LED lighting for improving well-being in a psychiatric hospital – A first look

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

A simple solution with separate day and night lighting systems, attempts to provide better experiences for staff and patients

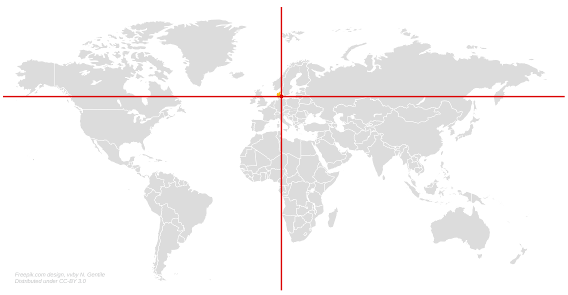
At Slagelse Psychiatric Hospital, they apply a simple strategy in an attempt to improve the well-being of staff and patients. In patient rooms, daylight and three downlights with a warm colour appearance provide sufficient light during the day. At night, two downlights reduce light levels and colour temperature to help create a calmer atmosphere.

The project

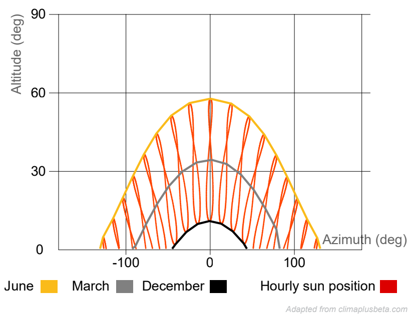
Completed in 2015, Slagelse Psychiatric Hospital (Fig. 1) is one of the largest psychiatric facilities in Denmark. The building's 44,000 m^2 floor area includes general and high-security wards, as well as training and research facilities. It was designed as a network of clusters with good connections between the different functions of the hospital. It achieved a silver rating in the Danish DGNB green building certification system that was first established in Germany in 2008. The lighting designers planned an extremely simple lighting design strategy in an attempt to provide better health and well-being for both patients and staff. An LED lighting system consisting of two separate circuits of luminaires was installed in the patient bedrooms and other areas of the hospital. The focus of this case study is on the patient bedrooms (Figs. 2 and 3). During the day,

Figure 1. Psychiatric Hospital in Slagelse, Denmark: Exterior (top left), inner courtyard (bottom left) and corridor in patient ward (right) under partly overcast sky on 26 February 2020.

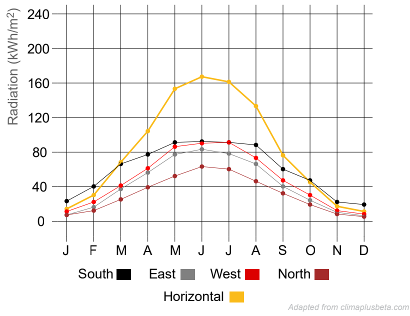
daylight is supplemented by three LED downlights with a correlated colour temperature (CCT) of around 2700 K providing an additional average illuminance of 250 lux on top of the daylight levels. At night, only two LED downlights in positions different from those operating during the day provide an average illuminance of just above 100 lux at a CCT of around 2000 K (measurements varied between 1750 K and 2200 K). Average daylight factor levels (DF) in the patient bedrooms are between 2 and 3 percent. A wall-mounted orientation light is installed adjacent to the base



Location: Slagelse, Denmark
55.40° N, 11.37° E



Sun path for
Copenhagen, Denmark
(55.67° N, 12.52° E)



Global horizontal and vertical radiation for
Copenhagen, Denmark
(55.67° N, 12.52° E)

IEA SHC Task 61 Subtask D

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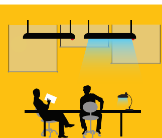

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Figure 2. Daylight (left), as well as day-time (center) and night-time (right) scenarios for electric lighting in a patient bedroom.

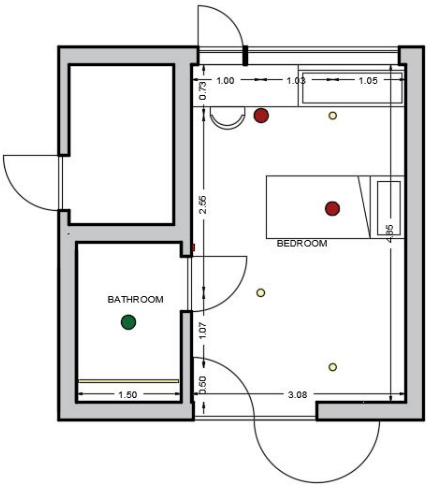

Figure 3. Typical floorplan of a patient room with bathroom.

of the bathroom door for wayfinding at night. The intention was to reduce patient anxiety, enhance their sleep quality and reduce the need for medication or fixation of patients. At the same time, it should help staff experiencing calmer conditions with fewer emergency responses (especially at night) and falling asleep more easily after returning home from a night shift. The lighting is controlled predominantly through programmed schedules via a central touch screen panel in each of the nurses' stations. The setting is changed from day to night and back to day the next morning. Patients and staff can turn on or off the lighting that is in effect at any time via switches in the patient rooms. In the rooms, however, they cannot change from night to day or day to night settings. Daylight-dependent dimming systems or occupancy sensors were not implemented. The Danish Building Code permits this, if the lighting predominantly serves a therapeutic purpose.

Monitoring

Researchers from Aarhus University's Lighting Design Research Laboratory visited the hospital on 26 February 2020. Photometric measurements were conducted on site throughout the day, including for several hours after sunset. Six members of the medical staff from different shifts working with psychiatric patients were interviewed in a process that allowed them to add their own impressions and comments. In addition, researchers collected technical information about the lighting installation and its operation from the technical service leader. Monitoring closely followed the protocols as established by the IEA-SHC Task 50 and extended by the current IEA-SHC Task 61.

Energy

The building's lighting energy performance was evaluated via calculations according to the European

Table 1. Energy Use and Lighting Energy Numeric Indicator (LENI) for the different lighting scenarios.

	Standard reference	Existing	Proposed change
Day (DF = 2%), (Average Illuminance -->)	300 lux	218 lux	218 lux
Hours	3000 Hours	3000 Hours	
Number of Luminaires	4 Ceiling	3 Ceiling	
Power per Luminaire	18.1 W	19.5 W	
Daylight-Dependent Control	yes	no	yes
Occupancy Sensor	no	no	yes
Total Annual Energy Use Day	98.5 kWh	175.5 kWh	64.9 kWh
Night (Average Illuminance -->)	100 lux	135 lux	135 lux
Hours	1000 Hours	1000 Hours	
Number of Luminaires	4 Ceiling	2 Ceiling	
Power per Luminaire	6 W	10.5 W	
Total Annual Energy Use Night	24.0 kWh	21.0 kWh	16.8 kWh
Total Annual Energy Use	122.5 kWh	196.5 kWh	81.7 kWh
LENI (for Room of 15 m^2)	8.2 kWh/m^2	13.1 kWh/m^2	5.4 kWh/m^2
Energy Savings compared to Standard Reference		-60.5%	33.3%
Energy Savings compared to Existing			58.4%

If avg. 300 lux during day and 100 lux at night	Standard reference	Existing	Proposed change
Total Annual Energy Use	122.5 kWh	257.1 kWh	104.4 kWh
LENI (for Room of 15 m^2)	8.2 kWh/m^2	17.1 kWh/m^2	7.0 kWh/m^2
Energy Savings compared to Standard Reference		-109.9%	14.7%
Energy Savings compared to Existing			59.4%

Standard EN 15193-1. The Lighting Energy Numeric Indicator (LENI) was determined for three different lighting scenarios (Table 1):

- A standard reference scenario with four ceiling-recessed LED panels and a daylight-dependent control system (representing a typical Danish code-compliant design)
- The actually existing lighting system with its different day and night scenarios
- A variant of the actually existing system with added daylight-dependent lighting control and passive infrared (PIR) motion sensors

The maximum power (W) of the LED luminaires and driver combinations were measured at Aarhus University and dimming values estimated on the basis of spectral and illuminance measurements taken on site. Subsequent DIALux simulations and EN 15193-1 calculations in an Excel-based spreadsheet provided the energy performance data. The actually existing lighting design with its different day and night scenarios would likely have resulted in a 60.5% higher lighting energy use than the standard reference case, because daylight-dependent dimming was not implemented. Added daylight-dependent dimming and occupancy sensors (absence factor 0.2) would have resulted in 33.3% energy savings compared to the standard reference. With illuminance settings of 300 lux from electric lighting during the day and 100 lux during the night, the existing design would have used 109.9% more lighting energy than the standard reference case without daylight-dependent dimming or occupancy sensors, and 14.7% less energy than the standard reference with the additional installation of daylight-linked dimming and occupancy sensors.

Photometry

Illuminance measurements were taken in one-metre steps along the centreline of the room for (a) daylight only, (b) electric lighting in the day setting and (c) electric lighting in the night setting. During the daylight assessment, the exterior horizontal illuminance was measured (approximately 20,000 lux around 13:00). The sky on 26 February 2020 was partly overcast. Some clear patches occurred. Direct sunlight did not strike the illuminance metre. The average daylight factor was above 2.1% in the patient bedroom and the illuminance above 300 lux for more than half of the room, thus meeting the recommendations for spatial daylight autonomy (sDA) of the European Standard EN 17037. Electric lighting alone provided more light in the day setting than required by the European Standard EN 12464-1, but would not meet the levels for “simple patient examinations” or “reading”. A reading light could be added to the room, but was not present during monitoring. Night lighting provided sufficient light for “night observation”. Luminance maps for the assessment of room brightness distributions and glare ratings (DGP and UGR) were created from two viewpoints (from the door entering the bedroom from the corridor and from the bed facing the bathroom wall with the TV) in the bedroom for all three lighting scenarios studied. Daylight could cause discomfort glare when entering the room facing the window (DGP clearly above 0.45). Electric lighting alone could potentially cause discomfort glare (UGR above 19) under the day setting, as one of the ceiling-recessed downlights is just above the patient when sitting on the bed. This is mitigated by the presence of daylight for most of the daytime hours, adapting the occupant to higher light levels. From the two viewpoints, the light source spectrum, correlated colour temperature (CCT) and colour rendering index (Ra) were determined. Differences between day and night settings were not as expected in the assessed bedroom. The spectral measurements were repeated in another bedroom on 23 November 2020, where they showed the expected differences (ca. 2000 K at night vs. 2700 K during the day).

Circadian potential

Spectral information, appropriately weighted, allows for assessment of the circadian potential of different lighting scenarios. The circadian potential expresses how a specific lighting scenario could potentially support a building occupant’s daily sleep/wake rhythm and well-being. This was evaluated using two metrics: the Melanopic Equivalent Daylight (D65) Illuminance (M-EDI) and the Circadian Stimulus (CS). Experience with these state-of-the-art metrics is still limited, but initial recommendations for appropriate values exist. Different spectrally weighted M-EDI levels contribute to inhibiting or enhancing the production of the

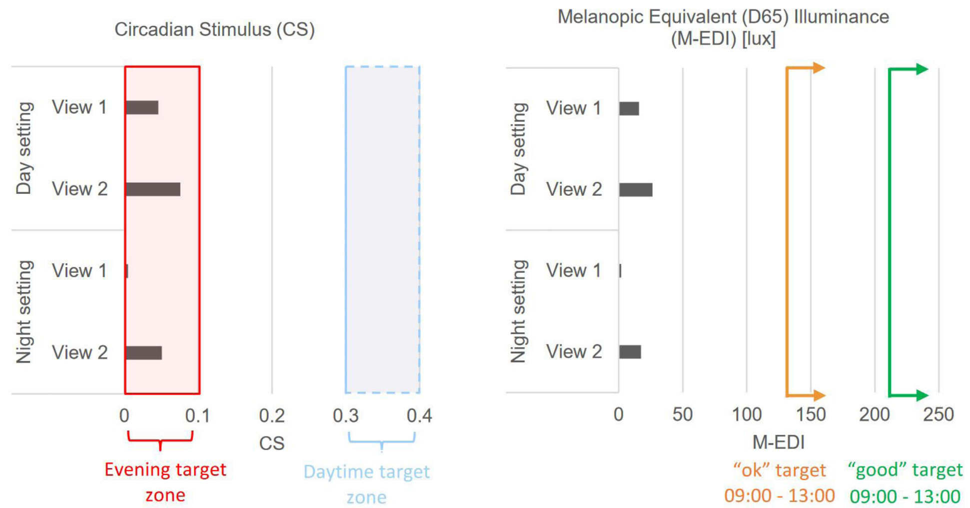

Figure 4. Left: Circadian Stimulus (CS) measured on 26 February 2020 at the eye of a hypothetical observer, 1.2 m above the floor from the two viewpoints. The target zones for evening and daytime refer to the recommendations of the Lighting Research Institute. Right: Melanopic Equivalent Daylight (D65) Illuminance (M-EDI) for the same situations. The target limits for “ok” and “good” refer to the recommendations of the WELL Building Standard V2.

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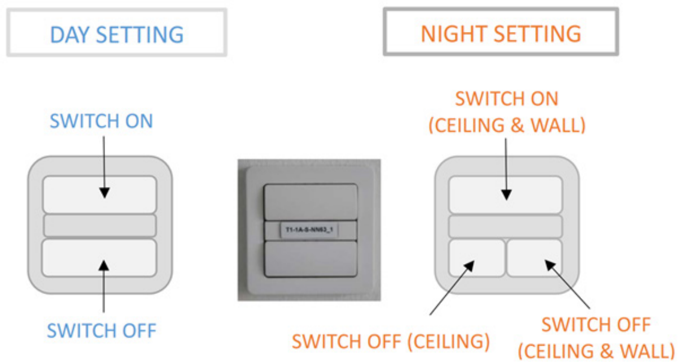

Figure 5. Wall switch that controls the electric lighting in a patient bedroom with changing functionality from day to night setting.

sleep hormone melatonin. To obtain good circadian conditions for increasing alertness and supressing melatonin production in the hours before midday, the WELL Building Standard V2 recommends an M-EDI of at least 218 lux at eye level. CS is the effectiveness in suppressing the production of melatonin from threshold (CS = 0.1) to saturation (CS = 0.7). The Lighting Research Center in Troy, New York suggests, that CS should be kept below 0.1 in the evenings and at night to enhance melatonin production for a good night's sleep. For increasing alertness, a value between 0.3 and 0.4 is recommended. For both metrics, the electric lighting scenarios during both night and day would provide good conditions for putting patients and staff to sleep. It is, however, highly unlikely that the electric lighting as installed can contribute to a well-balanced circadian rhythm of patients or staff, as the M-EDI and CS values for increasing alertness cannot be reached (Fig. 4).

User perspective

Six employees from the medical staff were interviewed about their experiences with the lighting system. The interview guide included questions on the visual experience, potential circadian effects on staff and patients, emotional impacts and practical aspects with implementation and use. Between 50% and 83% of the staff members thought the installed lighting was appropriate for the different rooms, with the highest percentage given for the patient bedrooms and 67% for the staff room and 62% for the corridors. The corridor was too dark for some. Only half of the staff members felt the common room lighting was appropriate. The others thought it was either too yellow or too sharp. The transition from night to day settings was seen as too sudden. Three persons experienced glare in the staff room. Compared to experiences in their old workplace, staff did not appear to notice any improvements in their personal energy level during work. Only one of the employees felt that sleep had improved to some degree since using the lighting system, and that physical well-being had greatly improved. Two employees felt that security in the ward had increased to a small degree. Two staff members indicated slightly less patient activity at night. One believed that there was a little less physical restraint use. Otherwise, they could not identify any effect of the lighting on the patients. While most of the staff believed the lighting made sense in their everyday activities and they would probably recommend it to others, they made clear suggestions for improvements. Instructions on the use of the lighting system were seen as insufficient by four of the six staff members. Half of the staff experienced weekly or monthly challenges in the everyday operation, such as not being able to switch off lights at the central touch panel and problems with the PIR-sensors in the bathrooms. Two experienced problems with the lighting during emergencies, including the lights turning off. The switches used, especially in the patient bedrooms, were confusing with functions changing between day and night settings and no labelling at all (Fig. 5).

Lessons learned

The lighting designers planned an extremely simple lighting design strategy in an attempt to provide better health and well-being for both patients and staff. Researchers also believe that simple systems can often outperform highly complex lighting systems. Unfortunately, the lighting in Slagelse was not as successful as perhaps possible as some of the original ideas were not implemented. Gradual transitions between the day and night setting and between night and day would have clearly improved the system, as would the introduction of daylight-dependent dimming of the electric lighting and occupancy sensors for saving electric lighting energy. Electric lighting during the day, especially on winter mornings when daylight is scarce, could not provide sufficiently high levels to provide energizing boosts.

Great, extremely simple initial idea with unfortunate implementation. With a little more effort, this could have been a great lighting success story.

Clear instructions for staff and patients about the purpose and use of the lighting system and its operation appeared to be missing, and control interfaces like switches were unnecessarily complex and confusing. Frequent operational problems also contributed to staff frustrations. The researchers recommended to review technical and operational challenges and to address them as soon as possible.

Further information

W. Osterhaus, I. Erhardtsen, M.Gkaintatzi-Masouti, K. Nielsen and F. Dobos. ELFORSK Project Report (PSO-351-041): Case Studies – Circadian Lighting, December 2020. https://elforsk.dk/sites/elforsk.dk/files/media/dokumenter/2021-03/351-041_AU_Circadian_Lighting_Case_Studies_Report_22Jan2021_Corrections.pdf

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