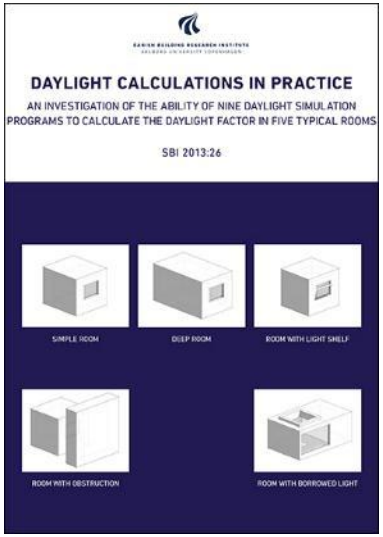


Daylight Requirements

Requirements for window area in relation to room or facade area



- Daylight Visualizer was used to investigate the Danish prescriptive requirements for daylight in buildings
  - Window to floor area ratio
- The study showed the prescriptive requirements did not ensure adequate daylight factor levels,
- … and tools, like VELUX Daylight Visualizer (http://viz.velux.com/), can be used as an argument to modify requirements for daylight in buildings.



Nine out of ten daylight simulation programs agree …

and therein lies a story worth retelling.

Artificial lighting requirements (DK)

Upper limit = maximum energy consumption (BR10)

A PROPER SOLUTION

Lower limit = minimum lighting quality (DS700)

DS700 mandatory because BR10 refers to it!

Current standards

REVISED VERSION PUBLISHED SOON

- DS700:2005
  Artificial lighting in workrooms
- DS 703:1983
  Directions for lighting in hospitals
- DS 704:1998
  Lighting - Definitions
- DS 705:2002
  Artificial lighting in dental consulting rooms
- DS 707:2001
  Sports lighting - Semi-cylindrical illumination

- DS/EN 12193:2008
  Light and lighting - Sports lighting
- DS/EN 12464-1:2011
  Light and lighting - Lighting of work places - Part 1: Indoor work places
- DS/EN 12464-2:2007
  Light and lighting - Lighting of work places - Part 2: Outdoor work places
- DS/EN 12665:2011
  Light and lighting - Basic terms and criteria for specifying lighting requirements
- DS/EN 1838:2013
  Lighting applications - Emergency lighting

DS700 – why not DS/EN 12464-1?

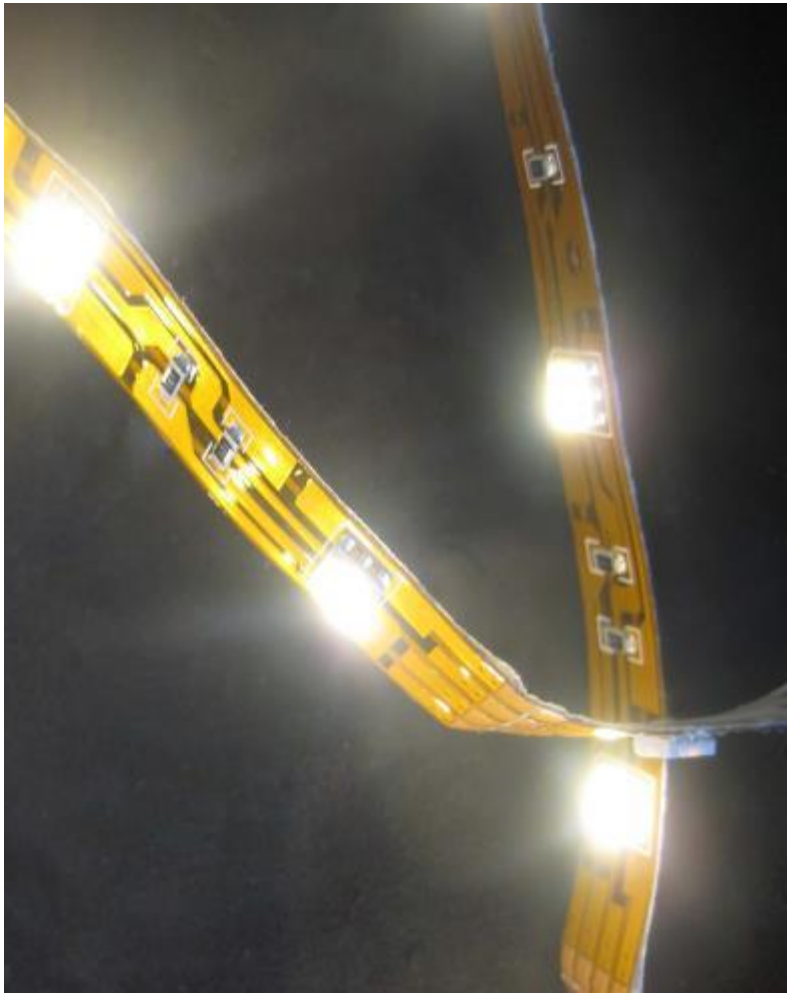
- **Glare** requirements are higher in DS700
- DS700 specifies **variation** in the artificial lighting as means to provide better visual conditions and save energy
- DS700 has more focus on the relation between lighting and **shape perception** than EN 12464-1
- DS700 in general specifies **lower illumination levels** as a result of Danish lighting culture. This leads to good low glare and low energy consumption.
- DS700 in general specifies demands higher on **colour rendering**

ERCO: Directed and diffuse light

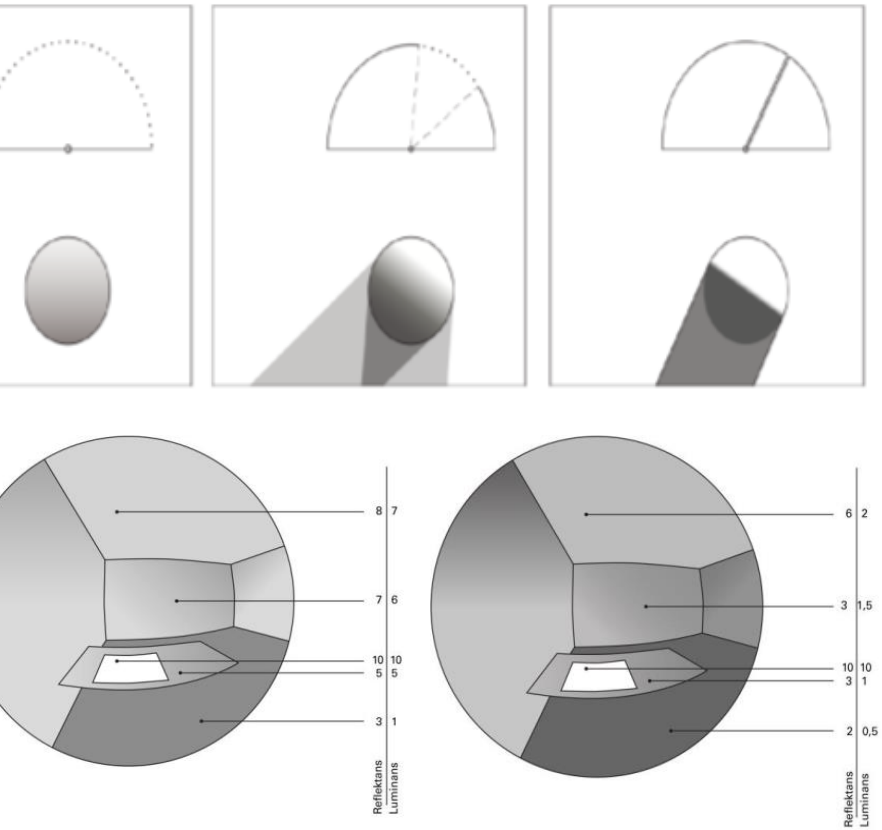
AIM for new DS700 ➔ Provide valuable input for next revision on EN12464-1

Why revising DS700?

- Closing gap to DS/EN 12464-1 while keeping Danish lighting culture
- New light sources: LED
- Updating room types and work tasks
- Update illumination requirements on task area
- New definition of maintenance factor
- Harmonize UGR glare limits with DS/EN 12464-1:2011
- New recommendations for illumination of vertical surfaces and cylindrical illumination levels
- Adapting daylight: Requirements apply no matter whether the room is lit by daylight, artificial light or a combination



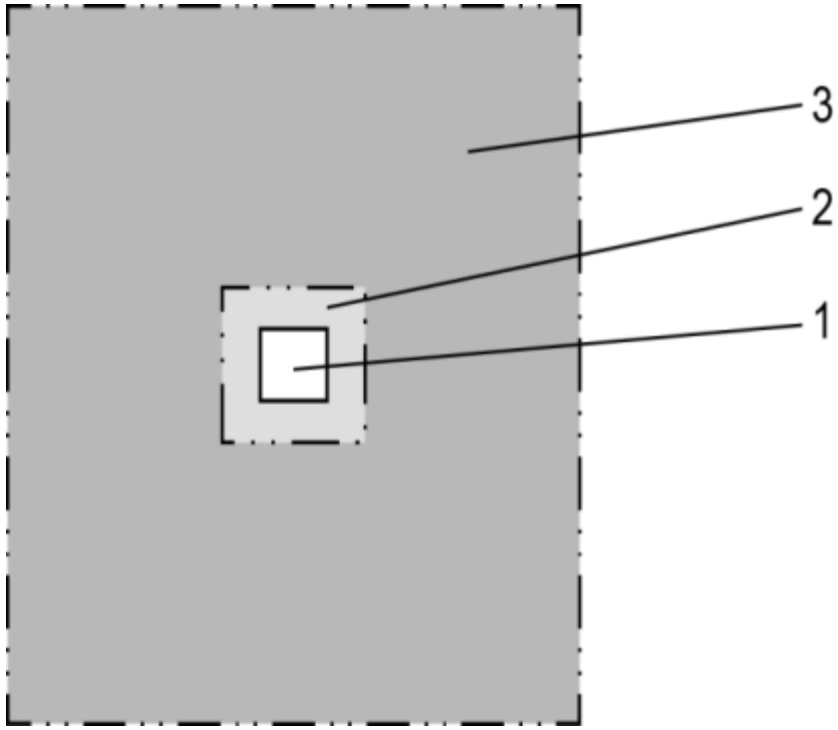
DS700:2014 looks like DS/EN 12464-1:2011



- Structure
- Tables
- Some elements from DS700:2005 remain:
  - A few illustrations
  - Texts about luminance and shape rendering in EN12464-1 are supplemented significantly with text from DS700
  - The paragraph concerning maintenance is extended considerably to cover LED
  - Some notes eg. from Annex A in the former DS 700 has been added to various sections

Clearer definitions

- Section 3. Terms and definitions: 59 important terms explained
- Task area: Position and minimum dimensions
- Calculation grid for illumination levels: Quantity of calculation points related to grid size



1. Task area
2. Near surroundings – minimum 0,5 m width around task area
3. Far surroundings – minimum 3,0 m width around near surroundings

New definition of uniformity

- $U_o = E_{min}/E_{mid}$
- ”Loophole” allowing -25% measured illuminance levels in discrete point omitted

Type område, opgave eller aktivitet	$\bar{E}_m$ lx	UGR_L -	U_o -	R_a -
Lægeklinikker, fodterapeut, optiker og lign.				
Undersøgelser mv.	200	19	0,6	90
Optisk værksted	500	17	0,6	80
Fodpleje	500	19	0,6	80
Lufthavne				
Afgangs- og ankomsthaller, baggageudlevering	200	22	0,4	80
Forbindelsesområder	100	22	0,4	80
Informationsskranke, indtjekningsskranke	200	19	0,7	80
Told- og paskontrol	200	19	0,7	80
Venteområder	200	22	0,4	80

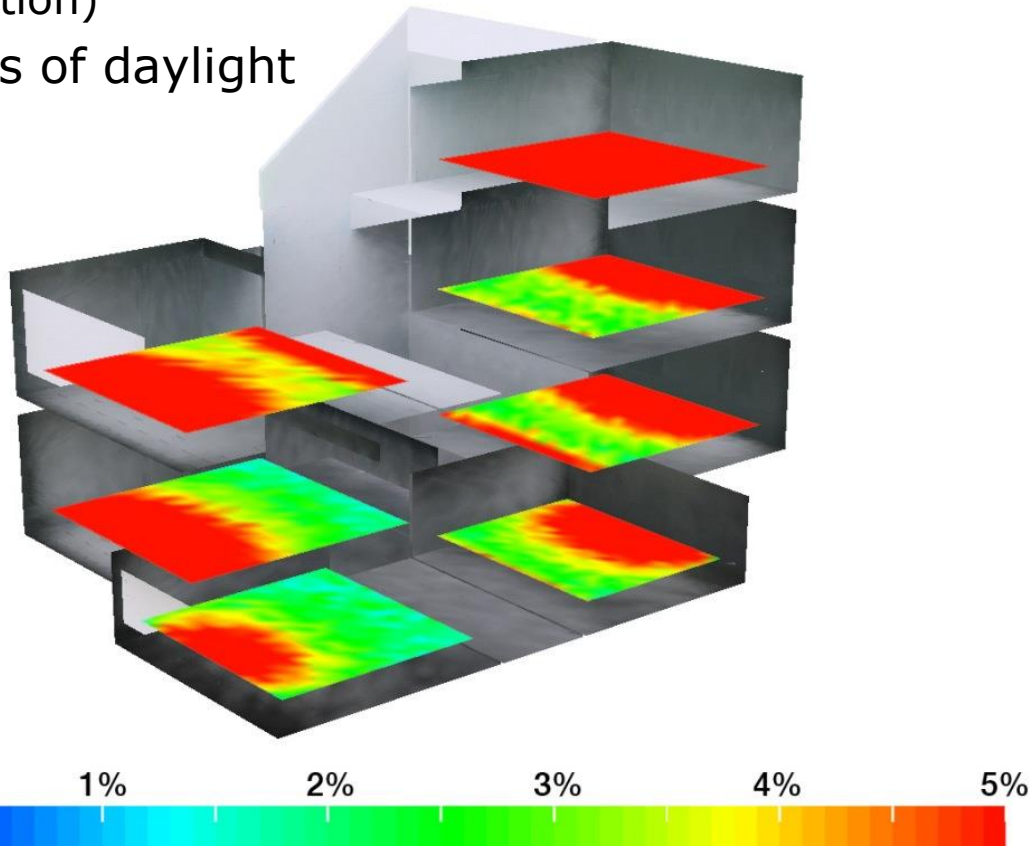
New requirements in schools and daycare institutions

Daycare	DS700:2005	DS700:2014	EN12464-01
Nursery and playrooms	200 lux	300 lux	300 lux
Handicraft room	200/500 lux	300 lux	300 lux

Schools and other educational premises	DS700:2005	DS700:2014	EN12464-01
Classrooms, tutorial rooms	200 lux	300 lux	300 lux
Evening classes, adult education, auditorium			500 lux
Art	200 lux	300 lux	500 lux
Woodwork	200 lux	300 lux	500 lux

New focus on energy and health

- Use daylight in an optimal way
  - Daylight control systems and manual controls
  - Maintenance and cleaning
  - Bright surfaces (diffuse reflection)
- New section on combinations of daylight and artificial light
- New sections on
  - More advantages in daylight
  - Lighting variations



Good lighting

- DS700:2014 specifies minimum quality
- Consequently: Complying with DS700 does not automatically provide quality lighting
- DS700:2014 is limited to lighting for occupants with normal vision
- Use contemporary knowledge to enhance lighting conditions
  - Use your eyes to judge glare conditions
  - Avoid excessive contrast in luminaires and room surfaces (also from daylight)
  - Evaluate aspects such as colour temperature and colour rendering (spectral qualities) at a higher level
  - Design lighting schemes that relate to function, tasks and time of day (diffuse/directed, dimming, partial illumination, white-tuning etc.)
  - Provide proper user control