Daylighting integration is an asset for the retail sector

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Generous windows, daylight harvesting and Human-Centric LED Lighting in the pilot project IKEA Kaarst store

At IKEA Kaarst daylight was brought into the exhibition area. This, combined with clever integration of electric lighting, has improved the shopping experience for customers and left the mark on a bunch of enthusiastic employees.

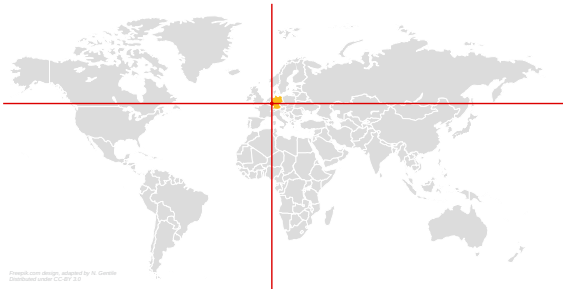
Figure 1. The IKEA shop in Kaarst as seen from the outside. The windows in the living room exhibition area can be seen at the top of the first flight of stairs.

The project

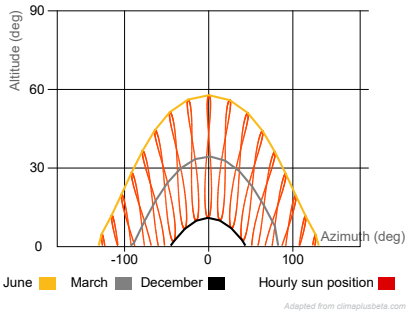
When you arrive at IKEA Kaarst, the feeling is that you are in front of yet another “blue-box” store of the famous furniture chain. But it is when you walk-in that the magic happens. In the “living room” exhibition area, large west-facing windows allows the afternoon sun illuminating sofas and tables (Fig. 2); the electric lighting is provided by LED luminaires dimmed with a daylight harvesting sensor (DHS), and a number of ceiling spot lamps. After walking through various departments, you will end up in the “home decoration” area, where fully-glazed windows provide most of the illumination and a most-welcomed connection to the outdoors; there, the electric lighting relies on traditional halogen spotlamps plus a proof-of-concept Human-Centric Lighting (HCL) consisting of LED panels with colour tuning. The light CCT changes overtime according to a predefined schedule which is intended to mimic daylight (Fig. 2).

Monitoring

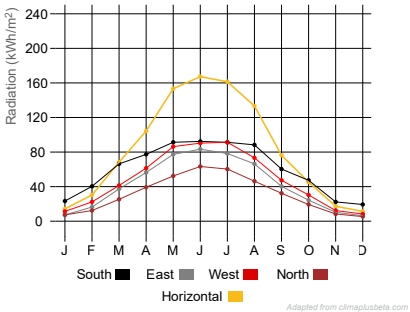
The site was first visited in February 2019, and then monitored for two weeks, slightly before the spring equinox. The field monitoring provided valuable insights as well as material to produce additional computer simulations. The simulations were used to evaluate daylight indicators such as the Daylight Autonomy (DA) or the Daylight Glare



Location: Kaarst, Germany
51.21°, 6.64°



Sun path for
Kaarst, Germany



Global horizontal and vertical radiation for
Kaarst, Germany

IEA SHC Task 61 Subtask D

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Figure 2. 'Living room' from the inside during the day (top-left), and from the inside druing evening (bottom-left). 'Home decoration' under daylight from the inside (top-right), and with the HCL LED lighting system in function, cool and warm CCT.

Probability (DGP). The monitoring shaped the recommendations of the IEA Task 61 Monitoring Protocol in a feed-forward/feed-back process (Fig. 3).

Energy

The LENI was calculated based on the real operational conditions of lamps (schedules and dimming levels). Indeed, the lighting management system logged status (on/off) and dimming levels lamps. The performance was good for the 'living room', but not for the 'home decoration' (Table 1). Additional savings provided by the DHS were marginal, due to the fact that DHS dimmed only the general lighting, consisting of already highly efficient LED. Halogen spotlights, indeed, were never dimmed, due to exhibition purposes. In addition, a DHS sensor was taped by the staff, due to the fact that, by changing products collection, the reflectances were changing and the system overdimmed the luminaires. This is a pretty known issue with DHSs and periodic calibration should be planned.

	LENI DHS	LENI No DHS	Savings
	kWh/m^2	kWh/m^2	kWh/m^2
Living room Dpt.	40.3	41.4	**1.1**
Home decoration Dpt.	84.0	84.7	**0.7**

Table 1. LENI for the monitored departments. Benchmark 78.1 kWh/m^2.

Photometry

The exhibitions are provided with a suggested walking

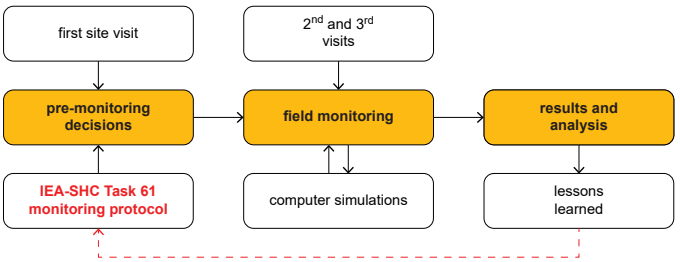

Figure 3. Workflow for the monitoring at IKEA Kaarst

path for visitors, which invites customers through all the stock. Therefore, photometric measurements for the two departments were done following two criteria: grid-based, as recommended by lighting standards, and path-based, that is following the suggested visitors path. The latter is meant to be more meaningful to evaluate the shopping experience of customers.

The 'home decoration' (HD) department was highly illuminated by both daylight and electric lighting. With daylight, the cylindrical illuminance was over 1000 lx in some points (Fig. 4). In the 'living room' (LR) department, values were lower, but more spread, with peaks over 500 lx close to the side windows. Similary, the mean and median DF for HD were 1.2 and 0.6 respectively, and 0.5 and 0.2 for the LR. The Daylight Autonomy (DA) at 300 lx with real monitored schedule was 62% and 72% respectively for the LR and HD departments. The average horizontal illuminance at head heigth was 627 lx during daytime and 600 lux at night-time for the LR, while, for the HD, it was 1456 lx and 1011 lx. Overillumination for the HD case, and high con-

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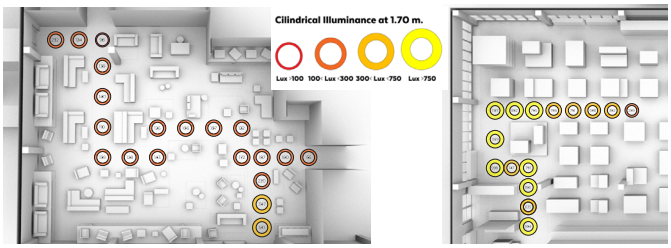

Figure 4. Cylindrical illuminance along the walking path at the Living Room (left) and Home Decoration (right) departments.

trast for the LR, suggest a potential risk for glare. Despite the extensive HDR imaging campaign during monitoring, there was no occasion with clear sky and sun in the field of view; the HDR were then used to calibrate a computer simulations. Once the model was calibrated, DGP analysis were run for time at glare risk. Not surprisingly, intolerable glare was occurring in many occasions; Figure 5 shows the example of February, 15th for the two departments at different time of the day.

But it is here that things get interesting. In the comments provided by customers and employees, glare from daylight was never mentioned as a problem. Instead, three customers complained about glare from spotlights. Arguably, penetration of sunlight, even at glaring levels, does not represent an issue in a retail store. Shopping for forniture is not a task which requires high visual focus, and actually direct sunlight resembles a common home situation. DGP has been created and validate for office tasks, afterall, and its use should be limited to these contexts. At a broader level, the discrepancy between measured DGP and actual users responses show the importance of combining technical and observed-based assessements when evaluating lighting projects.

Similar considerations apply to the view out. The floor area that had access to a quality view out, namely the area which had a vertical or an horizontal viewing angle to

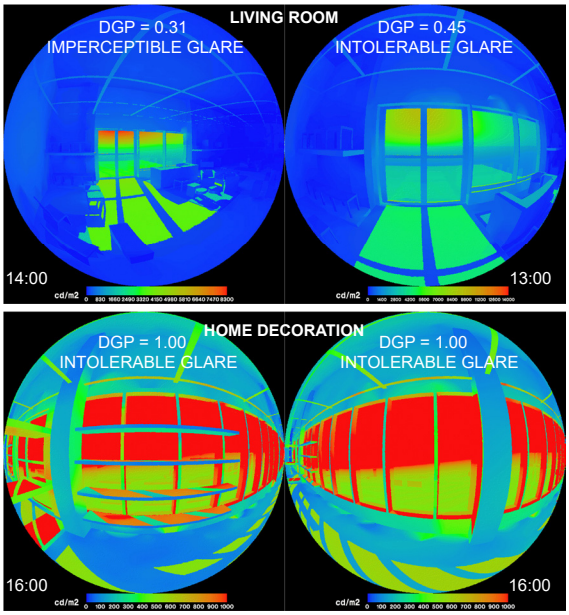

Figure 5. Calibrated simulation for DGP analysis in the LR (top) and HD (bottom) for February, 15th.

the outdoor equal or greater of 20 degrees, was 39% and 95% for the LR and HD department respectively. Namely, a pretty good access to the view out in both departments. But interviews showed that customers were a bit unhappy with the layers seen on the outside; one claimed that "*the view of the parking is not so great*", while another suggested that "*the most beautiful view is obstructed*". This is a good reminder that planning for a view is not only matter of guaranteeing visual connection to the outside, but also that aesthetic values of the view should always be considered.

Circadian potential

Daylight reaches the walking path, providing illumination and shaping the interior exhibition. But can it also provide a circadian stimuli? Certainly, short-term occupants like customers, can hardly benefit from high circadian potential, but it should not be forgotten that there is a permanent staff working in this shop. While office spaces are interested by a growing attention on circadian questions, there is a whole bunch of other workers which are daily exposed mainly to artificially lit environments. Therefore, the circadian potential of the space at IKEA Kaarst was evaluated by taking spot measurements of spectral power distribution (SPD) along the walking path in the LR and HM departments. The spot measurements were taken at eye level (1.7 m) and in four view directions per point. All the measurements were taken on the afternoon of March, 2nd 2019, with partly cloudy sky. The SPDs were imported to the so-called Lucas' toolbox using a 5 nm resolutions, and the Equivalent Melanopic Lux were calculated. A more intuitive representation of results is provided in Figure 6, where the ratio between melanopic and photopic illuminance (M/P) is reported. Ratios higher than 0.9 indicate a higher component of short wavelengths, namely blue-enriched, which may prompt alertness. For example, the WELL standard adopts a fixed M/P = 1.1 for daylight as illuminant. Figure 6 shows that even minor contributions of daylight are able to raise alertness all over the walking path. For the staff, it means they benefit from the sun as time-giver in large sections of LR and most of HM. Definitely not a secondary finding.

In HD, provided with HCL, the M/P ratio is generally very high, even at a distance from the windows. It is difficult to quantify if the effect is due to daylight only, or if the HCL system plays a major role too.

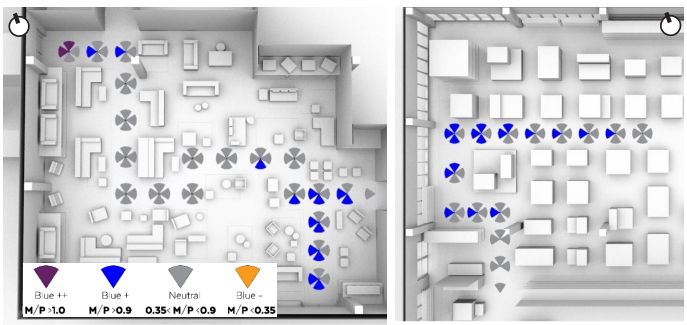

Figure 6. M/P ratio along the path for the Living Room (left) and Home Decoration (right) departments.

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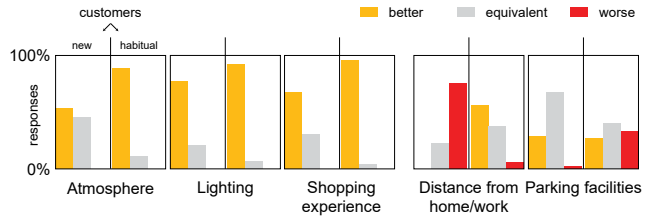

Figure 7. Evaluation from IKEA customers, either new or habitual to the shop in Kaarst.

User perspective

Customers could participate to an online survey by using a QR code hanged at some walls of walls of the LR and HD department. Workers who voluteered were interviewed. Ninety customers and twelve workers participated to the survey. None of the customers was new to IKEA, however some were habitual customers of this particular shop in Kaarst, while for other wast the first visit. Figure 7 is self-explanatory. The shop is not the most conveniently located for customers, and it does not provide more facilities or better parking. However, the great majority of customers thinks that the overall atmosphere and shopping experience is better than in other traditional IKEA shops. Most important, there is almost unanimity in judging the lighting better in this shop. Many customers took also the time to add some personal reflections on daylighting in the survey, like "*it is nice that the sun is coming in*". While nobody complained about glare from windows, one customer protested that "*The interesting products are not in the daylight*". Glare or direct sun can be sometimes a problem from the staff; for example, an employee at HD reported that "*is difficult to protect the plants and other items during sunny days*". However, this are minor issues in a bunch of positive comments, spacing from "*a lot of natural sunlight, one can see weather changes, natural light improves my mood*" to "*Light makes customers happy. They don't feel so locked up*". The staff showed appreciation for the HCL lighting too, claiming that was nice to see how electric lighting could follow the daily changes in natural light. Some of the staff complaints were actually about not having enough access to daylight: "[I don't like that there is] *no natural light in the neighbor department which also belongs to my workspace*". The interviewed staff have been working in another IKEA shops before and they described their current working environments in these terms: "*Today, my workplace it's much more pleasant*", "*I'm happier now*" and "*One is more positive and feels less like at work*".

"It is nice that the sun is coming in"

Lessons learned

Well-designed lighting means good presentation of products and, eventually, more sales. Lighting design in the retail sector focused on electric lighting, most probably for more than a good reason. But there are niches were daylight integration can actually improve the presentation of products; forniture shops are one of those. This case study demonstrates that integrated lighting schemes provide a number of assets beyond energy saving.

"The interesting products are not in the daylight"

Customers felt like at home in the new IKEA Kaarst shop and the employees where more satisfied of their working place. In a sense, integrated lighting may even built loyality to the brand.

In the context of this retails shop, we found that common daylight performance metrics are not always appropriate to describe the space. For example, DGP, which has been developed for office tasks, obviously could not describe the manifold feelings linked to glare in a shop context. This calls for a deeper understanding of integrated design, with more specific recommendations based on space usage and typology of users and activities.

Figure 8. Customers bringing products to daylight, a scene which was repeteadly witnessed during the monitoring.

Further information

Campama Pizarro, R. and Gentile, N. (2020). *A case study addressing the benefits of integrated solutions for daylighting and electric lighting in the retail sector*. Proceedings of the ISES Solar World Congress 2019, pp. 1825-1836, Santiago, Chile https://doi.org/10.18086/swc.2019.38.02

Campama Pizarro, R. (2019). *Daylighting and electric lighting integration in the retail sector: case study of IKEA Kaarst store*. Master thesis in Energy-efficient and Environmental Buildings, Faculty of Engineering, Lund University, Sweden.

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