# Aalborg University Copenhagen

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Aalborg University Copenhagen
Frederikskaj 12,
2450 København S, Denmark

Semester Coordinator: Giorgios Triantafyllidis

Secretary: Lisbeth Nykjær

**Supervisor(s):**

Jakob Markvaart

**Project group no.:** N/A

**Members:**

Alexandru Daniel Vlas

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**Abstract:**

This Master Thesis is attempting to improve the working conditions in offices by altering the light. The space which was investigated is a multi-occupant office from the headquarters of HeSaLight A/S, in Roskilde, Denmark. The following research question has been set at the beginning of the project:"How can I improve the working conditions at HeSaLight's Sales Office?"

In order to answer this question, the space was analysed to identify possible problems with the existing light installation. Night measurements showed that the average illuminance on people's desks was 50 lx, which is significantly lower than the recommended illuminance values for offices. Following these results, users were asked to participate in an interview and answer questions about their workspace. The majority was satisfied with the lighting conditions during the day, but they also confirmed the inappropriate light level during the night.

The proposed lighting solution is based on the existing space analysis and the users input. It is composed from three layers of light: general, task and accent lighting, with daylight as the primary light source. Electric lighting is used only in the areas which natural light is not sufficient, as the daylight factor calculation revealed. The task illuminance is increased to in accordance with the office light recommendations and the system is dynamic, creating a stronger connection with the outdoor environment.The proposed solution also facilitates the space to be used as a lighting showroom for the company's light fixtures.

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# 1. Acknowledgements

I would like to thank everybody from HeSaLight A/S for their support on this project. I would also like to thank Peter Gade and Martin Nielsen for their assistance as the company's representatives. Furthermore, I would like to thank Daniel Petersen and Peter Rietz, for engaging in conversations about office lighting which influenced the proposed solution.

I would like to thank each person who participated in the research interview. This project would have not been possible to complete without their valuable contribution.

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Finally, I would like to express my deepest gratitude to Enrique Guerrero, the friend and co-worker who inspired me to create this project.

# 2. Introduction

In recent years, an increased awareness of the advantages of using daylight in buildings, has turned daylight into an important factor when designing and creating sustainable architecture. In order to optimize daylight, there often seems to be a discrepancy between energy and health related factors. Moreover, people's relationship with sunlight is in many ways complex. The sun is essential for our existence on earth and sunlight is important for general well-being. However, people's fear for sunrays makes them protect themselves and according to Gunnarsen and Afshari (2009), the Danish population spent approximately 90% of the time indoor.

Health-wise, the morning sunlight is not the same as the evening sunlight and there is a mass of evidence suggesting that instead of maximizing the exposure of daylight it is about balancing light and darkness during the day and the night (Volf, 2013, p.93). Full glass houses could be built and we would all benefit from the natural light, but we would lack privacy and it will have a serious impact on our energy consumption.

Offices used to be designed as single-user spaces. Nowadays, with the advancing technology at our disposal, office areas have been changed and there is a possibility to have flexible arrangement of furniture and lighting, powerful wireless telecommunication devices - all designed to make people more productive and efficient, by working in a multi-user spaces. It's a great advantage to work in an open office together with other colleagues, because you can share information and every team member can be involved in the process, from the idea generation until the final submission.

More sustainable lighting designs have been implemented and there's been a shift towards teamwork and better quality of end products. However, there is little concern about how people are affected by light during a normal working day. We have a 24-hour availability of almost everything and that is vital for hospitals or transportation system, but there are some health consequences to this "society that never sleeps".

This thesis is a reflection on how light is affecting people working in an existing office, in Roskilde, Denmark. The aim is to provide a better lighting solution, seen from a health point of view.

## 2.1. Initial Problem Statement

Lighting designers have to be more concerned about the wellbeing aspect of their concepts, apart from the aesthetic and functional roles. When we approach the topic of light in office areas, it is important to ask "*how can a lighting designer improve the working conditions in an office, by altering the light?"* There are various lighting schemes and ideas that might solve this initial problem statement, but the important thing is to have people in the very center of the design, because they are the ones directly affected by light.

## 2.2. Idea Generation and Research Question

Office areas have become our second home and the more time we spend inside, the more we are affected by that type of environment. At HeSaLight A/S (HeSaLight - About Us, 2016), there is a constant activity from the headquarters in Roskilde, Denmark, to create lighting solutions for both indoor and outdoor spaces.

Being part of the lighting design team at the company, gave me the opportunity to work in the office and analyze the working environment. The most alert and busy people are in the Sales Department and their activity is almost 24/7, because time zone in Asia or South America is different than in Denmark.

The headquarters of HeSaLight are also used as a showroom for potential clients and thus office lighting becomes an important factor in the negotiation process. In general, people are not concerned about lighting and their focus is moved towards having a good social relation with the potential customers. But in this particular case, their attention also needs to be directed towards lighting products and how they function in an existing space, because images are more powerful than words, especially when one refers to light.

The sales office has pendant lamps with LED bulbs installed (see fig.1), to be used both for general and task lighting. As the company is evolving and creating smart designs, this lighting setup is not representing the company in a proper manner. Therefore it is time to create a new lighting solution, which is more suitable for the active environment and in accordance with the company's fast-growing pace.

Fig. 1 The existing office space from HeSaLight with pendant lamps

In order to solve this challenge, the research question was set:

*“How can I create a lighting solution that will improve the working conditions at HeSaLight’s Sales Office?”*

The following research and investigation is focused on this particular space, with the aim of creating a lighting solution that is improved from the existing situation and will also serve as showroom for potential clients in the future.

## 2.3. Sustainable lighting

Sustainable lighting is a design feature that takes into consideration the way light affects the environment on long term. It involves the process of creating energy-efficient lighting solutions, with a low impact on the environment, low maintenance and which are easy to operate.

Claude Mandil, the executive director of International Energy Agency (IEA - About Us, 2016) was trying to send a clear message out in the world - it is time for a change and the world has to shift from old incandescent light sources towards energy-efficient light sources such as the compact

fluorescent lamps (Light's Labour's Lost - Policies for Energy-efficient Lighting, 2006). There is an obvious need to innovate and become smarter through technology, which ultimately will improve the quality of life. However, the innovative compact fluorescent light was rapidly surpassed by the LED light sources, both in efficacy and quality of the light. As Claude Mandil was referring to the CFL light sources as the "*energy-saving light*" in 2006, so are the lighting designers today considering LEDs a superior energy-saving solution. Lighting history is showing that innovation is a constant ongoing process, which has been accelerated in recent decades by the numerous technological discoveries. Therefore, it is important to mention that although the LED technology is considered the best available option on the market at the moment, from an energy saving point of view, this might change in the near future.

The new technology that could be easily available in the near future is an organic light-emitting diode (OLED), which is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current (OLED, 2016). There are numerous companies and governments supporting this new low-cost, energy-efficient lighting alternative (Cynora - Project LEO, n.d.).

## 2.4. Office Lighting

The most widely used criterion to create good lighting in an office has been the average illuminance on a horizontal plane at desk height. It is commonly known as the work-plane. This was a reasonable approach because all the important details were situated on the tables, as most offices were using paper and the overall aspect of the space was acceptable (Jay, 1968). Since the introduction of computers and laptops, to speed up the working process, the criteria has changed. It is important to control the luminous distribution of the luminaires and the incoming daylight through windows, in order to avoid reflected images on the monitors. The screen technology has developed to a high degree of visibility of details and it is rarely influenced by the lighting in the room. In one study performed in a windowless office (Veitch and Newsham, 2000), the prefered illuminance level of the subjects was around 450 lx on their desks and in another study (Boyce et al., 2006) it was around 350 lx.

The next step in developing a sustainable lighting installation is to establish which light source will be primarily used to lit an office. The natural choice must be daylight, because the natural light has far better properties when

compared to electric light. It also provides a view-out, which is prefered by the large majority of office users and also a strong connection with the outdoor environment.

Next, the control systems have to be analyzed. Daylight is usually controlled by window blinds, which can be adjusted to block the direct light coming from outside, but from a lighting point of view, it is not just a simple open-shut operation. A study (Maniccia et al., 1999) done in private offices from the United States found that people adjusted the angle of their vertical blinds to occlude the sun and allow daylight to enter, while preserving a view-out. While performing this adjustments, the window performance was optimized according to the subject's needs.

Electric lighting controls can be used to switch or dim the light sources. It can also be automatic, based on the necessities of the space, or depending on the occupant's action. The effectiveness of these systems varies, depending on the space, accessibility and the satisfactory level of the occupants. There are three commonly used automatic lighting controls: time switches, dimming photosensors and occupancy sensors. Time switches are the most simple technology to install and use. Their function is to switch the light at various pre-programmed times. The most commonly known positions are on and off, but there are possibilities to have intermediate states. It is a useful technology that saves energy when a time schedule is developed, anticipating the hours where electric light is not needed. Dimming photosensors, also known as daylight harvesting sensors, are composed from a photosensor, a control algorithm and a dimming ballast, that dims the electric lighting when the amount of daylight increases. This type of system, according to studies done by Lynes and Littlefair (1990) and Rubinstein et al. (1999), can provide significant reductions in energy consumption.

The most frequently used electric lighting control is the switch-by-the door. The concept behind it is to switch on the light only when somebody is present and daylight is not available. However, for many activities, this ideal principle is not applied. A study performed by Crisp (1978) reported a series of patterns for light switching in multi-occupant offices in the United Kingdom. He found out that light was switched on only at the beginning and the end of the working day and that it was rarely switched during the day. This shows that in a multi-occupied office, no one is willing to take the responsibility to switch off the lighting while there are other people present in the space. There is a social inhibition against switching the electric lighting because it affects everybody and has the potential for aggravation. The same study reveals one factor is definitely affecting the switching patterns - the ease of understanding

the relation between light fixtures and switches. If there is no clear relation between them, the probability of switching is low.

One way to encourage switching in a multi-occupied space is to convert public lighting to personal lighting by giving each luminaire its own switch. Boyce (1980) noted some observations from a lighting installation that was fitted with pull-cord switches for each luminaire. They were rarely used, partially because the pull-cords were not easily accessible to some users and partially because the luminaires were not often located directly above the user's desk. These type of switches, together with modern infrared or wireless remote controls, are most likely to be used when the luminaire is positioned directly above the desk and thus can be considered personal lighting.

Although switches are still widely used for controlling office lighting, dimming and wireless technology have introduced the possibility for individuals to control the lighting in their working areas. According to Boyce et al. (2000), people tend to use these systems rationally, by choosing lower illuminance when working at a computer than doing the same task on paper. Furthermore, subjects who are given individual control choose a wide variety range of illuminances and many of them prefer a lower illuminance that the commonly recommended values for offices - 500 lx (*DS/EN 12464-1:2011*, 2015). Finally, some subjects used the dimming control more frequently than others, showing a great variety of preferences. Even though this study, correlated with another study from Boyce et al. (2006), are revealing some important facts about preference for lighting controls amongst people, it was performed for subjects working in an office for a short period of time (1 day). A longer field study was performed by Maniccia et al. (1999) and there was a difference in frequency with which the dimming control was used. In the shorter studies, the participants used the control systems for 8-10 times a day, while in the longer field study, the participants made an average of one dimming adjustment every four days. Even though people have an irregular behaviour towards control systems, it is important to recognize that they value having some individual control.

## 2.5. Daylight

Daylight has become an important aspect when designing with light. It is sunlight that sustains our life on this planet and even though we have the technology to create electric light that can maintain a 24-hour society, we can still use this light source to minimize the energy consumption, at the very least. The chapter contains an introduction about daylight and its relation with

people, based on the existing research. It also contains a short summary about daylight integration in buildings, based on EU recommendations and finally it presents the most commonly used daylight delivery systems.

### 2.5.1. Introduction to Daylight

Daylight has been the primary light source since the beginning of civilization. Without the Sun, life on our planet would not be possible because plant-photosynthesis is a light-dependent process releasing oxygen. The light emitted by the Sun surrounds us everywhere we look, during the day. Each object reflects light to some degree, which enables people to perceive its shape, color, shadow, roughness, etc. There are various electric lights that can simulate the daylight spectrum, but none of them can replicate the variation which appears at different times during a day, depending on the seasons and weather conditions. One important aspect that separates daylight from electric light is the greater amount of illuminance provided on both horizontal vertical surfaces. These high illuminance values are associated by occupants with increased preference and reduced sense of gloom (Shepherd et al., 1992). However, there is no guarantee that daylight will maximize the visual performance, due to glare and distractions and people will act to reduce the amount of daylight if it causes discomfort. Figure 2 shows that a person's productivity is influenced by both individual and system factors, created from the analytic hierarchy process developed by Saaty (1972).

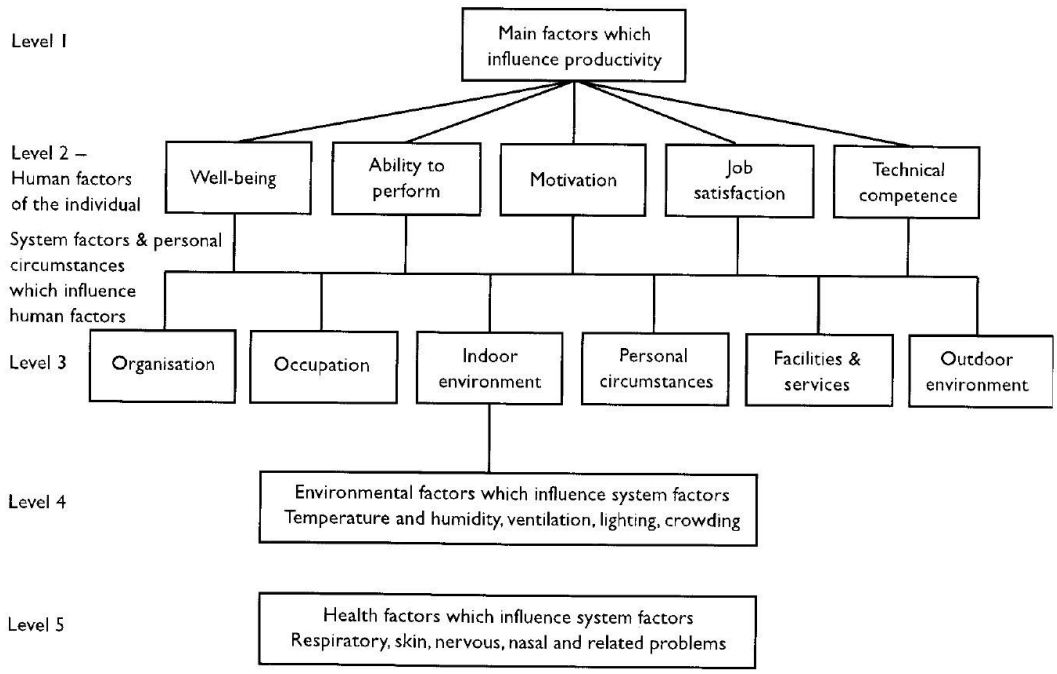



Fig.2 A schematic of factors that influence productivity at work, from Boyce et al.(2003), created from the analytic process developed by Saaty (1972)

Different electric lighting installations can change the mood of the people working in the space, at least for a short period of time (Baron et al. 1992). Studies from Markus (1965); Wells (1967); Heerwagen and Heerwagen (1986); Veitch et al. (1993) and Cuttle (2002) have shown that people prefer daylight over electric light as their primary source of lighting. An example of these findings is displayed in Table 1, created from Heerwagen and Heerwagen (1986) study, which shows the percentages of occupants from an office deciding whether daylight or electric light is better, in seven different cases.

Table 1. Percentage of occupants preferring daylight or electric light for different factor, from Heerwagen and Heerwagen (1986)

| Case | Daylight better | Electric lighting better | No difference | No opinion |
|---|---|---|---|---|
| For psychological comfort | 88 | 3 | 3 | 6 |
| For office appearance and pleasantness | 79 | 0 | 18 | 3 |
| For general health | 73 | 3 | 15 | 8 |
| For visual health | 73 | 9 | 9 | 9 |
| For color appearance of people and furnishings | 70 | 9 | 9 | 12 |
| For work performance | 49 | 21 | 27 | 3 |
| For jobs requiring fine observation | 46 | 30 | 18 | 6 |

This preference trend for daylight as the primary lighting source is complemented by studies from Collins (1975) and Ludlow (1976), which showed that people prefer to sit by the windows.

The observations above suggest that one reason why daylight is prefered is that it can meet the requirements for both task illumination and ambient lighting for the space, while also offering a view-out. Furthermore it creates a strong connection with the outdoor, in terms daytime and weather conditions. By comparison, electric lighting installations, can solve the task illumination requirements but often do little for the atmosphere in the space and rarely provide any variation over time, minimizing the link between indoor and outdoor.

### 2.5.2. Recommendations for Daylight Integration in Buildings

There are two main guidelines for daylight integration in buildings. One is based on the German DIN 5034 standard collection and the other one is created by the European Committee for Standardization - CEN/TC 169/WG 11, which is due to be adopted at the end of 2017 (CEN/TC 169/WG 11, 2016).

The EU Daylight Standard that is due to be adopted specifies that in order to determine whether or not there is sufficient daylight to provide adequate lighting conditions inside a room depends on the size and type of the windows, the shading of windows by surrounding buildings and trees, the depth of the room and its usage (required luminosity, daytime and/or nighttime use). Either generated by artificial light or daylight, the luminosity of a room is described by the illuminance of the individual surfaces (room surfaces and work surfaces). The illuminance E (lx) is the total quantity of light falling from all directions on a unit area of surface. It is the quotient of luminous flux incident on a surface ($lm/m^2$ = lx). In order to provide comparable data on the quality of daylight conditions in an interior space, the calculations are based on the assumption of an overcast sky. On a horizontal surface outdoors, this light source generates an illuminance of 10,000 lx. The quantity of light that can actually be made use of in the room is expressed by the daylight factor D (%). A daylight factor of 5 % suggests, for example, that an illuminance of 500 lx is provided at a specific position in a room (usually a horizontal work surface at a height of 0.80 m). Alongside the size and position of window openings, the light transmission τ of the glazing and the reflective capacity of the room-enclosing surfaces are also important for the lighting conditions of a room. The CEN/TC 169/WG 11 standard also provides minimum recommendations for achieving an adequate indoor lighting and an adequate view-out, by using natural light. It also specifies recommendations for the duration of sunshine exposure within habitable and occupied rooms. Furthermore, it gives information on how to limit glare and provides methods of calculation and verification of daylighting conditions.

Annex A (Minimum recommendations) from the standard provides information about the minimum requirements for daylight in a room. Furthermore, recommendations for medium and high daylighting of a space are also established. These indications, detailed in Table 2, are proposed for spaces which have facades and rooflights as daylight openings.

Table 2. Minimum recommendations of daylight provision by daylight opening from facade and rooflights, as well as higher levels of a well daylit space (CEN/TC 169/WG 11, 2016)

| Level of recommendation | Type of Daylight Opening | Illuminance | Daylight Factor |
|---|---|---|---|
| Minimum recommendations | From facade | 300 lx over 50% of space, 50% of daylight hours *and* 100 lx over 100% of space, 100% of daylight hours | $D_T > D_{300}$ over 50% of space *and* $D_{TM} > D_{100}$ over 100% of space |
| | From rooflight | 300 lx over 50% of space, 50% of daylight hours | $D_T > D_{300}$ over 100% of space |
| Recommendations for medium daylighting of a space | From facade | 500 lx over 50% of space, 50% of daylight hours *and* 300 lx over 100% of space, 100% of daylight hours | $D > D_{500}$ over 50% of space *and* $D > D_{300}$ over 100% of space |
| | From rooflight | 500 lx over 50% of space, 50% of daylight hours | $D > D_{500}$ over 100% of space |
| Recommendations for high daylighting of a space | From facade | 750 lx over 50% of space, 50% of daylight hours *and* 500 lx over 100% of space, 100% of daylight hours | $D > D_{750}$ over 50% of space *and* $D > D_{500}$ over 100% of space |
| | From rooflight | 750 lx over 50% of space, 50% of daylight hours | $D > D_{750}$ over 100% of space |

In the table above, the following abbreviations have been made:

- $D_T$ is the target daylight factor relative to a given illumination to be exceeded for more than half of daylight hours, over 50% of the space for windows, or 100% of the space for rooflights
- $D_{TM}$ is the minimum target daylight factor relative to a given illuminance to be exceeded for more than half of daylight hours, over 100% of the space for a window
- $D_{300}$ is the value of daylight factor at a place where 300 lx is exceeded for more than half of the daylight hours
- $D_{100}$ is the value of daylight factor at a place where 100 lx is exceeded for more than half of the daylight hours

The standards also states that in order to meet the recommendations above, it is possible to compute the daylight factors. The daylight factor is the ratio of

the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, excluding the contribution of direct sunlight to both illuminances (CEN/TC 169/WG 11, 2016). For example, in Copenhagen, Denmark, the minimum values of daylight factor (D) for windows and rooflights to exceed 100 lx, 300 lx, 500 lx and 750 lx during 50% of daylight hours are 0.7%, 2.1%, 3.5% and 5.3%. Furthermore, there is a recommendation for view window (daylight opening), which should have the minimum dimensions of 1m x 1.25m (width x height). Finally, a room should receive sunlight for a longer duration than 1.5 hours, during cloudy sky conditions, on March 21st.

This recommendation is useful for architects, engineers and lighting designers who are working together to design a new space which could use daylight as a primary light source. For existing spaces, these guidelines can be of use when investigating whether or not daylight can be considered as primary light source. It can also be used to determine the contribution of natural light in the space, which is important because it can reduce the power consumption of the electric light.

### 2.5.3. Daylight Delivery Systems

Daylight can be delivered in a space through windows, skylights or other distribution systems, such as light shafts, ducts and pipes. The most common daylight delivery system is through windows. The advantage of windows is that it offers daylight in the space and a view-out, but the amount of daylight decreases drastically as the distance from the window increases. Skylights are able to deliver daylight to an entire space, but the view-out is again limited to the sky. Furthermore, skylights provide effective daylight immediately beneath them, which could be enough for a single-storey office, but for multiple storeys, an additional system is necessary.

Louvres and blinds

Fixed horizontal louvers and external Venetian blinds can provide a precise control for directing daylight in a space. It is possible to give these devices two functions, daylight guidance and sun protection, by adding special coatings and shaping the elements accordingly. Venetian blinds, of which the top third can be controlled separately, are able to direct natural light into the interior and provide shading for the lower area, simultaneously (Figure 2)

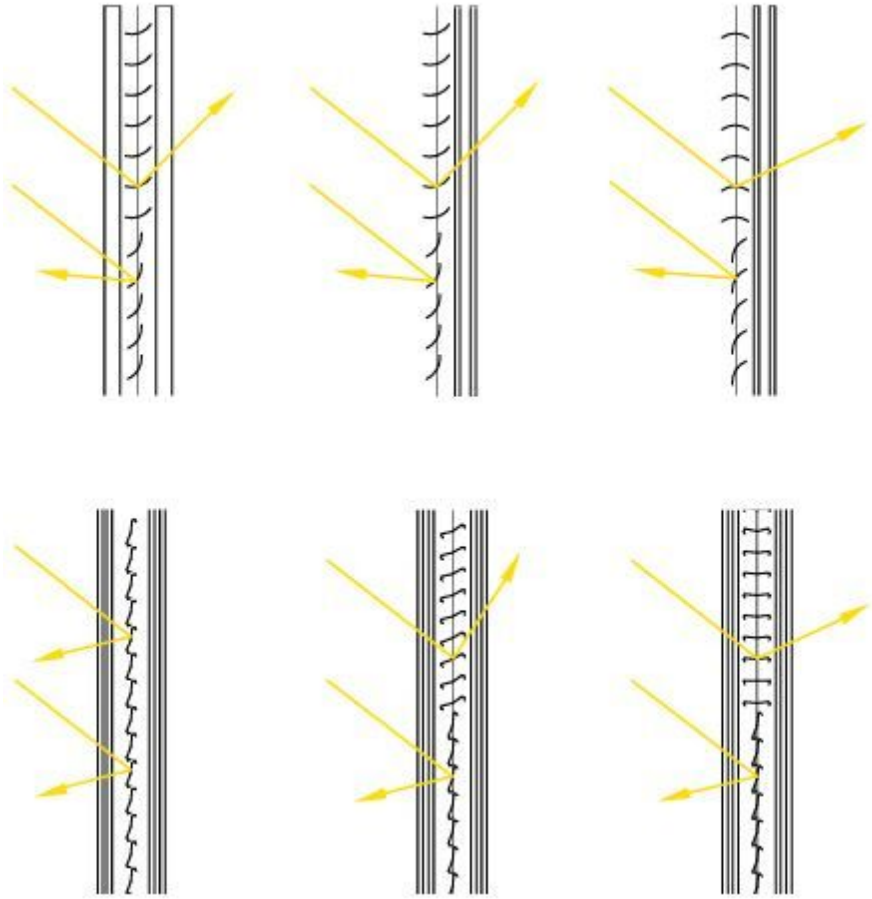


Fig.2 Venetian blinds with separate control for the top third (figure taken from Richarz and Schulz, 2013, p.80)

## Light-directing glass

The cavity between the panes of double or triple glazing windows can be used to insert optical elements or blades which are designed to reflect or spread the light (see Figure 3). These solutions allow diffuse light to enter the space, whereas direct sunlight is directed either inwards or outwards.

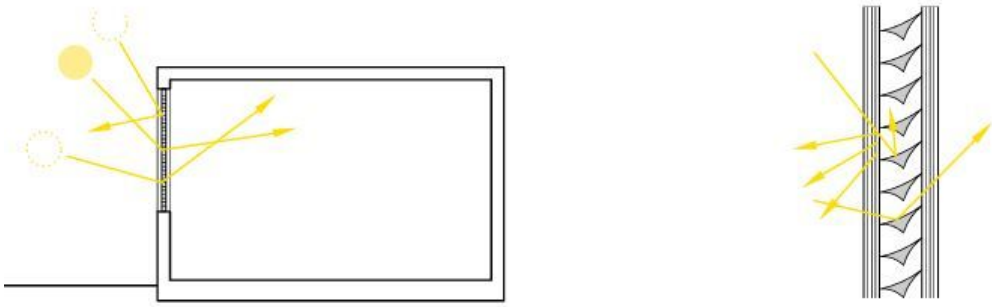


Fig.3 Acrylic sheet with a prismatic patterned surface figure taken (from Richarz and Schulz, 2013, p.80)

## Skylights

Skylights can reduce the power consumption significantly, if they are well distributed in a space. However, depending on their orientation, it can also increase the heat load and therefore all the energy savings achieved through lighting is used for cooling. A typical skylight and its components are illustrated in Figure 4.

The amount of light that can be provided through skylights depends directly on how much daylight is available outside, which varies with weather conditions, the time of day and the season of the year. The greatest amount of daylight is available on bright sunny days. On very dark, rainy days less daylight is provided and the power consumption will increase, because electric light is required in the space.

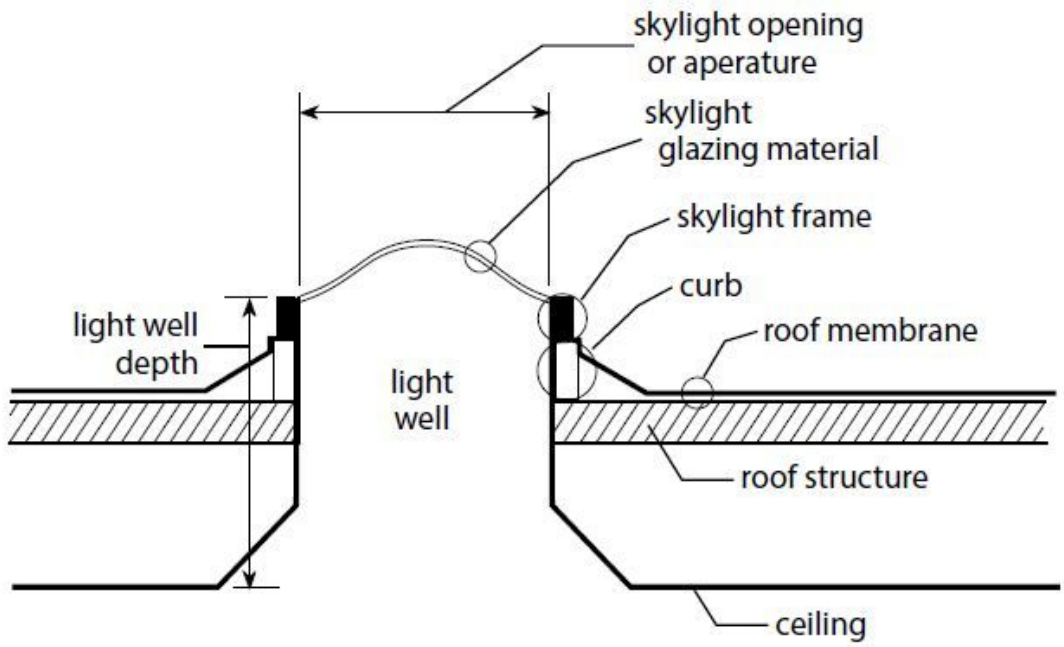



Fig.4 Typical skylight with its components (figure taken from Skylighting Design Guides, 2014, p.9)

The shape of a skylight also affects the quantity of sunlight entering in a building's interior at different times of the day. For example, a flat glazed skylight on a flat roof will receive very little sunlight when the sun is low in the early morning and at the end of the day. However, a skylight with angled sides, whether a bubble, pyramid, or other raised shape, will receive more sunlight at these low angles (see Figure 5).

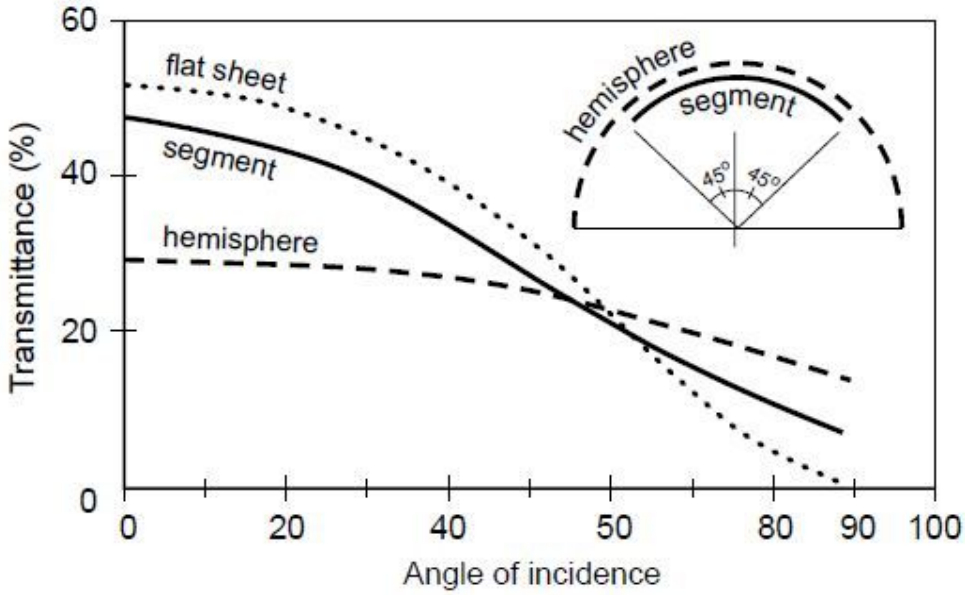



Fig.5 The difference in transmission of solar energy for a 50% translucent glazing material as a function of the angle of incidence for three different shapes—a flat skylight, a hemispherical skylight, and a segment of a sphere (which most closely models the typical bubble skylight); (figure taken from Skylighting Design Guides, 2014, p. 13)

The figure above shows that for very low sun angles (60º - 90º angle of incidence), the rounded shapes will collect noticeably more light. Furthermore, it reveals that they also admit less light at midday.

The size, shape and number of skylights on a roof are among the most basic decisions affecting performance of a skylighting system. Skylights have different shapes and sizes, depending on the space. The most commonly used types are displayed in Figure 6.

The challenge for the designer is to integrate the form and light admitting properties of the skylight with the design concept for the building. Before choosing the final solution, there is usually a debate between large skylights far apart versus smaller skylights spaced closely together. Large, widely spaced skylights are usually the most economical to install, but may produce bright conditions under the skylights, and relatively dark conditions in between. This results in uneven light distribution, reduced energy savings, and possible glare problems. Small closely spaced skylights, on the other hand, will provide more uniform lighting conditions and greater energy savings, but are more expensive.

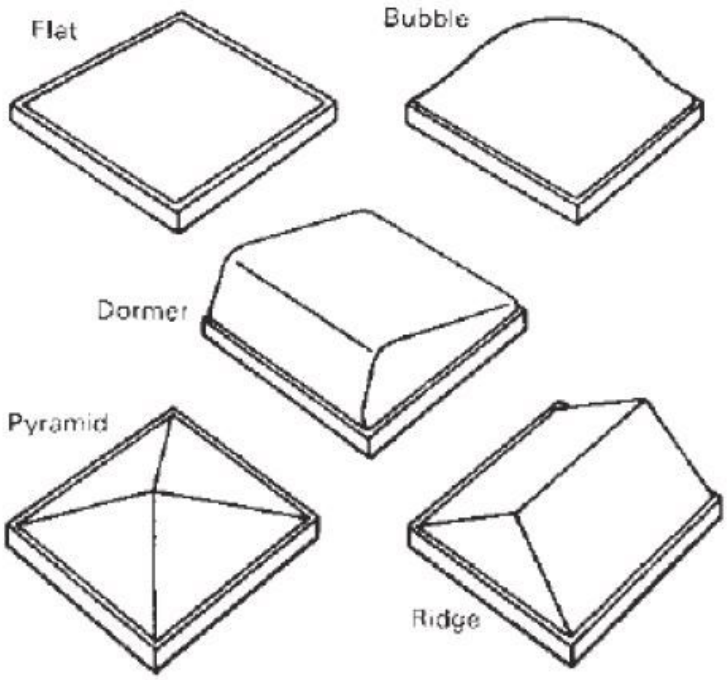



Fig.6 Various types of skylights (figure taken from Skylighting Design Guides, 2014, p. 14)

The general rule-of-thumb is to space skylights at 1.0 to 1.5 times ceiling height (center-to-center in both directions) as displayed in Figure 7. This assumes a highly diffusing glazing and a small depth for light wells (Skylighting Design Guides, 2014). Their placement must be coordinated with the structural, mechanical and lighting systems, for a balanced design.

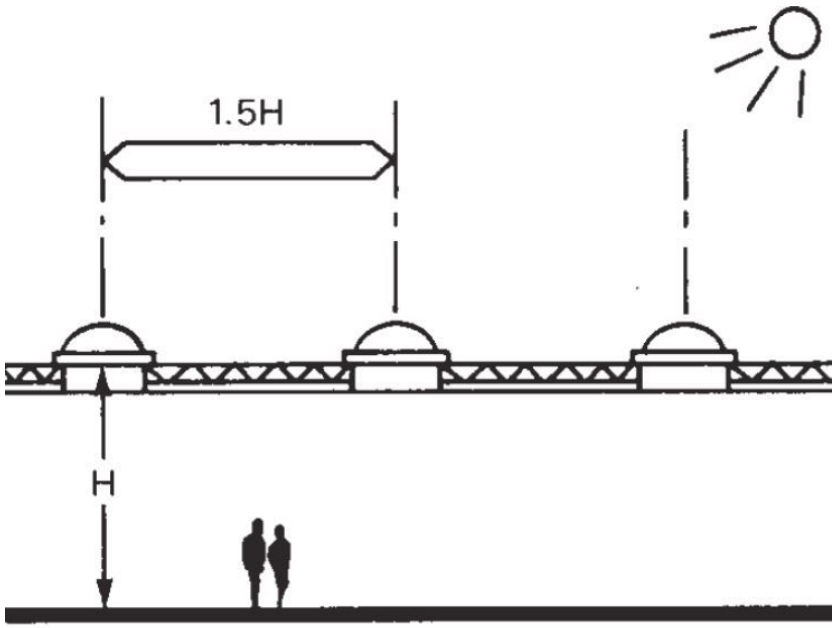



Fig.7 Skylight spacing according to the rule-of-thumb (figure taken from Skylighting Design Guides, 2014, p. 14)

According to Skylighting Design Guides (2014), the higher the visible transmittance of the material, the more efficiently the skylight can provide light in the room below. Diffusion of sunlight is the key to avoid spots where sunlight is more concentrated, which can create areas that are both too bright and less comfortable due to the radiant heat of the sun. Highly diffused skylights are useful to achieve uniform illumination, allowing the overall lighting system to be more efficient.

## 2.6. Circadian Rhythm

This subchapter is introducing the circadian rhythm and its relation with light, based on research that has been done in this field. It also describes the effects of light on the human circadian rhythm and the consequences that will occur during well-timed and inappropriate light exposures.

### 2.6.1. What is the circadian rhythm?

The circadian rhythm is a biological process that displays an endogenous and entrainable oscillation of about 24 hours (Circadian rhythm, 2016). These processes are driven by an internal clock and they have been observed in plants, animals and other organisms. In other words, the circadian rhythm is a process that originates from within an organism (endogenous) and occurs when rhythmic physiological or behavioral events match their period and phase to that of an environmental oscillation (entrainable).

The circadian clock in the suprachiasmatic nuclei (SCN), situated in the brain, generates a rhythm that is near to 24 hours. The 24-hour light-dark cycle is the most important time signal and this light information is captured exclusively by the eyes. The SCN receives a direct projection from the eye and light detected via the retina. This is the primary time-giver (zeitgeber) that synchronizes the timing of sleep and other circadian rhythms (Lockley and Foster, 2012, p.20).

The circadian rhythm was first explored by Jean-Jacques d'Ortous de Mairan in 1729, on a plant. In 1866, William Ogle noted that the human body temperature was increasing in the early morning and decreasing during the evening, regarding of the environment. Finally, the concept of circadian timing system was promulgated by Bunning (1936). He suggested that circadian rhythms were driven by an endogenous clock that was entrained by an external signal such as the alternation of light and darkness. Furthermore, he also hypothesized that interruptions of the normal light-dark cycle would shift

the phase of the clock, meaning that exposure to bright light early in the night would lead to a phase delay, while late night exposure would lead to a phase advance.

Czeisler et. al (1981) demonstrated that when light was provided at high illuminances, the light-dark cycle was an important entrainment signal. There are many studies which proved that light exposure is a major exogenous (external) stimulus for humans (Boyce, 2014, p.93). Other studies have shown that other cues might impact the circadian rhythm, such as social signals (Aschoff et al., 1971), activity in the night (van Reeth et al., 1994) and also exercise (van Someren et al., 1997)

Over the last decades, numerous studies have been done to demonstrate and understand how light acts as a pacemaker for the human sleep-wake cycle. The main breakthrough is the discovery of a new photoreceptor called the intrinsically photosensitive retinal ganglion cell (ipRGC), in the human retina (Berson et al., 2002; Berson, 2003). Figure 8 illustrates the two main photoreceptors (rod and cones) and the new ipRGCs.

The new photoreceptor is not found at the same level of the retina as the rod and cone photoreceptors used by the visual system, because it is a special form of ganglion cell. The photopigment found in ipRGCs is melanopsin (Kumbalasiri and Provencio, 2005). When extracted, it was proven that melanopsin is mostly sensitive to short-wavelength light, with a maximum absorption at a wavelength of 480 nm (Berson, 2007). The ipRGCs have a slower response than rods and cone photoreceptors and because of their rarity and structure, the photon capture probability is lower, when compared to the other two photoreceptors (Do et al., 2009). This means that a bright illumination is required to produce a sustained response so that the ipRGCs can signal the retinal irradiance (Berson, 2003).

The ipRGCs are very sensitive to blue light and because of that, they shift the timing of the circadian clock and they have a major role in suppressing melatonin production, reducing sleepiness and improving reaction times (Lockley and Foster, 2012).

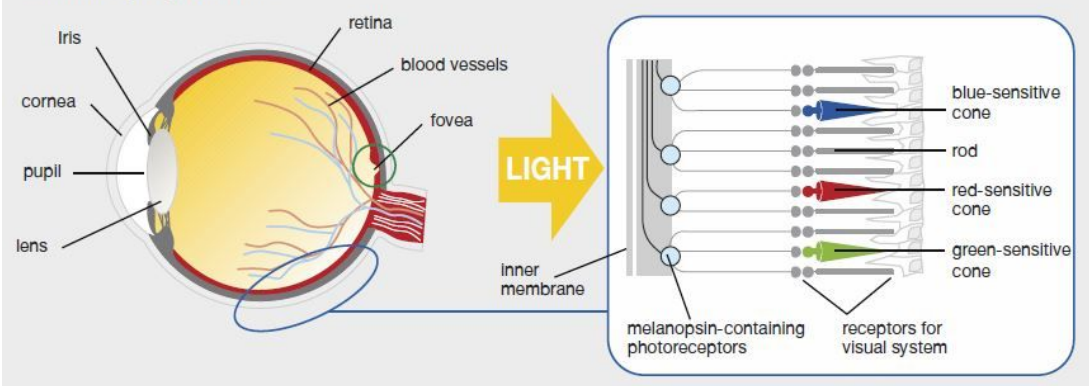



Fig.8 The three photoreceptors (rod, cone and ipRGC). The most sensitive ipRGCs are in the lower area of the retina. Figure taken from “Impact of Light on Human Beings” (n.d.)

Melatonin is a hormone released in high concentrations at night, therefore it is through melatonin secretion that our body knows when it is dark and its production can be inhibited by light, which could lead to sleeping disorders and insomnia. Melatonin is produced mainly by the pineal gland, although there are other regions of the body that may produce small amounts. (Boyce, 2014, p.95). Serotonin is a neurotransmitter which regulates mood, appetite, pleasure and memory. Scientists have made an association between serotonin and depression, but more research is needed to establish the exact relationship between them (Serotonin, 2016). There is a direct connection between melatonin and serotonin, because melatonin is derived from serotonin (Pineal Gland and Melatonin, 2003).

### 2.6.2. Light effects on the circadian rhythm

The circadian rhythm can be affected by relatively low light levels, if the exposure is over several hours. Therefore, bedside lamps and computer screen have an effect on the sleeping pattern and may cause sleep disorders. Circadian misalignment can appear when people are not exposed to a stable 24-hour light-dark cycle, for example in night shifts or after travel (jet-lag effect). Brain activity shows increased alertness, cognition, memory and mood during well timed light exposures. Inappropriately timed light exposure can therefore disrupt the level of alertness, performance and mood, alongside with sleep (Lockley and Foster, 2012). Wehr et al. (1995) reported that most people who live in an urban environment at temperate latitudes show no seasonal variation in the duration of melatonin secretion. This means that constant use of electric light after sunset or in the early morning is suppressing the melatonin secretion and therefore removes any season variation (Wehr, 2001).

Blue-light therapy in the morning has proven to be effective in the treatment of seasonal affective disorder (SAD), which is caused by seasonal changes in light-dark exposure (Lockley and Foster, 2012). Daylight exposure can generate vitamin D, which is good for people's health because it can prevent depression, osteoporosis, cancer and other conditions. (Vitamin D — Health Professional Fact Sheet, 2016).

# 3. Methods

This chapter describes the methods used to interview office users at HeSaLight. It describes how the existing space was analyzed and finally, it presents the 3D simulation method used for modelling the space and simulating the new lighting proposal.

## 3.1. Involving the target group

In every lighting design that aims to improve the working conditions for a specific group of people, it is essential to involve them in the process. This can be done by asking them to comment on the existing situation, in order to identify possible problems.

### 3.1.1. Interviews with office users

The hypothesis of this interview is that the current lighting does not satisfy the needs of the people who are using the space on a daily basis. The aim of the interview is to identify possible problems with the current light installation, after collecting and comparing the results.

The interview was performed with the people that work in the 1st floor office at HeSaLight, in a neutral space, preferably a conference room. Other places were used if the conference room was not available. This interview was performed with both open and specific questions and it was adapted according to each interviewee's answers, to get as much detailed information as possible. It also included follow-up questions, to ensure that the subjects are not giving contradicting answers.

The interview was limited by time, since it was performed during the normal working hours of the employees. It was set to approximately 10 minutes per person, with a possibility to extend the time limit.

### 3.1.2. Interview setup

Each person was be briefed about the topic of the interview - Research about light in their working space. After that, they were presented with the recording device (smartphone) and they were asked for permission to be recorded. Finally, it was stated, for each individual, that the recordings would be used for research purpose only and that their identity will be protected.

After the short brief, there was be a dialogue between interviewer and interviewee, in a casual language but with focus on the subject. During the interview, the aim was to build a dialogue that will lead to findings about the space.

The specific questions listed below are essential for the study and were asked in the interview:

Q1. *How would you describe HeSaLight as a company?*
*Q2. Is your desk positioned close to a window?*

- *If yes - then - Do you think the natural light has a positive impact on you?*
- *If no - then - Would you like to have a light setup that simulates the natural light?*

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*
Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*
Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

Question 1 is created in order to find out how would people describe the company. It is expected to find some similarities in their description which could be used in the proposed solution. The subjects will describe indirectly the company's brand.

Question 2 is focused on the office space where the subjects perform their usual tasks. The goal is to find out whether or not their desks are positioned close to a window, because it could have an impact on their work. It is related to the studies done by Wells (1965); Markus (1965); Heerwagen and Heerwagen (1986); Veitch et al. (1993) and Cuttle (2002) which have shown that people prefer daylight over electric light as their primary source of lighting. Furthermore, it is also related to the findings from Collins (1975) and Ludlow (1976), which showed that people prefer to sit by windows.

Subjects will be asked about the possibility to have a light setup that simulates the natural light, if their desks are not positioned closed to a window. This question will be used to determine if the lack of natural light is problematic.

Question 3 is introduced to give people the chance to evaluate the light level on their tables. It is related to the studies done by Veitch and Newsham (2000) and Boyce et al. (2006) where the prefered illuminance level of the subjects was 450 lx for the first study and 350 lx for the second one, meaning that the preferred illuminance values are different, depending on the subject's own opinion. It is expected to receive different evaluations, both appropriate and inappropriate.

Question 4 is created to discover whether or not people are aware about the effects of the electric light on themselves. It is related to the circadian rhythm and the studies performed by Bunning (1936) and Czeisler et. al (1981) which revealed that light was an important entrainment cue (signal). It is also interesting to discover how people associate the expression "warm or cold light" in an office. The question is also related to the studies done by Berson et al. (2002), Berson (2003) which discovered the new ipRGC photoreceptors in the human retina and the study done by Berson (2007) which has proven that melanopsin is mostly sensitive to blue light. It is expected that some subjects would consider the light spectrum as well as the visible light.

Question 5 was designed to give people the chance to express their opinion about a new light installation in the space. It is interesting to find out if they have any preference about the light distribution, products or control systems. It is again related to the studies that influenced Question 3, but also by the research done regarding lighting controls by Crisp (1978), Littlefair (1990), Rubinstein et al. (1999) and Maniccia et al. (1999).

Flexibility is important in an active working environment and for that reason, the people who are unable to participate to the interview have received a document with the five specific questions defined above and space for additional comments. The detailed description of the e-mail and the document can be found in Appendix 1. Detailed answers from the recorded interview can be found in Appendix 2.

## 3.2. Office Space Analysis

The existing office space was investigated to determine the current situation, from a lighting point of view. It is essential to discover whether or not the

space requires changes in the future, in order to improve the current working conditions.

Space dimensions

The dimensions of the office space (length, width, height) was be determined based on technical drawings. The original drawings of the space are provided by the company and can be found in Appendix 3.

Additional modifications to the office, which are not displayed on blueprints, were determined based on site measurements. All the measurements were performed using a Leica DISTO D5 (Leica DISTO D5, n.d.) digital laser tool.

Materials characteristics

The materials characteristics were investigated to determine the reflection factor. The measurements were be performed with a lux meter, following the procedure described below:

1. The sensor was be placed on the material to measure the incident flux and the value was recorded
2. The sensor was turned, facing the material in the same spot, to measure the reflected flux and the value was recorded
3. The following formula was be applied to calculate the reflection factor: $\rho = (E_r / E_i) \times 100$
4. The final values [in percentage %] were be added in a table, with corresponding pictures.

Note: $\rho$ - reflection factor; $E_r$ - reflected illuminance from the material [lx]; $E_i$ - incident illuminance hitting the material [lx]

The lux meter that was used is a RS-105 Light Meter (RS-105 Light Meter, n.d.) provided by the company.

Windows and Skylights

The windows and skylights were be examined by observation and based on technical drawings provided by the architecture firm who was commissioned to design the building. Its positions and dimensions (height, width and depth) were determined based on the technical drawings.

The transmittance factor for both type of openings was determined based on the manufacturer's specifications. If this option is was not available, the transmittance factor was be determined based on observations and recommendations from the EN 15193-1 standard (DS/EN 15193/AC:2010, 2010), Table C1a (for windows) and Table C3a, C3b (for skylights).

Light Fixtures

The existing light fixtures were analyzed based on observations, measurements and technical specifications from the manufacturer, in order to determine the luminous flux, light distribution, color correlated temperature and power consumption.

The mounting height was determined based on measurements taken with the Leica DISTO D5 digital laser tool.

Daytime and Night-time Horizontal Illuminance

The horizontal illuminance was measured during the day using the SPIC-200 spectral irradiance colorimeter (SPIC-200 Spectral Irradiance Colorimeter, 2012). During the night, the measurements were performed using the RS-105 Light Meter. Electric light had a contribution because it was switched on during normal working hours. Outdoor electric lighting had a relatively small contribution to the indoor light scene in the night, therefore it was be neglected during night-time measurements.

Light measurements were done to determine the horizontal illuminance on desks, tables and walking areas from the office. The measurement were performed by placing the sensor of the lux meter in a horizontal position, on the table or floor. The recorded value was recorded in a separate document. The measured points were marked on the plan in order to have a clear correlation. The average horizontal illuminance was calculated in both daytime (under overcast sky conditions) and night-time for the desks which are positioned close to the windows, desks positioned in the middle of the room, floor and the communications table.

Daylight Factor

The daylight factor is an important aspect to be investigated, because it shows the natural light level inside the space. Mapping the office according to the daylight factors revealed areas which receive sufficient natural light in order for the users to carry on their tasks, without electric light contribution. It

also revealed areas which do not receive sufficient natural light and require permanent electric lighting.

The calculation to determine the daylight factor was performed using a light simulation software. According to DIALux 4.12 producer (DIALux - DIAL, 2016), the software is able to simulate the daylight factor in overcast sky conditions, following the CIE 110-1994 (CIE, 2016) recommendations. The rendering algorithm of this software is based on radiosity (DIALux 4 Calculation Kernel, n.d.). A study from Iversen et. al (2013) showed that daylight factor results based on DIALux calculations are within acceptable limits and therefore can be used in the existing space analysis.

## 3.3. 3D Modelling and Light Simulation

The existing space was modelled based on the technical drawings provided by the company, measurements and observations, using DIALux 4.12. This software can calculate both electric light and daylight and it is a widely accepted simulation tool in the lighting industry. It can also import .ldt photometric files, which are used to simulate the physically-built light fixtures of a manufacturer.

The office light simulation was used to test and illustrate the proposed solution. The software has been created to help lighting designers and other specialists to verify a proposed solution, by consulting specific values such as illuminance, luminance, glare, power consumption, etc. by generating a calculation report. In addition, DIALux can be used to create renderings, which complemented the calculations.

The following procedure was be used, in a simplified version:

1. The technical drawings of the existing space were consulted using Autodesk AutoCAD 2016 Student Version (Autodesk, 2016), because they were provided in an digital form, with the .dwg file extension.
2. The top-view drawing was imported in DIALux 4.12.
3. The space was be modelled having the top-view drawing in the background.
4. The doors, windows and skylights were placed inside the model according to the exact position specified in the drawing. Their height was set according to the section drawings of the existing space.
5. Other structural elements such as beams, columns, etc. were created based on the top-view and section plans.

6. Furniture was added based on the information from the drawings. If that option was not available, the existing furniture was be measured on site and positioned approximately in the same area as in the office.
7. The reflectance factors of all materials were indicated based on the material characteristics.
8. The transmittance factors of all windows and skylights was chosen based on the windows and skylights measurements.
9. The lighting fixtures of the proposed solution were introduced.
10. Calculation surfaces were added for each desk and other relevant areas. These calculation surfaces were used to display horizontal illuminance values.
11. Different light scenes were created to illustrate the proposed lighting scenarios.
12. Renderings have been created to illustrate the different proposed lighting scenarios during the day.
13. The calculation report was generated to display all the calculations in the space.

The outcome was a proposed lighting solution that improves the working conditions of the users at HeSaLight, composed from a calculation report, which contains test and results, and renderings, which helped to visualize the design.

# 4. Results

This chapter presents the results of the interviews with the daily-basis users from the office at HeSaLight. Furthermore it reveals the results from the analysis of the existing space, from a lighting point of view. It also contains the author's initial observations, presented in a qualitative discourse.

## 4.1. Interview-based Results

The interviews were conducted in two different days due to the availability of the employees. The first day of interviews was on the 12th of April 2016 and 5 subjects out of 12 were questioned. In the second day of interviews, on the 26th of April 2016, 4 subjects were available for the interview. The three remaining subjects, who were unable to participate at the interview were asked to answer in writing and none of them replied to the paper-based interview request. The answers for each specific question were analyzed in order to find similarities and to establish a tendency amongst the subjects.

Q1. *How would you describe HeSaLight as a company?*

All the subjects answered this question in a unique way. For example, Subject 4 described it as "*a journey*" because the company has developed in the same time as the LED technology while Subject 1 said: "*I feel we are a little family here*". Finally, Subject 2 confessed: "*for me it's the company where I had the most fun working because of the new things we are doing in terms of new products, new markets and new solutions. It's been an incredible experience!*" Four subjects used the word "*innovative*" in their answers. This is the most frequent word used to describe HeSaLight. The other frequent words used are "*fast growing*" which appeared 3 times, while "*different*" and "*amazing*" were used 2 times each. All the keywords used to describe HeSaLight are illustrated in Figure 9.

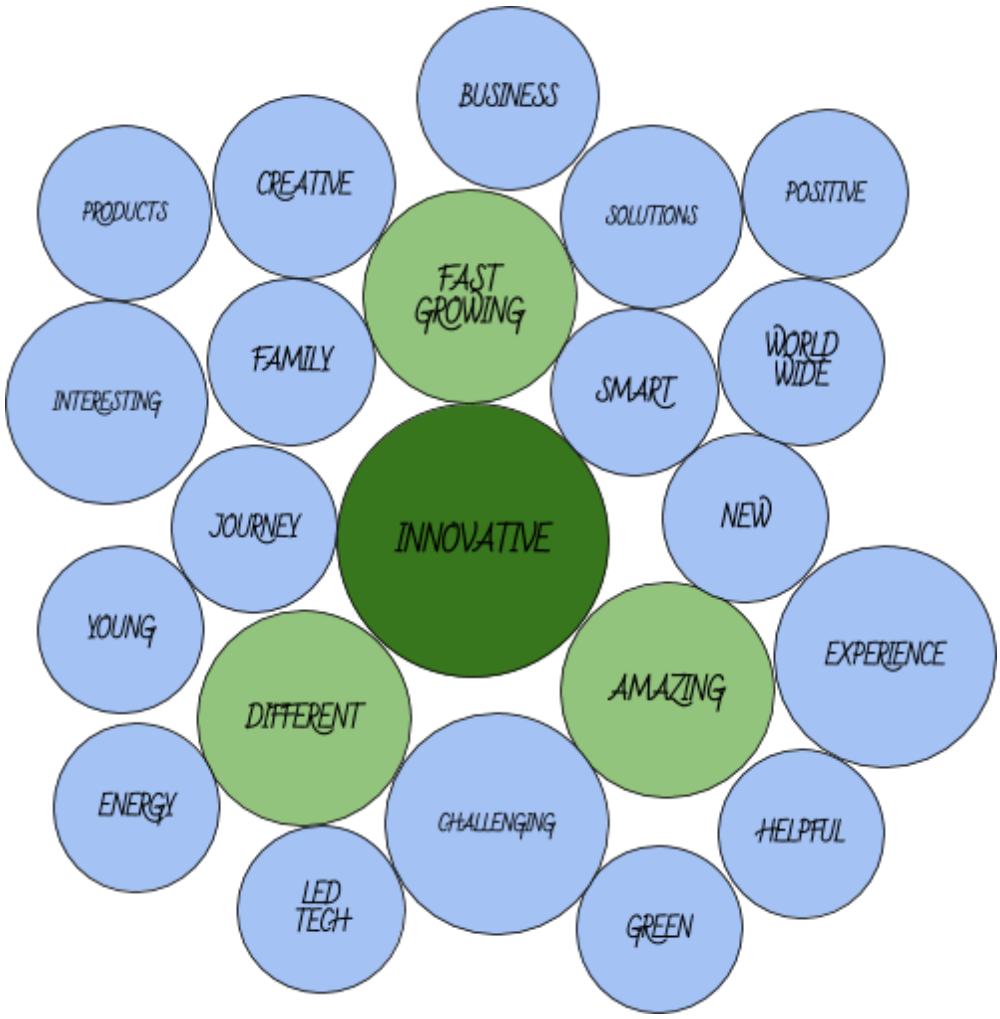



Fig.9 The keywords describing HeSaLight as a company, based on subjects answers to Q1.

*Q2. Is your desk positioned close to a window?*

Six subjects answered "yes" and three subjects answered "no". Depending on their answers, one of the following questions was asked:

- *If yes - then - Do you think the natural light has a positive impact on you?*

  Four subjects believed that natural light has a positive impact upon themselves. Three out of four explained that natural light has a positive impact on their mood. Subject 4 and 9 have been experiencing a difference in their performance and mood after they moved from the middle of the room to a desk that is positioned closed to a window. Subject 4 was very aware of the light impact upon himself, saying: "*Because of the long and dark winter in Denmark, if you're missing the natural light it can have a negative impact on your mood. Also the performance can suffer! The circadian rhythm is affected by this lack of sunlight.*"

  One subject did not believe that natural light has a positive impact, explaining that he is using the vertical curtains to block direct natural light. Another subject was not sure whether or not natural light has a positive impact.

- *If no - then - Would you like to have a light setup that simulates the natural light?*

  Two subjects would prefer to have a light setup that simulates the natural light. One subjects explains: "*I would like to have it because I don't like to sit next to a real window.*" One subject did not answer the question.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

Six subjects found the light level on their desks appropriate during the day but inappropriate during the evening, in the absence of natural light. Two of the subjects argued that it is difficult to read paper documents. Subject 4 explains: "*It is much better where I sit now. [...] Before, when I finished my tasks I felt like I'm losing my focus but now it is much better and there are some periods when I don't feel the need to use my glasses because the light is coming from a very good angle."* Two subjects evaluated the light level on their desks as being appropriate during the entire day, even in the absence of natural light. One subject described the light level as being inappropriate during his working hours, because there is "*too little light*" on the desk.

The follow-up question about glare revealed the following results: five subjects have experienced glare during their working hours. Three of them experienced glare from the electric light and one experienced glare from both electric and natural light. When asked about experiencing glare during the working hours, Subject 9 explains: "*Yes, definitely! When you look directly at the lamps, which is a sign that we should have a better light fixture than the existing one.*" Three subjects did not experience glare during their working hours.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

Four subjects stated that they would prefer cold light in the morning. Subject 7 argues: "*I would prefer to have cold light. It makes me more active!*" and furthermore, Subject 4 associates warm light with his private home by saying: "*I would leave the warm, yellowish light for my living room.*" One subject would prefer neutral light and goes into details: "*I need something to keep me awake, but not cold. Maybe something inbetween [...] like 4000K, not 3000K.*" Another subject prefers natural light, explaining that warm light "*is a little bit cozy and it makes you feel better, but I think it could also make you inefficient.*" Finally, three subjects would prefer to have warm light in the morning.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

The subject's answers vary a lot. There are no similarities in their answers, except for two aspects, concerning the control system and the light fixtures. Four subjects would prefer to have a new light installation with individual control and two subjects would prefer panel lights to be part of the new solution. Subject 9 believes that the space should be turned into a showroom which would potentially impress clients and employees.

The keywords determined from the user's answers are represented in Figure 10, illustrating their vision regarding a solution that would represent the company.

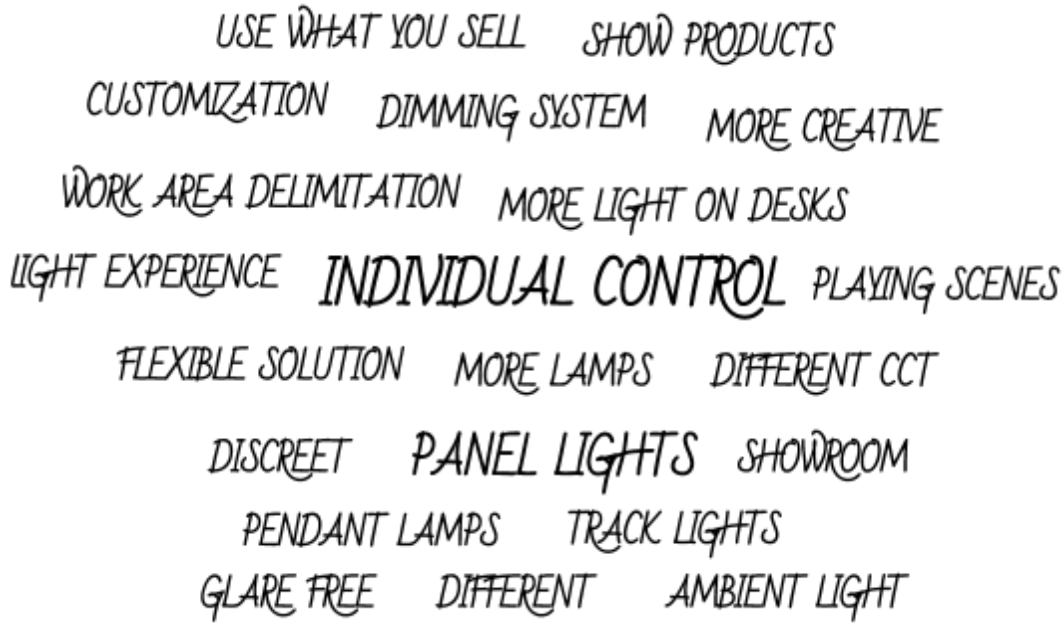



Fig.10 Keywords describing the solution that would represent HeSaLight

After the recording device was turned off, six subjects were asked an additional question about the possibility of transforming the space into a live showroom, where customers could see different products from HeSaLight functioning in an active environment and all of them found the concept interesting, understanding the potential impact on sales and identity of the brand.

## 4.2. Results of the Office Space Analysis

This subchapter presents the existing situation in the office, both during the day and during the night. In addition, it also contains the initial observations of the space.

Initial Observations

The space appears to be well lit during the day, except in the winter. Because of the cloudy sky and the short days during that season, the space appears to be dark and all colors seem to converge to nuances of grey. During summer, spring and autumn the office is more comfortable work-wise. Daylight changes the appearance completely, turning it into an attractive industrial workspace, with sharp material contrast and enhanced room height. Looking at the electric light, it seems that the pendant lamps have an industrial appearance, complementing the space. One might go further and say that the office has pendant sculptures. But during the night, they are not providing a good light. The lamp's cover is translucent and because of that, a large

portion of the light is directed away from the desks. What is left hits the tables and the floor, but it's not much. This is a problem because even though the lamps have an appealing industrial design, they are not providing the light that people need. If a person is looking directly at the lamp, he or she will experience glare, even though the LED bulb has a diffuse coating. One bulb has even a visible flicker, meaning that it's getting near to the end of it's service. Even though there is a low illuminance in the space, the light distribution appears to be uniform, giving the impression of an average illuminance around 100 lx.

The desks are state of the art, because the height can be adjusted and the color is matte black. It's different from the usual light wood patterns or any other material. They are positioned in groups of two, with a fabric separator between them. The walls are painted white, contrasting the the black painted metal beams. The ceiling is made from aluminium and it is reflecting a portion of the light. Elements such as the catalogue stand and the world map are not highlighted, meaning that the space has no dramatic lighting effects, just a flat, uniform light distribution. The noise level is increasing fast in some moments during the day, because it is an open office and people are communicating in Danish, Spanish, Serbian, Italian, etc. There are some noise-reduction wall tiles, but it's not enough and it creates discomfort.

Overall, the space is comfortable to work during the day, except during the winter. Noise can be a problem sometimes, but it's not constant. In the absence of natural light, the current electric light system does not provide enough light for reading, writing or even computer-based tasks. There is a lot of potential for this space to be transformed, from a lighting design point of view.

Material characteristics

The material types, characteristics and location are illustrated in Table 3, with corresponding pictures. The calculated reflectance factors are presented in Table 4.

The ceiling was too difficult to reach, therefore the measurements were not performed as planed. As an alternative, knowing that the ceiling is made from matte aluminium, the reflectance factor was set to be 65%. The typical reflectance values for this type of material are between 55% and 75%, according to Materials - Light Reflecting Factors (n.d.).

Table 3. Material types, characteristics, locations and images from the office space

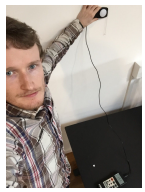
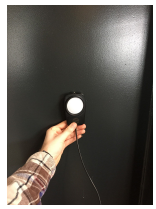
| Nr. Crt | Material | Characteristics | Location | Image |
|---|---|---|---|---|
| 1 | Parquet | laminate, dark brown | Floor |  |
| 2 | White Paint | reflective | Walls |  |
| 3 | Linoleum | black, matte | Desk Tables, Tables, Cabinets |  |
| 4 | Textile Cover 1 | black | Catalog Stand |  |
| 5 | Textile Cover 2 | white | Desk Separator |  |
| 6 | Metal | black paint | Beams |  |
| 7 | Plastic | white | Coffee Table |  |

Table 4. Reflectance factors of the analyzed materials

| Nr. Crt | Material | Reflected Illuminance $E_r$ | Incident Illuminance $E_i$ | Reflectance Factor ρ |
|---|---|---|---|---|
| | [-] | [lx] | [lx] | [%] |
| 1 | Parquet | 28 | 140 | 20 |
| 2 | White Paint | 75 | 131 | 57 |
| 3 | Linoleum | 15 | 179 | 8 |
| 4 | Textile Cover 1 | 10 | 131 | 7 |
| 5 | Textile Cover 2 | 16 | 69 | 23 |
| 6 | Metal | 18 | 243 | 7 |
| 7 | Plastic | 203 | 421 | 48 |

Windows and Skylights

The office space has 5 windows, from which 2 are placed on the north facade and 3 are situated on the east facade. All the windows have the same dimensions, 2000mm x 2100mm (width x height), and are positioned at 0,00m from the floor (see Figure 11)

The transmittance factor for the windows was determined based on the VELFAC A/S (Velfac - Kontakt, n.d.) catalogue specifications observations on site. The windows are VELFAC ENERGY 200, clear, double glazed, with a 1.1 insulation factor and a transmittance factor of 80% (Velfac Catalogue, 2015). Details about the windows coefficients are displayed in Table 5.

The skylights are positioned on the ceiling and act as daylight openings and are also part of the ventilation system. The dimensions are 2400mm x 1200mm x 400mm (length x width x light well depth). The shape is similar to the one in Figure 4. Details about the skylights in relation to the space are illustrated in Figure 12.

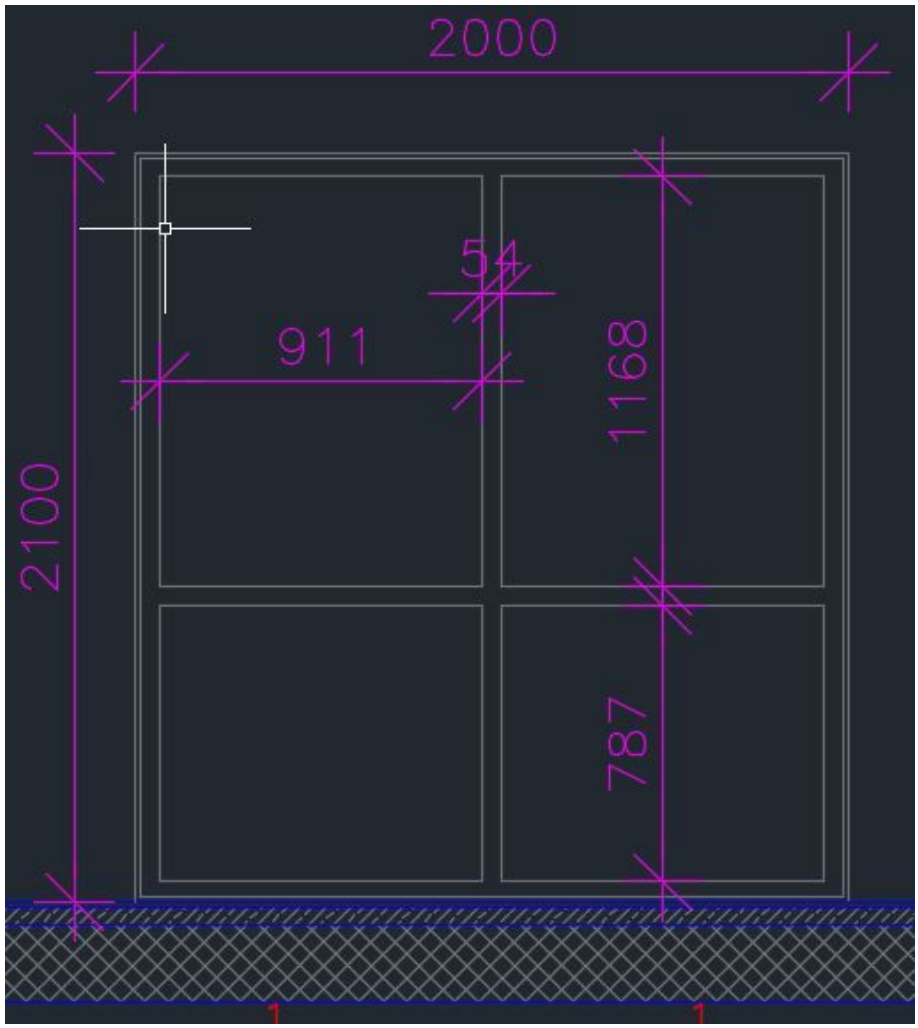



Fig.11 Window dimensions and position in relation to the office floor

Table 5 Windows coefficients for VELFAC 200 ENERGY (based on Velfac Catalogue, 2015, p.59)

| Construction | Type of glass | U-value | g-value | LT-value |
|---|---|---|---|---|
| 4-16-4 argon | Energy/Energy North | 1.02 | 52% | 77% |
| 4-16-4 argon | Clear/Energy | 1.11 | 62% | 80% |
| 4-16-4 argon | Clear Low Iron/Energy South | 1.26 | 77% | 82% |
| 4-18-4-18-4 argon | Energy/Clear/Energy North | 0.50 | 43% | 65% |
| 4-18-4-18-4 argon | Energy/Clear/Energy | 0.53 | 50% | 72% |
| 4-18-4-18-4 argon | Energy South/Clear/Energy South | 0.62 | 62% | 73% |

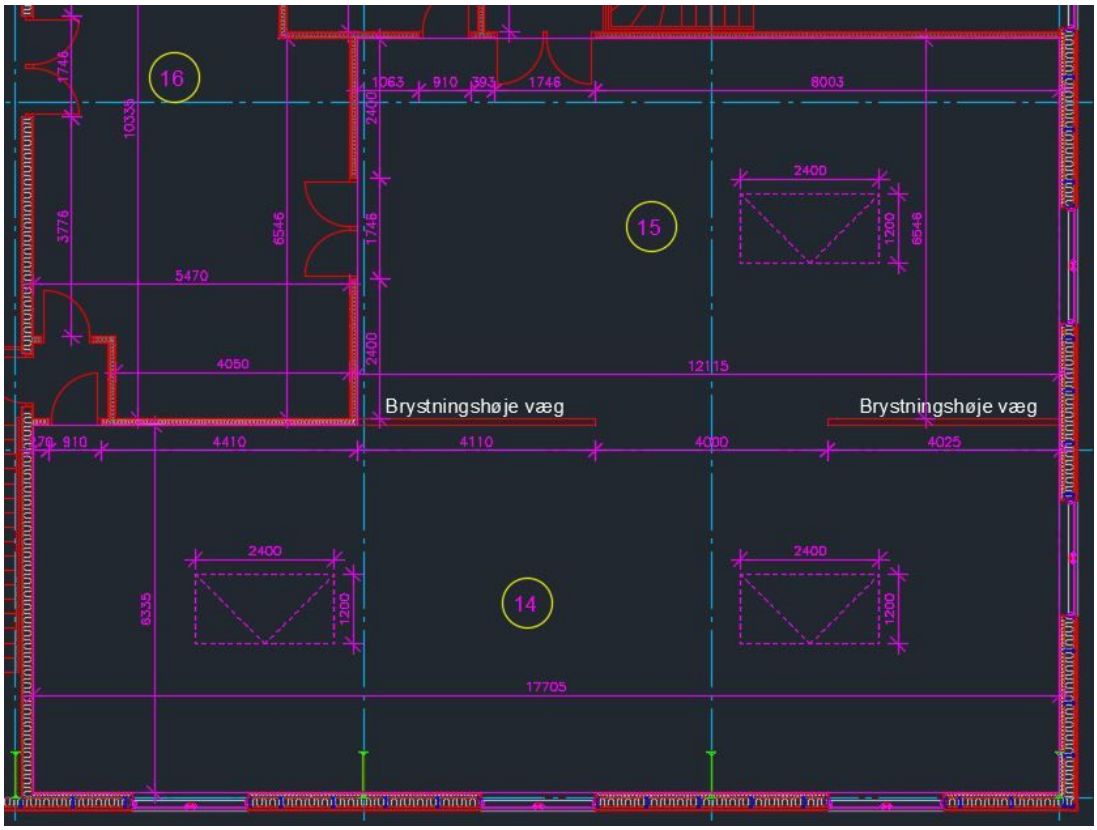



Fig.12 Skylights position and dimensions in relation to the space

Information about the type of material and its transmittance factor were not provided in the technical drawings and the manufacturer is unknown, therefore the transmittance factor was determined solely on observations and standard recommendations. The material chosen is polycarbonate, double glazed, 6mm, opal with a transmittance factor of 64%, as it resembles the skylights' existing material.

Light Fixtures

The office space has 24 pendant lamps, mounted at 3.00m above the floor and desks. The fixtures are uniformly distributed in the space, with a 3 x 4 (no. of rows x no. of lamps per row) arrangement in the first part of the space and 2 x 6 arrangement in the second part of the space. Figure 13 illustrates the lamp arrangement towards the north facade of the office. Details about the position of the lamps, based on observations can be found in Appendix 4.

The light fixtures were refurbished with LED light sources produced by the company. The E27 15W bulbs are omnidirectional and they are suitable for retrofit projects. The luminous flux is 1170 lm, with a color rendering index of 80 Ra, 3000K CCT, frosted cover and 78 lm/W efficiency. The full specifications can be found in Appendix 5.

Fig. 13 Lamps Arrangement on the North Facade.

Daytime and Night-time Horizontal Illuminance

The horizontal illuminance was measured both during the day and during the night in two separate days. Appendix 6 contains detailed results of the horizontal illuminance measurements.

The first measurements were taken on the 26th of April 2016, during normal working hours between 16:00-17:00, in cloudy sky conditions. The electric light was switched on and the measurements were performed for all the working areas and the floor. The average horizontal illuminance was calculated for the desks that are positioned closed to the windows, desks positioned in the middle of the room, floor area and the communication table (see Table 6).

The highest average horizontal illuminance is 2469 lx for a desk positioned close to a window and the lowest average horizontal illuminance is 444 lx. For desks which are positioned in the middle of the room, the highest average horizontal illuminance is 501 lx and the lowest average horizontal illuminance is 124 lx.

Table 6. Daylight Average Horizontal Illuminance in the Office

| Space Area | Measuring points | Daylight Average Horizontal Illuminance |
|---|---|---|
| Desks positioned close to the windows | 8-11; 24-27; 29-30; 35-38; 48-49; 51-54 | 1463 lx |
| Desks positioned in the middle of the room | 2-5; 17-20; 41-44; 64-67 | 242 lx |
| Floor Area | 1; 6-7; 12-16; 21-23; 28; 31-34; 39-40; 45-47; 50; 55-58; 61; 63; 68-69 | 375 lx |
| Communications Table | 59-60 | 713 lx |

The second measurements were taken on the 6th of May 2016, in the absence of daylight between 00:00-01:20. The same measuring positions were used, for both tables and the floor. The average horizontal illuminance was calculated in the similar way as for the daylight measurements (see Table 7).

Table 7. Night-time Average Horizontal Illuminance in the Office

| Space Area | Measuring points | Daylight Average Horizontal Illuminance |
|---|---|---|
| Desks positioned close to the windows | 8-11; 24-27; 29-30; 35-38; 48-49; 51-54 | 53 lx |
| Desks positioned in the middle of the room | 2-5; 17-20; 41-44; 64-67 | 59 lx |
| Floor Area | 1; 6-7; 12-16; 21-23; 28; 31-34; 39-40; 45-47; 50; 55-58; 61; 63; 68-69 | 52 lx |
| Communications Table | 59-60 | 76 lx |

The highest average horizontal illuminance is 60 lx for a desk positioned close to a window and the lowest average horizontal illuminance is 44 lx. For desks which are positioned in the middle of the room, the highest average horizontal illuminance is 94 lx and the lowest average horizontal illuminance is 31 lx.

Daylight Factor

The daylight factor was calculated in the office space using DIALux 4.12 and are based on the radiosity rendering algorithm (see figure 14). The space was

modelled according to the technical drawings and measurements taken on site. Reflectance factors were applied to all surfaces according to the calculated values of the existing materials. The date for calculation was set to be on 21.03.2016 at 12:00, with an overcast sky and 12209 lx for outdoor horizontal illuminance.

Fig.14 Daylight rendering of the office space

The calculation surface was divided into a grid with 1m distance between 2 points and the results reveal an average daylight factor ($D_{av}$) of 2.2%, with the maximum daylight factor ($D_{max}$) of 11% and the minimum daylight factor ($D_{min}$) at 0.10%, at 0.8m from the floor. This height was set because the table height is 0.8m and therefore the calculation surface should be at the same level as the working areas. The detailed calculation report can be found in Appendix 7.

Based on the daylight factor, the space was divided into different zones, from 1% or below areas until 10% and above, in steps of 1% (see Figure 15). This gives a clear perspective regarding the brightest areas, where natural light is sufficient and the darker areas, where electric light is needed during the day.

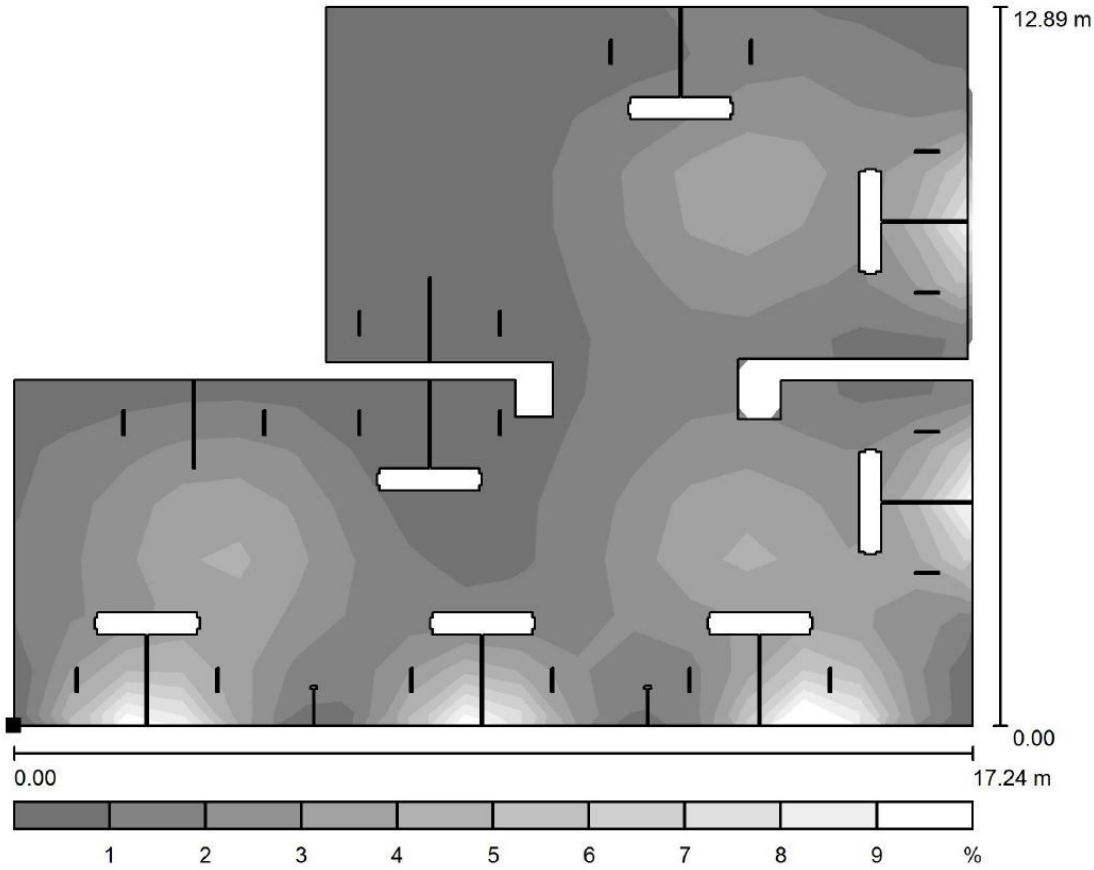



Fig.15 Daylight Factor Zones in the Office

# 5. Discussions

This chapter contains discussions about the interviewing method and the results obtained from the subjects answers. Furthermore, it presents the positive and negative aspects of the existing office space and what could be done to improve the working conditions and finally, it introduces a discussion about dynamic lighting in the office, which could be correlated to some extent with the circadian rhythm research available at the moment.

## 5.1. Interviewing Method and Results

The interviewing method was created to involve the people who are working in the office directly in the design process. Its aim was to identify possible problems with the current light installation, by having a one-on-one interview. The interviews were done using open and specific questions and that appeared to be capture people's attention and interest, because the majority of the answers were strictly related to the subject and also creative, in relation to questions 1 and 5. The balance between the two types of questions was appreciated by the subjects, who were comfortable during the interview.

The follow-up questions were introduced as a requirement to clarify some of the answers. It was particularly useful after Question 3 was asked, because the subjects had the tendency to answer "*Yes*", but then they revised their answers and explained why is it appropriate and what are the problems which they have encountered. Therefore, the follow-up questions proved to be an important addition that helped the interviewer to obtain valid answers. The time limit of the interview was set to 10 minutes and it proved to be useful when trying to convince people to participate for the interview. Some subjects chose to extend the limit by their own free will, partially because they found some questions challenging and partially because of the relation with the interviewer.

The people who were unable to participate in the interview were asked to answer in writing. An email was sent (see Appendix 1) to each person, containing information about the interview and the questions. None of the subjects replied, therefore this approach has proven to be unsuccessful. One reason why it was unsuccessful could be the high amount of tasks and another one could lack of time due to travelling amongst the subjects. Furthermore, the fact that the subjects were asked to write down their answers could be seen as time consuming, when compared to an oral interview. An alternative for paper-based answers might be interviews via the internet or by proposing an online survey with scale questions.

The questions and answers are analyzed below, followed by potential biases that might occurred during the interview.

**Question 1** - "*How would you describe HeSaLight as a company?*" offered a variety of answers because it was an open question. Each subject had a different vision about what HeSaLight is. The word "*innovative*" was the most frequently used, with "*fast growing"*, "*different*" and "*amazing*" following afterwards. This shows that people are confident and motivated to be part of the company. It also shows that they are open to new solutions and opportunities that could improve the brand image in the future. Based on the answers of this question, the proposed solution should be different than what people normally expect. It must be flexible to cover the needs of current and new employees and it should inspire people, but most of all, it should introduce something new in their working space.

**Question 2** - "*Is your desk positioned close to a window?*" was introduced to discover people's opinion about daylight. It confirmed the conclusion of the studies done by Wells (1965); Markus (1965); Heerwagen and Heerwagen (1986); Veitch et al. (1993) and Cuttle (2002) which show that people prefer

daylight over electric light, because six out of nine subjects have their desks positioned close to a window and five of them believed that natural light has a positive impact on themselves. Two out of three subjects which have their desks in the middle of the room would prefer to have a light installation that simulates the natural light. This confirms the fact that people prefer daylight over electric light and also indicates the need have a stronger connection with the outdoor environment. Based on the answers to this question, the majority of the subjects prefer to work in daylight conditions and believe that natural light has a positive impact on themselves.

It is important to state that light is one of the factors that could generate a positive impact on someone's work. Other aspects are also significant, such as motivation, well-being, job satisfaction, etc., showing that light might not be the most important factor.

**Question 3** - "*When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*" is related to the prefered illuminance on subject's desks. It was expected that answers would be both in favour and against the existing light situation, but the results are showing a different type of evaluation. Seven subjects had initially evaluated the light level as appropriate. The topic was pursued further, using follow-up questions and the following conclusion was formulated: The majority of the people evaluated the light level as being appropriate during the day but they also explained that the light level is inappropriate during the evening. This is probably influenced by the fact that the majority of the subjects are not spending a lot of hours in the office after sunset, hence the initial positive evaluation.

Overall, eight out of nine subjects stated that the light level is inappropriate during the evening. In this way, they identified the first significant problem of the existing light installation, which is insufficient light during the night. This is also confirmed by the results of the night-time horizontal illuminance measurements. The second problem identified by the users, based on the follow-up questions, is that the existing light fixtures are causing glare, particularly when looking directly at them. This finding confirms the initial space observation that the existing lamps are causing glare. Furthermore, the results confirm to some extent that people's preferences on illuminance levels are different, which was demonstrated by Veitch and Newsham (2000) and Boyce et al. (2006).

**Question 4** "*In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*" was introduced to discover if people are aware

about the effect of electric light on themselves. The results are showing that some subjects are aware of the effects caused by electric light. They associate “cold light” with being active and awake, confirming indirectly the conclusion formulated by Berson (2007) which states that melanopsin is mostly sensitive to blue light and the fact that light is an important entrainment signal. The subjects also associate “warm light” with their private homes and some would prefer it instead of cold light. Again, this shows that preferences about light in a space varies, depending on the people’s perceptions and ideas. The two choices of words, “warm” and “cold” might have influenced people because they only understood it as “visible light” and did not considered the light spectrum, as it was expected. Also the word “morning” should have not been introduced in the question, because it restricts the answer to the first part of the day only and not the entire working day. Therefore, the question should be reformulated in order to make the subjects to reflect more on their prefered CCT. For example, the question could be reformulated as “*What colour should the light have during your working hours?*”

**Question 5** “*If you would be given the chance to change the light installation, what solution would represent HeSaLight?*” was an open question for the subjects, giving them the opportunity to imagine working under different lighting conditions. The answers were rather reserved in the beginning because most of the subjects did not expect this question. Some admitted that they never thought about a new lighting solution in the office but then they managed to find a more comprehensive way of answering this question. The effect was exactly as expected - to make the subjects think about a new solution - and the most frequent feature was “individual control”. There is no doubt that people would prefer this type of control, as it was also observed by Boyce (1980), Boyce et al. (2000), Boyce et al. (2006) and Maniccia et al. (1999). In terms of preferred lamps, the results varied, even though the most popular fixtures are “*panel lights*” according to two subjects. Because of the large variation of answers, a new solution could be done with several different light fixtures and the acceptance probability might be higher than compared to a solution which is limited to only one product, as for example LED panels.

Turning off the recording device and asking an additional question about the possibility of transforming the space into a showroom may have been a good solution, because people opened up and they were very keen about this concept. This also shows that some people may have been inhibited by the recording device and therefore some of their answers might have been biased.

Another important bias during the interviews is the personal relationship between interviewer and interviewees. Because of this, some answer might have been offered in contradiction with the subject's beliefs. Another bias might be caused by the fact that some subjects knew about the project before the interview. Furthermore, another bias could be the relationship between the employees and the management of the company, meaning that some subjects might be inhibited by the reaction of their superiors, concerning negative aspects about light on their workplace. The fact that English was used in the interview could also be a bias, because none of the subjects has English as their native language. The leading bias is present in Question 3, because it contains one of the possible answers - "*appropriate*", which may have influenced some subjects.

In general, the interview was successful because the majority of the users participated and answered all the questions. They also identified two problems, regarding insufficient light in the evening and glare caused by the existing lamps. Furthermore, the subjects is open to the idea of transforming the space into a showroom with the company's products. It is also important to mention that the interviewing method could be improved in the future, in order to avoid some of the biases and to obtain more data from the subjects, by adding additional questions and having a neutral interviewer.

## 5.2. Office Results and Improvements

Measurements performed in the office during the day, showed that nine out of ten desks which are positioned close to a window, seem to receive sufficient natural light for tasks to be performed in normal conditions, when compared to the DS/EN12464-1 standard recommendation of an average maintained horizontal illuminance of 500 lx. The only exception occurred for one desk, which had an average horizontal illuminance of 444 lx. When it comes to the desks which are positioned in the middle of the room, only one received sufficient natural light (501 lx). The rest of them had average illuminance values below 500 lx. The floor area had an average of 375 lx, which means that natural light is sufficient to navigate in the space. These results were taken under cloudy sky conditions, meaning that the outdoor illuminance is relatively constant but even so, the weather conditions can change and it could potentially influence the results. Furthermore, some results might be higher than normal, because electric light was turned on.

Daylight factor calculation showed an average of 2.2% in the space, under overcast sky conditions and 12209 lx for outdoor horizontal illuminance. Based on CEN/TC 169/WG 11 recommendations, the space is not meeting all

the criteria, because there is a large area in the middle of the room with illuminance values under 50 lx (see Figure 16). This means that electric light is needed during the day, in that particular area. The desks which are positioned close to the window receive sufficient light and therefore electric lighting could be dimmed or turned off, in order to reduce the power consumption. However, this type of setup is specifically described for the existing light scene, created on 21st of April 2016 with the limitation provided by the “overcast sky” from DIALux, assuming that the outdoor illuminance is constant, when in fact weather conditions are changing constantly. Even though this is an important bias for the results, the calculation can reveal areas which are more favourable for work in daylight conditions and it’s an important step in quantifying daylight.

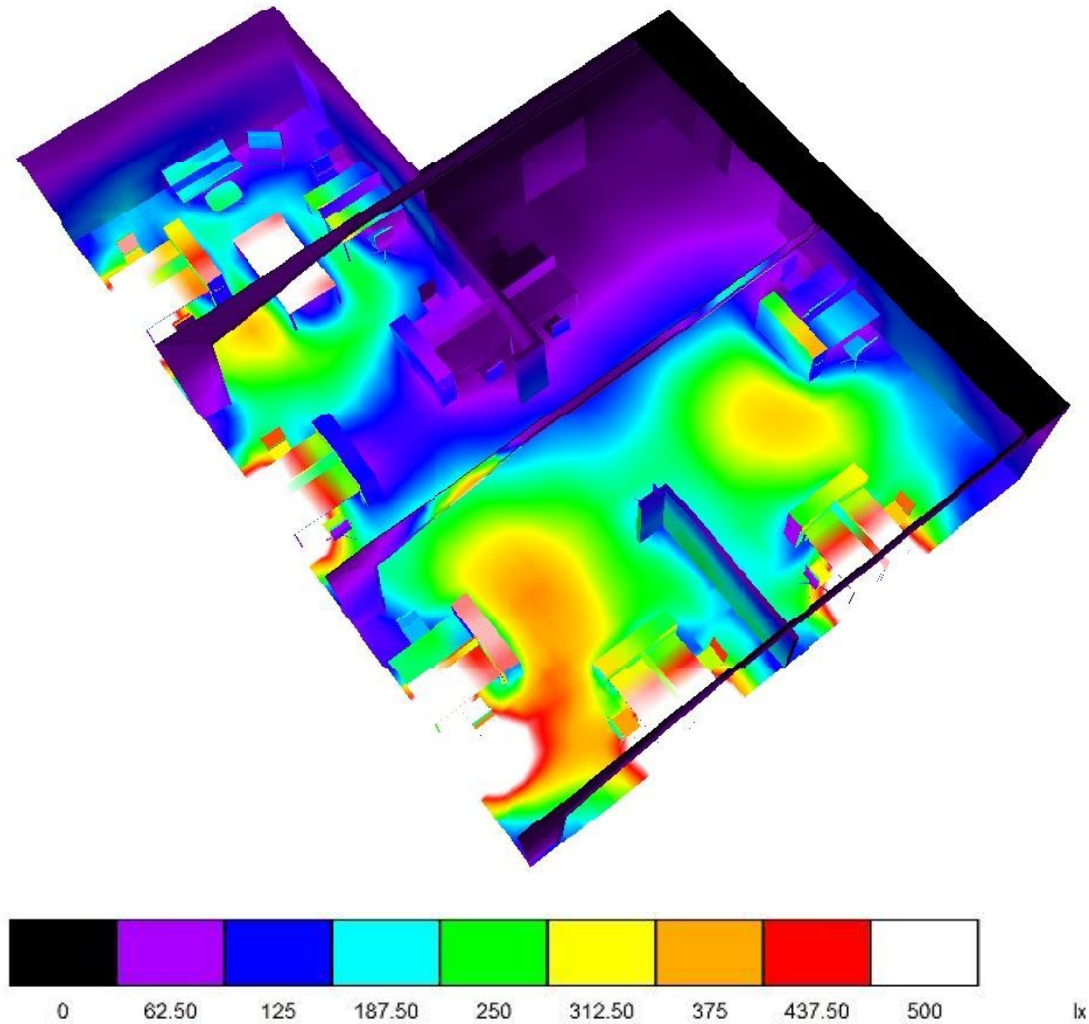



Fig.16 Illuminance map using false colors based on daylight factor calculation

The working conditions have to be improved by implementing a new smart lighting solution with sensors that could measure the light level in the room and adjust the luminous intensity of the lamps accordingly. For example, if

daylight is not sufficient in the middle of the room then the lamps in that area could be adjusted to provide the necessary amount of light, while in the rest of the lamps are turned off because daylight provides sufficient light.

Based on the measurements taken in the office during the night, all the desks have an average horizontal illuminance below the standard recommendations. The average horizontal illuminance recorded on the majority of the desks is nine times lower than the recommended value for offices (500 lx). Furthermore, the floor area has an average of 50 lx. This leaves a lot of room for improvements in order for the space to meet the recommendations of DS/EN12464-1 standard.

The lamps cause glare according to the subjects interviewed and the initial observations from the space, even though the bulbs have a frosted cover. This is partially because the light source is very small, compared to the dimensions of the space and partially because human eyes are attracted to the brightest points from a space. Therefore, the new light system has to reduce glare and provide a comfortable environment for work in the absence of natural light.

Based on the answers from the interviews, the majority of the subjects are not working in these lighting conditions too much, except during the winter, when the days are shorter than in the other seasons. Some subjects stated that they have difficulties reading paper-based documents in the evening, because the light level is too low. This problem could be solved by increasing the illuminance level on their tables and in the surrounding areas. Most people would prefer to have individual control rather than a master switch, which is part of the existing solution. The light is switched on at the beginning of the day and off at the end of the working day and no one takes the responsibility of switching off the lighting. There is a significant difference between an automated intelligent system which could balance the illuminance depending on the daylight availability and a manual control system, which allows individuals to set their preferred illuminance and color correlated temperature. The first system can be discrete and might even produce some energy savings in the space but in the same time it could be less appealing for the users. The manual system is strongly preferred by users but it might end up being used on rare occasions (Maniccia et al, 1999). Furthermore, the energy savings might be significantly lower or none at all, depending on the maximum illuminance available.

The preferred color correlated temperature, based on subject’s answers is cold, meaning that the majority would prefer electric light to be around 4000K

or more, in the morning. This information is useful, but incomplete because subjects were limited to the starting part of the day. Kruithof's curve (see Figure 17), shows that light sources with high CCT should not be used at low illuminances because the space will appear cold and undesirable. Light sources with a low CCT should not be used at high illuminances because the space would appear unnatural. The combinations of illuminance and CCT which lie between the two areas are the ones preferred. However, the validity of Kruithof's study is questionable, because in offices where users have sufficient time for chromatic adaptation, a combination which would be in the upper or lower area will become acceptable if the illuminance is sufficient for their task (Boyce, 2014, pp. 254-255).

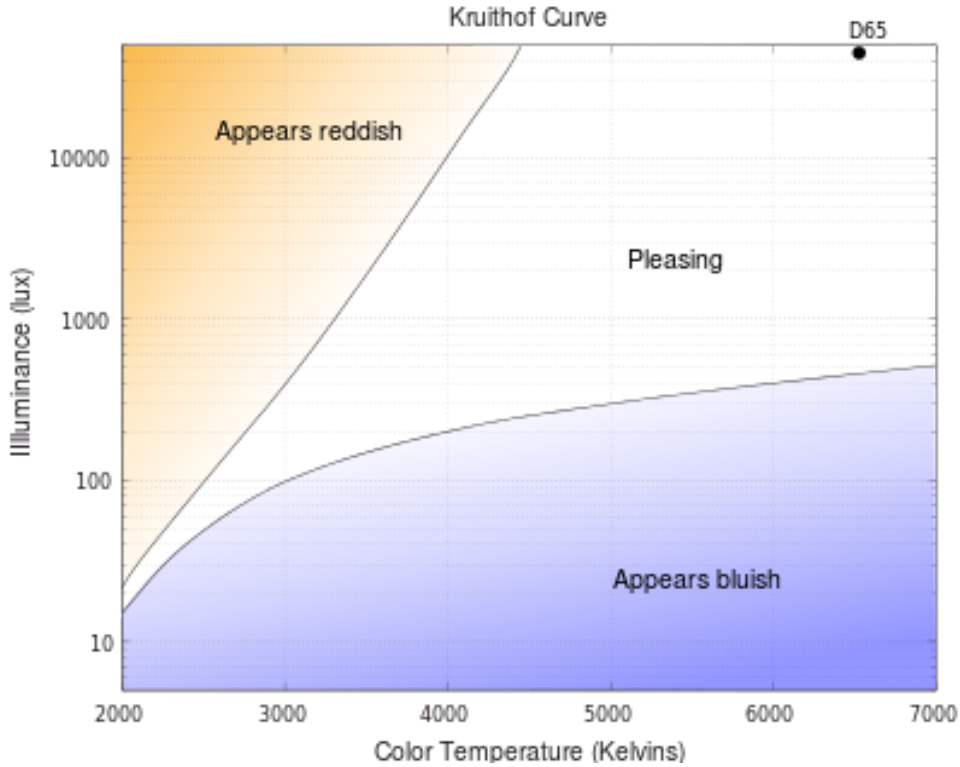



Fig. 17 Kruithof's Curve based on illuminance and CCT (figure taken from Kruithof Curve, 2016)

Therefore, the color correlated temperature of a light source is less decisive for people's satisfaction with lighting, when compared to illuminance. Choosing a light source with CRI 80 or higher will produce more saturated colors and a better visual clarity, leaving the CCT to be set according to a preferred value indicated by users.

## 5.3. Dynamic Lighting

Light, seen from a health point of view, can improve people's general well-being and according to Lockley and Foster (2012), blue light therapy in the morning has proven to be effective in the treatment of seasonal affective disorder (winter depression) which is caused by changes in the seasonal light-dark cycle. There are many studies which revealed that light exposure is a major stimulus for humans, along with social signals, night activity and exercise. Knowing that ipRGCs have the maximum absorption at 480 nm (Berson, 2007), the system could be designed to entrain the circadian rhythm during the working hours and it might increase productivity amongst employees. According to Wood et al. (2013), the amount of melatonin suppression is determined by the spectrum of the light, the amount of retinal irradiance and the time of exposure. A study from McIntyre et al. (1989) shows the melatonin suppression in relation to light exposure. Subjects were exposed to an illuminance of 200, 400 and 600 lx between midnight and 03:00 (see figure 18). The melatonin level increased after the light was removed.

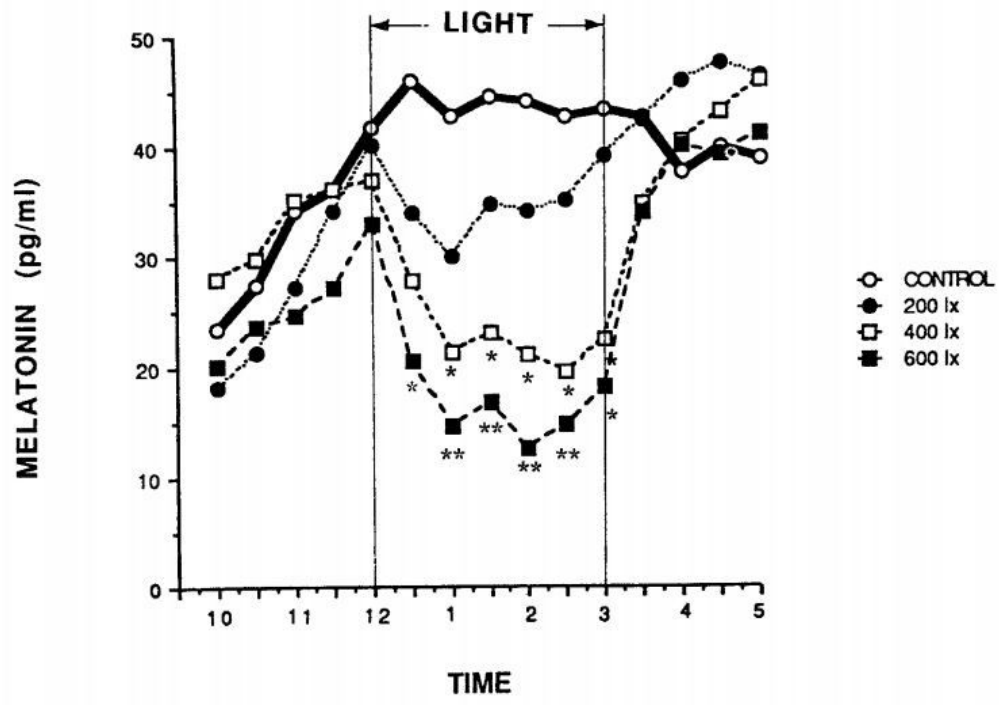



Fig.18 Melatonin concentrations of subjects at different hours of the day, for 200, 400 and 600 lx; figure taken from McIntyre et al. (1989)

Even though it might not have a strong influence during the summer for example, this system could potentially impact the employees during the winter, because of the weather conditions in Denmark. Some subjects mentioned in the interview that during the winter it is very difficult to focus and be active. Therefore it would be relevant to test this hypothesis and compare it

with the results recorded in the other seasons in order to determine if either task performance or sleep is positively affected.

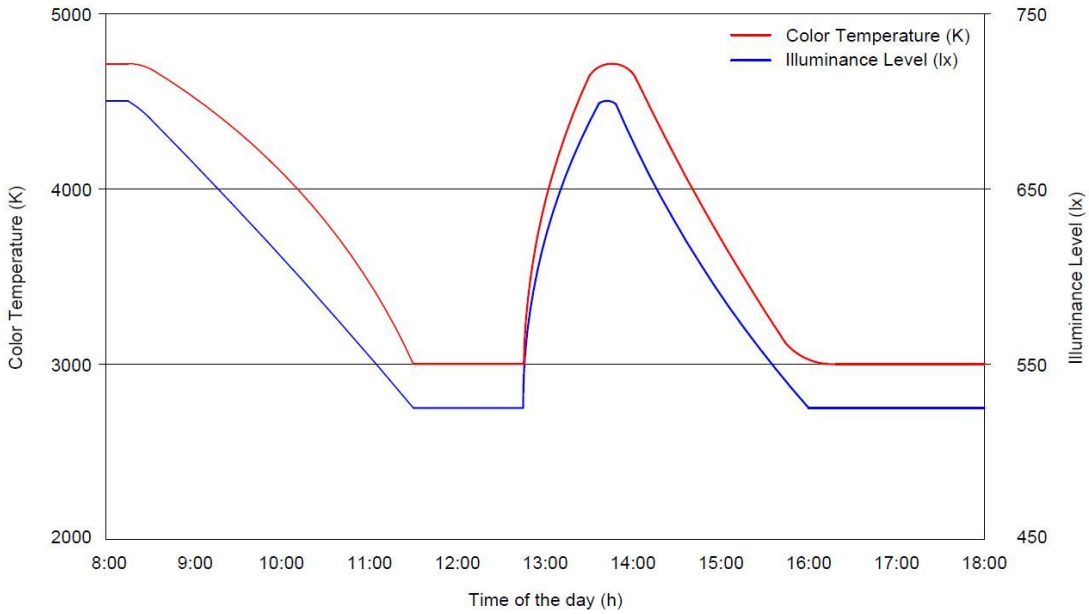



Fig. 19 Proposed dynamic lighting scheme for a normal working day, between 8:00 and 16:00, at HeSaLight (figure created based on the scheme proposed by de Kort and Smolders, 2010)

The lighting system should have fixtures which can be adjusted by changing the CCT and illuminance. For example a high CCT (4700K) and high illuminance (700 lx) in the morning and after lunch, with a gradual transition to a lower illuminance (500 lx) and lower CCT (3000K) in the rest of the time (Boyce, 2014, p.148). This type of system would affect the circadian rhythms of the employees by increasing their alertness when they arrive in the morning and also after lunch, because some people might experience a decrease of alertness known as post-dip lunch (Davila, 2009). Figure 19 shows a proposed dynamic lighting scheme during a normal working day at HeSaLight. However, a dynamic system as the one described above might not affect the performance or sleep quality of the employees, if daylight is altering the light spectrum and illuminance (de Kort and Smolders, 2010).

## 6. Proposed Lighting Solution

The proposed lighting solution is created to improve the working conditions for the daily-users of the office space at HeSaLight. The aim is to transform the space into a lighting showroom, where people can still perform their tasks as usual and customers can see different lamps functioning. The system is divided in three layers of light, supplementing daylight during the day and covering all the necessities in the absence of natural light.

## General Lighting Layer

This layer is essential for light uniformity in the space. The lamps are positioned in the office in order to supplement task lighting both during the day and during the night. Other additional usage could be for cleaning or other maintenance operations which do not require a high illuminance level. The light layer is displayed in Figure 20.

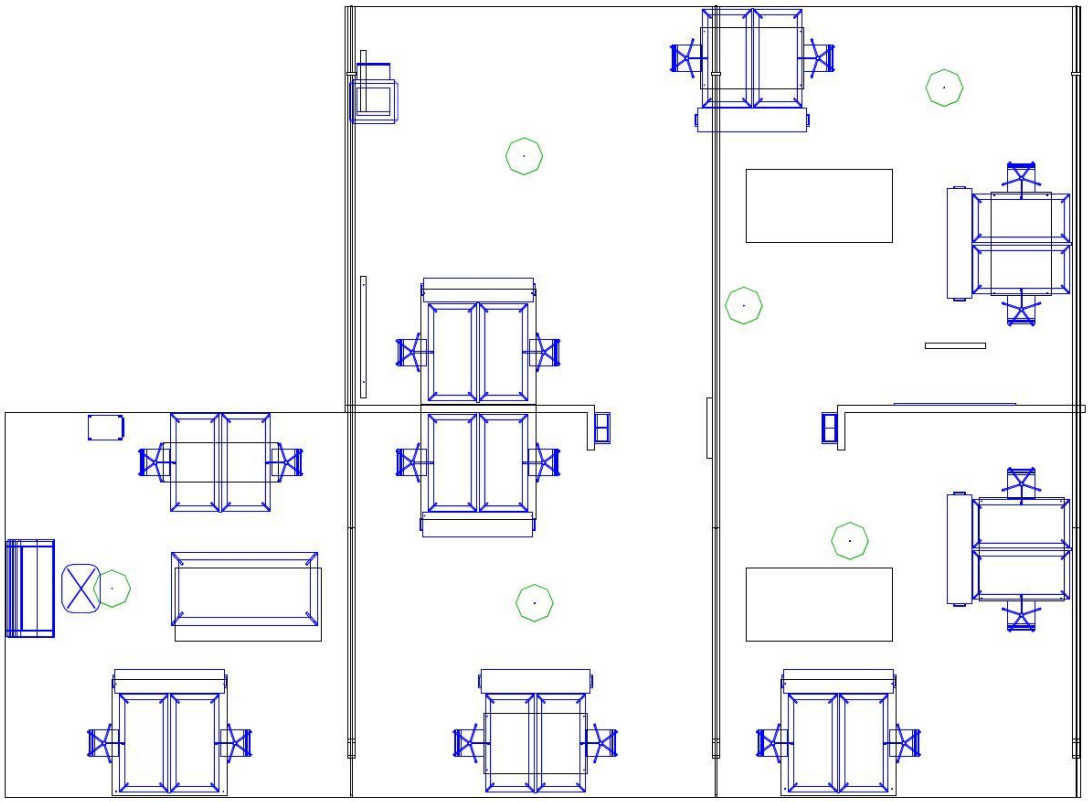


Fig. 20 General Lighting Layer (green color) in the office space

## Task Lighting Layer

The Task Lighting Layer was introduced to ensure that each desk has an appropriate illuminance for people to perform their tasks normally, from a lighting point of view. The desks were divided into working areas and each area is provided with a pendant light island.

The pendant light islands are designed to fit in recessed panels or downlights. It is similar to a false ceiling, which is traditionally used in offices, but in this case it is only hanging above each desk (see Figure 21). Furthermore, it can also support surface-mounted light fixtures. The advantages of these pendant light islands are:

- **Flexibility** - The current light setup can be changed while maintaining the existing islands.
- **Distribution** - These islands can be mounted anywhere in the space, ensuring that new desks can benefit from the same type of task lighting.
- **Individuality** - Each working area has it's own light setup and people could choose the light fixtures.
- **Marketing** - The company could promote various products in different islands.
- **Innovation** - This islands are a combination of traditional pendant fixtures from industrial halls, false ceilings from offices and the LED technology in a new approach for task lighting.

The material used to construct these islands can be mineral fiber or something similar. It will improve the acoustics of the space, but in the same time it might create an impression of smaller space. Each desk has a lamp mounted directly above it and this is because the system is enhancing the sense of private lighting.

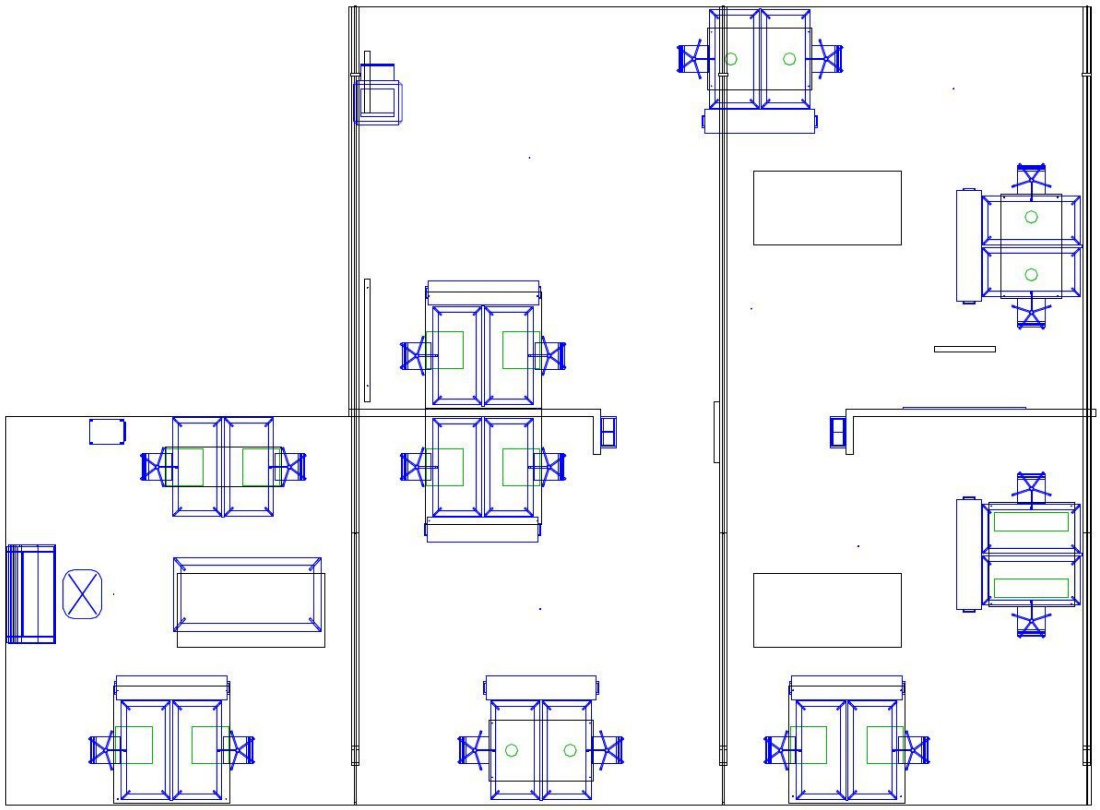


Fig. 21 Task Lighting Layer (green color) in the office space

### Accent Lighting Layer

This layer is designed to bring contrast and break the daily working routine. The existing space offers the potential of using track-lights to highlight

different areas such as the world map or the catalogue stands (Figure 22). This is particularly useful when the showroom light scene is in use, because it will capture people's attention.

For example, highlighting the world map sends a message about an international lighting company. Enhancing the product catalogues will invite people to take one with them before they leave and find a lamp which is suitable for their needs (Figure 23). However, this type of lights can cause glare and discomfort amongst people and therefore it will not be used during normal working hours, except for short periods of time when the space will be presented as a showroom.

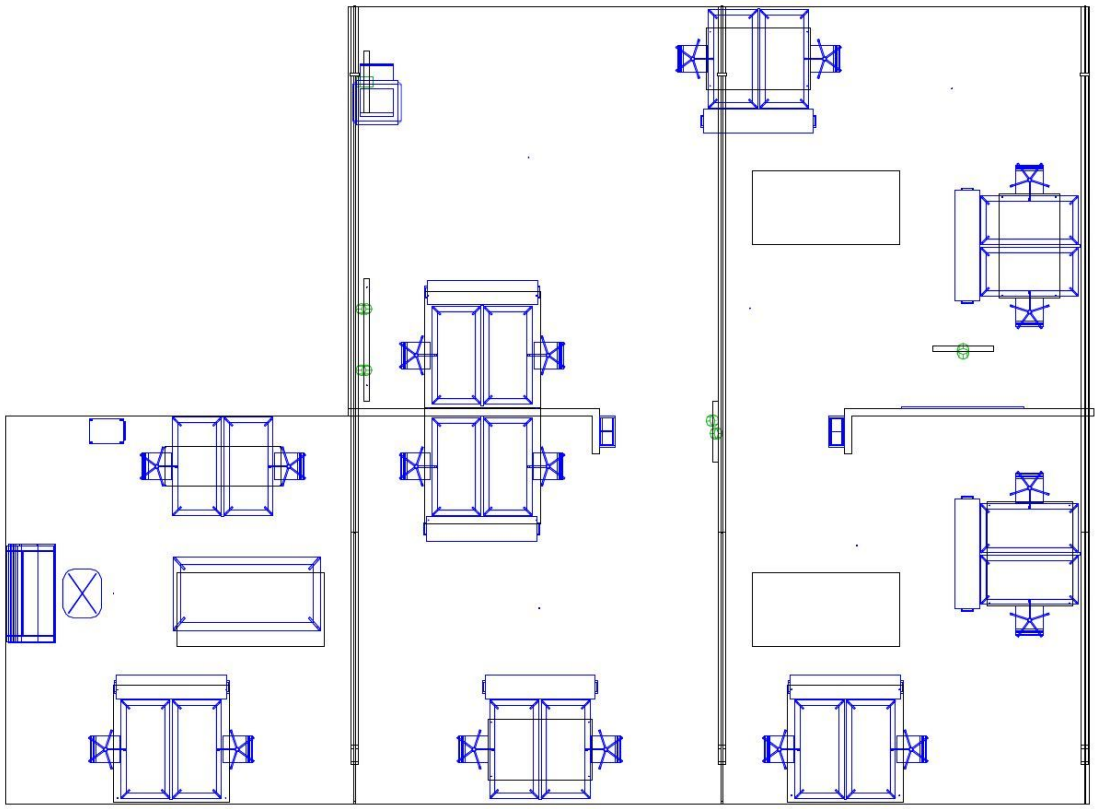


Fig. 22 Accent Layer Lighting (green color) in the office space

**Improvements**

The proposed solution is based on the existing position of the furniture from the space. It provides 500 lx in average on each table, according to the EU Recommendation during the night, which is a significant improvement from the existing situation, where the average is 50 lx.

During the day there are areas which do not receive sufficient natural light, as the daylight factor calculation is showing. The proposed lighting system can

compensate for the lack of daylight and ensure that the illuminance level is appropriate for the people's tasks, by using data from daylight sensors.

For example, the sensors could be introduced for each working area and the rest of the space to measure natural light. This data is then transmitted to a DALI control unit (DALI, n.d.) which will reply by dimming up or down the electric light. In this way, the electric light is used rationally and some energy savings might be achieved. Compared to the existing system, the new solution is based on three layers instead of one, which is currently used for both task and general lighting.

Fig. 23 Highlighting the World Map and the Catalogue Stand with track-lights

The proposed system aims to remove the conventional switches by-the-door and have an intelligent way of providing light in the space. Furthermore, it is far more discrete than the existing solution, because the dimming function can be programmed to be smooth, increasing or decreasing the light level in an area while giving people time to adapt. Light in work areas which are not occupied by any users can be dimmed to a low illuminance value, which will reduce the energy consumption.

Discomfort glare is also reduced when compared to the existing solution, because the small light sources are removed and the new fixtures have diffuse optics. The only exception is the track-lights used in the Accent Lighting Layer.

**Limitations**

The proposed system is based solely on products developed by the company, which are not designed to change the CCT. Therefore the light fixtures will have a constant color temperature, until new versions will be developed to enable CCT shift. Because of this light fixtures limitation, the dynamic lighting system that was proposed and discussed will not be implemented. However, due to the systems flexibility, the fixtures could be changed in the future and the system would be ready for tests.

The system is simulated using DIALux 4.12, and there could be some differences between the calculated results and measured results after the system has been implemented. One reason might be the maintenance factor used for calculation, which reduces the luminous flux of all lamps with 10% and the other one could be the difference between the reflectance factors from the software compared to the real ones. More tests are needed before the actual implementation, by building a small scale or 1:1 mock-up of the office or using another calculation software.

The control system is automated, by using daylight sensors and DALI communication protocol which means that human intervention will be minimum. However, before this system is ready to use, tests have to be performed to avoid unnecessary dimming due to temporary changes in weather conditions. But even with a precise dimming delay, the illuminance might fall below the average level and some users could be affected.

Detailed calculations for a proposed Daylight, Night Work and Showroom light scene, together with the technical datasheets of the lamps used can be found in Appendix 8. The dimming values for each light scene, the positions and the mounting heights of the lamps can be found in Appendix 9. Renderings of the proposed lighting solutions can be found in Appendix 10.

# 7. Conclusions

The interviewing method has proven to be useful in this project, because it involved the office users directly in the process and they were able to identify problems concerning the existing light system. Subjects evaluated the light level as being insufficient during the evening and they also experienced glare from the current fixtures.

The analysis of the space provided valuable information about the existing space, regarding material characteristics, daylight openings, light fixtures and

illuminance levels. The horizontal illuminance measurements at night showed that desks have an average illuminance of 50 lx, which is ten times lower than the EU office recommendations. The daylight factor calculations, though limited by constant outdoor illuminance, indicated areas in the space which require constant electric light but also other areas where natural light is sufficient for office-based tasks. This was also confirmed by the daytime horizontal illuminance measurements.

Designing a lighting system for multi-occupant offices is very challenging because the subjects have different preferences in terms of illuminance level, color correlated temperature and control. This has also been found by Veitch and Newsham (2000) and Boyce et al. (2006) in offices, where the preferred average illuminance varied.

In principle, a dynamic lighting system could entrain the circadian rhythm and increase productivity of the employes during normal working hours. However, this might not be possible if daylight is present, because it will alter the spectrum of the light. More research is need on this subject, particularly in offices from Denmark over an extended period of time.

The proposed lighting solution is based on three layers: general, task and accent lighting. The calculated illuminances are in line with the EU standard recommendations for offices, increasing the average task illuminance in the evening and also during the day, in areas where daylight is not sufficient. Furthermore, the system is designed to use daylight as the primary light source and to compensate by using electric light only when it is necessary. Finally, the space can be used also as a lighting showroom by the company, to highlight some of their lamps. Therefore, it can be concluded that the research question which was set in the beginning has been answered and the working conditions in the office at HeSaLight are improved.

The study could be beneficial for lighting designers who are facing the challenge of creating a new light installation in an existing space because it shows how to involve the users in the process, how to analyze the space and how to propose a solution that is improving the working conditions.

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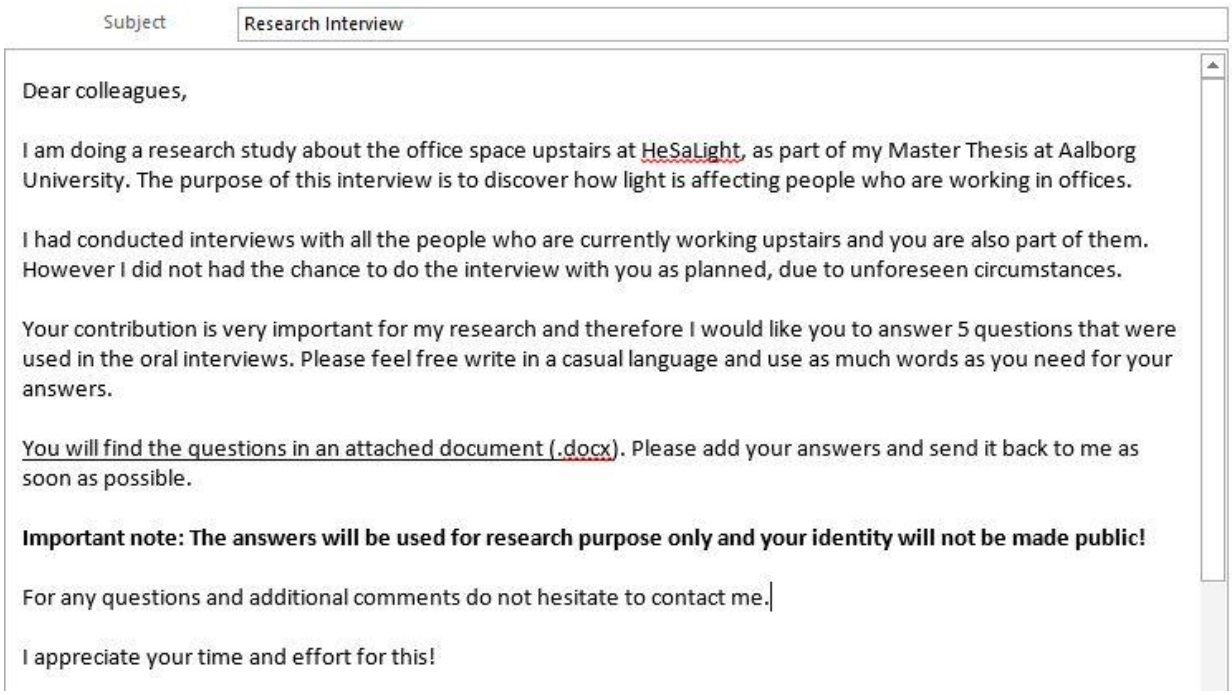
# Appendix 1

Email and Document for the interview in writing


Subject Research Interview

Dear colleagues,

I am doing a research study about the office space upstairs at HeSaLight, as part of my Master Thesis at Aalborg University. The purpose of this interview is to discover how light is affecting people who are working in offices.

I had conducted interviews with all the people who are currently working upstairs and you are also part of them. However I did not had the chance to do the interview with you as planned, due to unforeseen circumstances.

Your contribution is very important for my research and therefore I would like you to answer 5 questions that were used in the oral interviews. Please feel free write in a casual language and use as much words as you need for your answers.

You will find the questions in an attached document (.docx). Please add your answers and send it back to me as soon as possible.

**Important note: The answers will be used for research purpose only and your identity will not be made public!**

For any questions and additional comments do not hesitate to contact me.

I appreciate your time and effort for this!

**Name:**

Please answer all the questions listed below and use as much words as you need to answer. The results will be used for research purposes only and your identity will not be made public.

Q1. ***How would you describe HeSaLight as a company?***

*Q2.* ***Is your desk positioned close to a window?*** (depending on your input, please answer one of the follow up questions afterwards)

- *If* ***yes*** *- then -* ***Do you think the natural light has a positive impact on you?***

- *If* ***no*** *- then -* ***Would you like to have a light setup that simulates the natural light?***

*Q3.* ***When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?***

Q4. *I**n the morning when you arrive at the office, would you prefer a warm or cold light? Why?***

Q5. *I**f you would be given the chance to change the light installation, what solution would represent HeSaLight?***

**Additional Comments (if any):**

# Appendix 2

Recorded Interview Answers

**Subject 1**

Q1. *How would you describe HeSaLight as a company?*

A: HeSaLight is an innovative company, with green lighting solutions. It provides the best lighting solutions for the customers. I feel that we are a little family down here.

*Q2. Is your desk positioned close to a window?*

A: Yes.

- *If yes - then - Do you think the natural light has a positive impact on you?*
- A: No, I do not receive any direct natural light. It is indirect lighting received from the other side of the office. I only have the LED lighting from the ceiling.

FQ: There is a curtain blocking the direct natural light?

A: Yes.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: Yes, but I would prefer to have more light because it feel better.

FQ: Do you need more light to be able to read?

A: Yes.

FQ: Do you think that there is a big contrast between your computer screen and desk?

A: No, I don't think so.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: Warm light is a little bit cozy and it makes you feel better, but I think it could also make you inefficient. Work-related I would prefer natural light.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: I would change the colour of the light and maybe I would add more [lamps]. I think the panel lights that we have downstairs are providing a better light for work. The existing fixtures look unnatural when you look at them.

FQ: Are these fixture causing you glare?

A: Yes. I believe they cause a lot of glare.

FQ: If you would be given the chance, would you change them to something that is more efficient and glare-free?

A: Yes, definitely.

After the recording device was turned off, Subject 1 was asked an additional question about the possibility of transforming the space into a live showroom, where the customers could see different products from HeSaLight functioning in an active environment and he was very keen about this idea. He believed that it is a good idea which would impress the potential customers.

**Subject 2**

Q1. *How would you describe HeSaLight as a company?*

A: HeSaLight is a company that is growing very fast, but for me it's the company where I had the most fun working because of the new things we are doing in terms of new products, new markets and new solutions. It's been an incredible experience! [...] We have a unique solution that we can provide to the customer [...] We are a company that reacts very fast and this helps us to grow and follow the customer needs [...]

*Q2. Is your desk positioned close to a window?*

A: My desk is positioned in the middle of the room, 3-4 m away from the window and I have a skylight over my head, so I'm not missing light at all. I feel comfortable!

- *If no - then - Would you like to have a light setup that simulates the natural light?*
- A: Yes, definitely! I would like to have that because I don't like to sit next to a real window.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: I have not thought about it! I can manage but maybe now that I'm thinking about it… It is a little bit too dark in some occasions, especially when it is very cloudy or during the winter when I'm working late.

FQ: Have you experienced glare during your working hours?

A: Yes, sometimes I have to move my chair or my screen because of the light coming from the window or from the ceiling and it bothers me when I'm looking at my computer screen.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: I would not prefer warm light, because probably I would feel tired, especially in the winter. I need something to keep me awake, but not cold. Maybe something inbetween [...] like 4000 K, not 3000 K.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: I like the panel lighting solution for offices. But I don't think that in this space this solution is feasible, because of the ceiling. I also like the current lighting solution with pendant high bays. I have not seen all our solutions work, so it would be difficult to choose a solution.

After the recording device was turned off, Subject 2 was asked an additional question about the possibility of transforming the space into a live showroom, where the customers could see different products from HeSaLight functioning in an active environment and he was very keen on this idea. He believed that it is a good idea, for both customers and sales agents, because they will be given the chance to see some of the products working in a space.

**Subject 3**

Q1. *How would you describe HeSaLight as a company?*

A: It's an amazing company! You feel the positive atmosphere whenever you enter our door.

*Q2. Is your desk positioned close to a window?*

A: No, but I have a window behind me.

- *If no - then - Would you like to have a light setup that simulates the natural light?*

- I would at least prefer to have more light on the desk.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: I think it is insufficient for my tasks.

FQ: Do you think that there is a big contrast between your computer screen and desk?

A: No, I think there is a good uniformity but there is too little light on the desk.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: I would prefer cold light, especially when I have to work.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: I think all solutions from HeSaLight are good! I just need more light on the desk and I would like to be able to turn it on and off from my desk.

**Subject 4**

Q1. *How would you describe HeSaLight as a company?*

A: I would describe it as a journey because the company has been developing in the same time as the LED technology.

*Q2. Is your desk positioned close to a window?*

A: Yes, now it is, but in the beginning it was not. My workplace used to be in the middle of the room, far away from all the windows. I felt that I needed more light and right now I am close to a window.

- *If yes - then - Do you think the natural light has a positive impact on you?*

- A: Yes, such a big impact! [a short pause for personal reasons]. Because of the long and dark winter in Denmark, if you're missing the natural light it can have a negative impact on your mood. Also the performance can suffer! The circadian rhythm is affected by this lack of sunlight [...]. Light is so important! I've never realized how important it is until I saw you working on this project to improve the lighting conditions in the office.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis? If you can compare the two desks positions...*

A: It is much better where I sit now, because I work with a lot of graphic materials and I have long periods where I'm not moving my eyes from the monitor. Before, when I finished my tasks I felt like I'm losing focus in my vision but now it is much better and there are some periods when I don't feel the need to use my glasses because the light is coming from a very good angle.
It is important to have an electric light system that will cover all the necessities when the winter starts!

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: Specifically for the tasks I'm doing at the company, I would like to have clear white light. If it is possible with a high colour rendering. I would leave the warm, yellowish light for my living room.

FQ: Have you experienced glare during your working hours?

A: Not really, because the height of the luminaires compared to the desks is not so low, so it is not in your range of vision. But right now I don't feel it so strong and I think the amount and quality of light is missing a little bit.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: Maybe pendant lamps positioned exactly above the desk. In generally it should be a solution that is flexible. If there is a delimitation of the specific working areas and you have specific luminaires for that, it would be nice but obviously you need ambient light as well [...] Track-lights for decorations on the walls. The possibilities are endless but if you ask me, these delimitations of working areas are essential.

After the recording device was turned off, Subject 4 was asked an additional question about the possibility of transforming the space into a live showroom, where the customers could see different products from HeSaLight functioning in an active environment and he was very keen on this idea. He believed that it is a good idea, because the company can exhibit its products and it will help the Marketing Department in the process of convincing new clients.

**Subject 5**

Q1. *How would you describe HeSaLight as a company?*

A: The company is producing and selling LED products all over the world, mainly for industrial, public and retail sectors. Our way of doing business is different from our competitors.

*Q2. Is your desk positioned close to a window?*

A: Yes, next to a window.

- *If yes - then - Do you think the natural light has a positive impact on you?*
- A: Now when you ask me, yes! But I have never thought about that.

FQ: Do you have any idea why?

A: I guess it's the UV light, but it is just a guess.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: Yes.

FQ: Is that true for both daylight and in the absence of natural light?

A: I believe so! I didn't notice anything negative during the winter for example.

FQ: Have you experienced glare during your working hours?

A: Yes, from the sun. In the early morning it hits directly into my eyes, but I use the blinds to stop it.

FQ: What about glare from the electric light?

A: No problems.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: It's funny that you ask, because I sell light and I advise people about light but I have never thought about my own light! [...] 3000 or 4000K, in that area.

FQ: So would you prefer to have a warmer light than it is today?

A: Actually I don't know how warm it is, but I think it's ok as it is now..

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: We don't have any dimming systems in our spaces and I think it would be good that have that, in order to save energy and also show it to our customers.
FQ: Would you prefer to have your personal control system or general master switch?

A: It could be good, because people are different. I could adjust the light in the area that I'm sitting depending on the light outside and how I'm feeling. Also sometimes you need more light for some tasks and other times you read and then maybe you need another light setup. The more flexibility, the better it is.

FQ: What's your opinion about the possibility of transforming the office space into a live showroom?

A: I think that is the best you could do. To use what you sell! It doesn't matter what are you working in: if you work with smartphone, you should show smartphones! We work with light and we should show the possibilities that we have for our light products. I think that would be a great thing!

**Subject 6**

Subject 6 is not working in the Sales Department's Office. Subject 6 is a lighting designer at HeSaLight and his knowledge and opinion about light and space are important due to the experience accumulated over the years. Therefore the five specific questions were modified in order to relate to the subject's position and knowledge.

Q1. *How would you describe HeSaLight as a company?*

A: It's a company divided in two major areas: sales area and production with pre-sales area. The sales area is very focused on selling products and the pre-sales and product development area are focused on the products itself, to make them work.

Q2. What is your impression of the upstairs Sales Department's office?

A: My first impression is that it feels more cold than downstairs due to the temperature and also because of the black and shiny surfaces and the more cold light they have upstairs. It feels more comfortable to be downstairs because we chose our own products with a warmer color temperature. If it feels more efficient to be upstairs, I don't know… But you have a better view and it feel more open.

Q3. If you compare the light levels in the office downstairs versus the Sales office, how does it appear?

It feels lower than downstairs. I believe we have a much better light on our tables and I have noticed that some people who are sitting upstairs in the corners, they don't have sufficient light. It seems that they miss some light locally on their tables.
Q4. Did you experience glare while being in the office?

A: Rarely, because it's a diffused bulb they have upstairs. It's strong but not very efficient. It is not comfortable when you accidently stare directly at it.

Q5. Do you think daylight has a significant contribution in the space?

A: I don't think it is possible to achieve the light level required for office tasks of 500 lux with daylight alone. It is the north and east facades and even though it should be enough, it does not seem to reach the far corners of the office. It's only the people that sit right next to a window that benefit from it.

Q6. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: We used the panel lights a lot and it's an overall well functioning fixture that represents HeSaLight, but then again I miss having some spotlights here and there, to make some

changes in the scene, to get some sharp lights, contrast and shadows. It could be useful to represent some of our products, track-lights for instance.

Q7. Would you prefer to change the light installation from one with uniform light distribution to one that would provide contrast and it is work-orientated?

A: The panel lights are more or less sufficient for working environments, but you still need some contrast to feel comfortable and I feel that I miss that in my area as well. It would be interesting to focus on the sound-absorbing panels for example, to highlight them.

Q8. How would you like to have the control system for a new installation upstairs? Individual or general?

A: Of course I would prefer an individual control, but for this space I have to say no, don't make it individual because it's not a personal space! If you could use the daylight to dim the electric lights and override it when necessary, that I would find very interesting.

**Subject 7**

Q1. *How would you describe HeSaLight as a company?*

A: Very fast growing company. Smart company because of the smart solutions and products. Helpful for other companies and people because the solutions save a lot of energy.

*Q2. Is your desk positioned close to a window?*

A: Yes, it is close to a window.

- *If yes - then - Do you think the natural light has a positive impact on you?*
- A: Directly I don't know, but maybe on my mood.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: It is difficult to say if it is or not appropriate, but for me it is good.

FQ: What about the electric light in the absence of natural light?

A: The light is not strong enough. It's difficult to say..

FQ: Are you able to read documents?

A: Yes.

FQ: Even on paper?

A: Not on paper, only on my monitor. On paper is more difficult in the evening when the light from outside is missing.

FQ: Have you experienced glare during your working hours?

A: No, I did not.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: I would prefer to have cold light. It makes me more active!

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: I don't have any idea about what kind of light we should have, but maybe it could be interesting to have some playing scenes in the building, or to play with the walls. To be more creative!

After the recording device was turned off, Subject 7 was asked an additional question about the possibility of transforming the space into a live showroom, where the customers could see different products from HeSaLight functioning in an active environment and he was very keen on this idea, because it would have a powerful impact on the new clients.

**Subject 8**

Q1. *How would you describe HeSaLight as a company?*

A: It's an innovative company.

*Q2. Is your desk positioned close to a window?*

A: No, it's not close to the window.

- *If no - then - Would you like to have a light setup that simulates the natural light?*
- A: Yes, that would be good.

FQ: Do you feel like you're missing the natural light when you're at work?

A: No, because most of the time I'm looking at my screen.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: Yes, so far it's been good.

FQ: Are doing mostly computer based tasks or also paper based tasks?

A: Both, but most of the time is computer based tasks.

FQ: Do you also think that during the evening, when there is not natural light coming in, the light level is appropriate?

A: No, if you are a designer and you are working with materials you need better lighting. Also for printing you need the right light to examine the prints.

FQ: Have you experienced glare during your working hours?

A: No, I did not experienced any glare.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: It depends on the season. I like the white LEDs, because when you visit other offices, often their light are yellow.

FQ: So you prefer cold light?
A: Yes.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: Wow! I'm not sure… I would have to see different solutions, to test them and then to choose one.

**Subject 9**

Q1. *How would you describe HeSaLight as a company?*

A: HeSaLight is an innovative and interesting company. [...] The whole energy in the company is amazing! The company is growing constantly and after you've been out of the country for 1-2 weeks and you come back, you always see somebody new coming to work. It's very challenging!

*Q2. Is your desk positioned close to a window?*

A: Yes, it is.

- *If yes - then - Do you think the natural light has a positive impact on you?*

- A: Yes, definitely. I'm not thinking about it but in the beginning I did not sit next to a window and I definitely felt a difference. I had more energy! And I believe lighting has an important effect on your work.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: Yes, especially now, when I'm sitting next to a window. But probably there could be more light in the ceiling that would make it better. [...] I'm satisfied with the conditions at the moment.

FQ: Even in the evening, when there is no natural light coming in?

A: Probably not! I could imagine that it could be better.

FQ: Have you experienced glare during your working hours?
A: Yes, definitely! When you look directly to the lamps. Which is a sign that we should have a better light fixture than the existing one.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: I would prefer warm light, but then again you need to work, so it depends what you do.

FQ: So would you prefer something warm and cozy or something more cold and neutral?

A: Neutral would be better, because it is inbetween [...] If it's too cozy it might not be clear enough, so definitely something neutral.

Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: Like a talked to some of my colleagues, we should make HeSaLight a showroom! Maybe the person who is sitting in front of me wants some warm light and I want cold light… We should be able to adjust that! We invite our agents and customers in here and if we could show them in here what we could do, this would be the perfect place to do this.

**Subject 10**

Q1. *How would you describe HeSaLight?*

A: HeSaLight is a young and innovative company that looks at lighting in a different way than the majority of the players in the lighting industry.

*Q2. Is your desk positioned close to a window?*

A: Yes, it is next to a window.

- *If yes - then - Do you think the natural light has a positive impact on you?*

- A: I assume it has an impact on my work as I usually feel better when I'm working in natural light as opposed of working only in electric light.

*Q3. When you think about the light level on your table, would you evaluate it as appropriate for the tasks you are performing on a daily basis?*

A: I think it is sufficient light to read what I have on paper and also on my monitor.

FQ: Even in the evening, where there is no natural light coming in?
A: It will be less light, especially in the winter and the sun has set. Is it enough? I haven't experienced it as a problem up until now.

FQ: Have you experienced glare during your working hours?

A: No, not unless I look directly at the lamps. In general I don't notice the light that we have here for anything bad or annoying, but on the other hand I don't notice it for anything good necessarily either.

Q4. *In the morning when you arrive at the office, would you prefer a warm or cold light? Why?*

A: I would assume that around 3000K, 2700K is ok for office lighting.

FQ: Would you like to have an individual control system?

A: I think it would be interesting to have the possibility of adjusting some settings on your own. When you have a big office space like this, the light is uniform. So if everybody like uniform

lighting, that’s perfect! (laughs) But usually people want some kind of customization or something specific for them, so if there is a solution like that, I would expect that people would experience that the light was better because they had some input about how the lighting is.

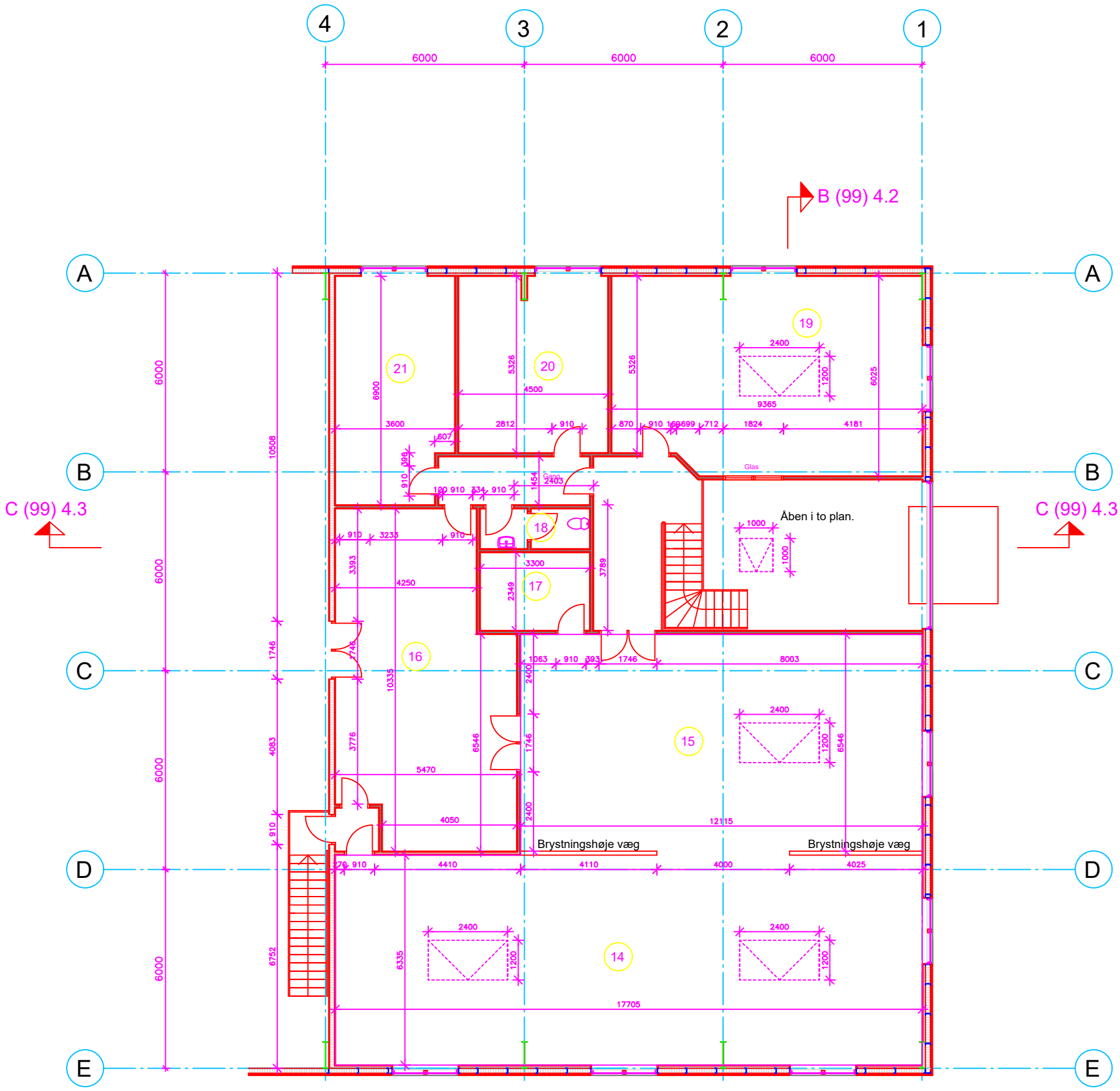
Q5. *If you would be given the chance to change the light installation, what solution would represent HeSaLight?*

A: Good lighting is something that is unambiguous, that you don’t necessarily look at nor does it draw attention to itself, but you have sufficient light for the tasks that you have to do, in a comfortable way. It should be in a way that you are not aware of, consciously.

After the recording device was turned off, Subject 10 was asked an additional question about the possibility of transforming the space into a live showroom, where the customers could see different products from HeSaLight functioning in an active environment and he found the concept interesting.

# Appendix 3

Existing Office Space Drawings




# Plan - 1. sal.

B (99) 4.2

| Rum nr.: | Betegnelse: | Netto areal: |
|---|---|---|
| 14 | Design | 110,0 m² |
| 15 | Indkøb / marketing | 81,1 m² |
| 16 | Kollekttionsprøver | 60,1 m² |
| 17 | Arkiv til labels m.v. | 7,8 m² |
| 18 | Toilet m. forrum | 4,0 m² |
| 19 | Showroom | 55,1 m² |
| 20 | Salgschef | 24,0 m² |
| 21 | Direktør kontor | 24,0 m² |

| REV. | DATO: | ÆNDRINGER |
|---|---|---|
| REV. | | |
| REV. | | |
| REV. | | |
| REV. A | 19.11.2007 | Diverse ændringer |

BYGGESAG: Nyt Firmadomicil

BYGHERRE: Iceman - G.S. & Co. A/S

EMNE: 1. sals plan

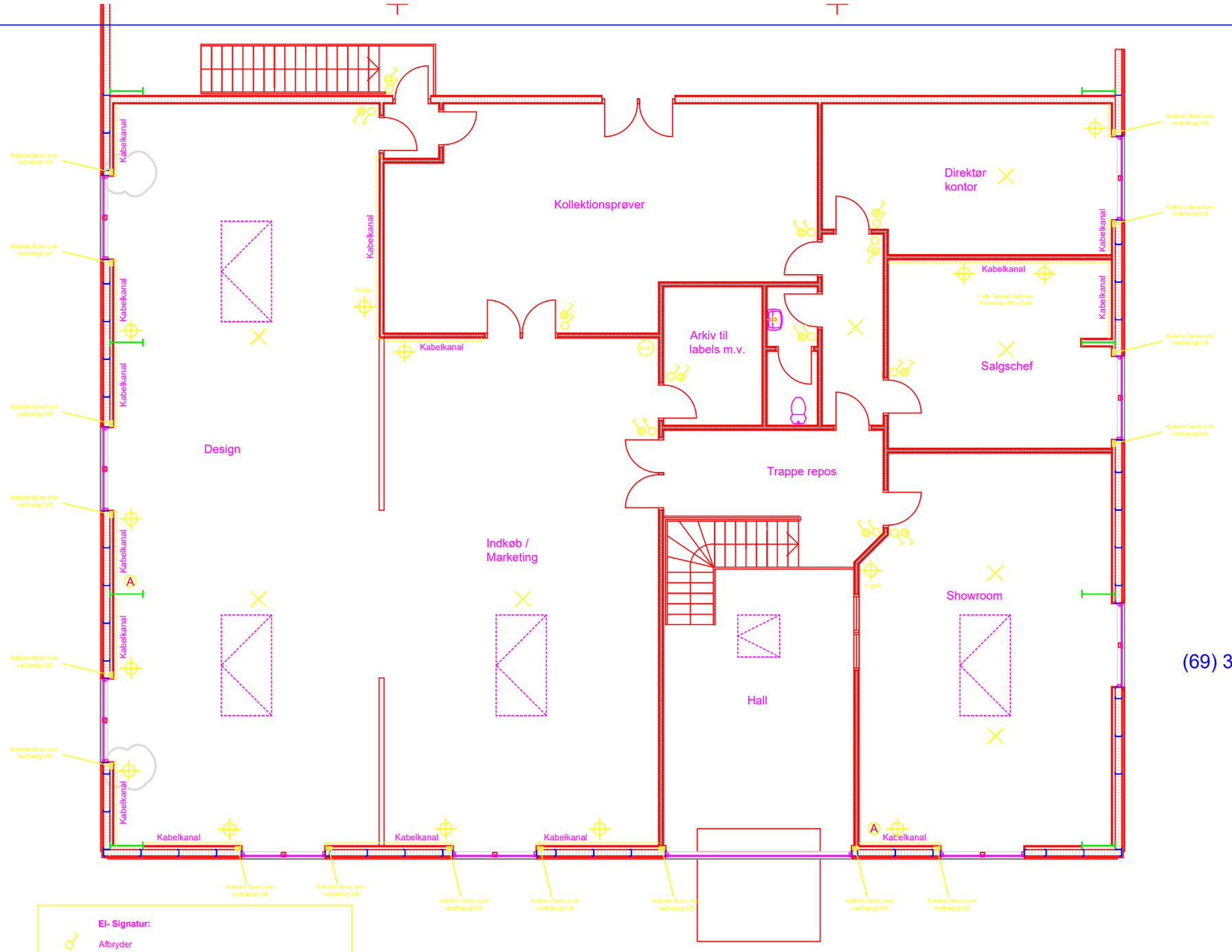
SAGSNR.: 1583

TEGN. NR.

DATO: 27.09.2007 MÅL: 1:100 TEGN. AF: BP

a/s dansk halentreprise
vejlevej 59 . dk-8700 horsens . tlf (+45) 75 64 23 66 . fax (+45) 75 64 39 20 . dh@danskhal.dk

(99) 3.2




**EI- Signatur:**

- Afbryder
- Afbryder m. korspondance
- 230 V. Stikkontakt
- 230 V. Dobbelt stikkontakt
- 400 V. Stikkontakt
- (A) Antennestik
- Vægudtag for spejlbelysning - Dåser siddende 2000 mm. over færdig gulv til overkant kontakt.
- G — Dåser siddende 300 mm. over færdig gulv til overkant kontakt.
- Arbejdsstation:
  -3 stk. 230 V. Stikkontakter
  -2 stk. EDB-Stik på selvstændig EDB-gruppe
  -Bagdåser til 1 stk. telefonstik, samt 1 stk. EDB-stik.
- Strømudtag til spot / lamper

| REV. | DATO: | ÆNDRINGER |
|---|---|---|
| B | 01.04.2008 | Diverse ændringer jf. fax af d. 27.03.2008 fra bygherre |
| A | 26.02.2008 | Diverse ændringer jf. fax af d. 25.02.2008 fra bygherre |

BYGGESAG: Nyt Firmadomicil

BYGHERRE: Iceman - G.S. & Co. A/S

EMNE: El-plan, 1. sal

SAGSNR.: 1583

TEGN. NR.

DATO: 22.02.2008 MÅL: 1:50 TEGN. AF: BP

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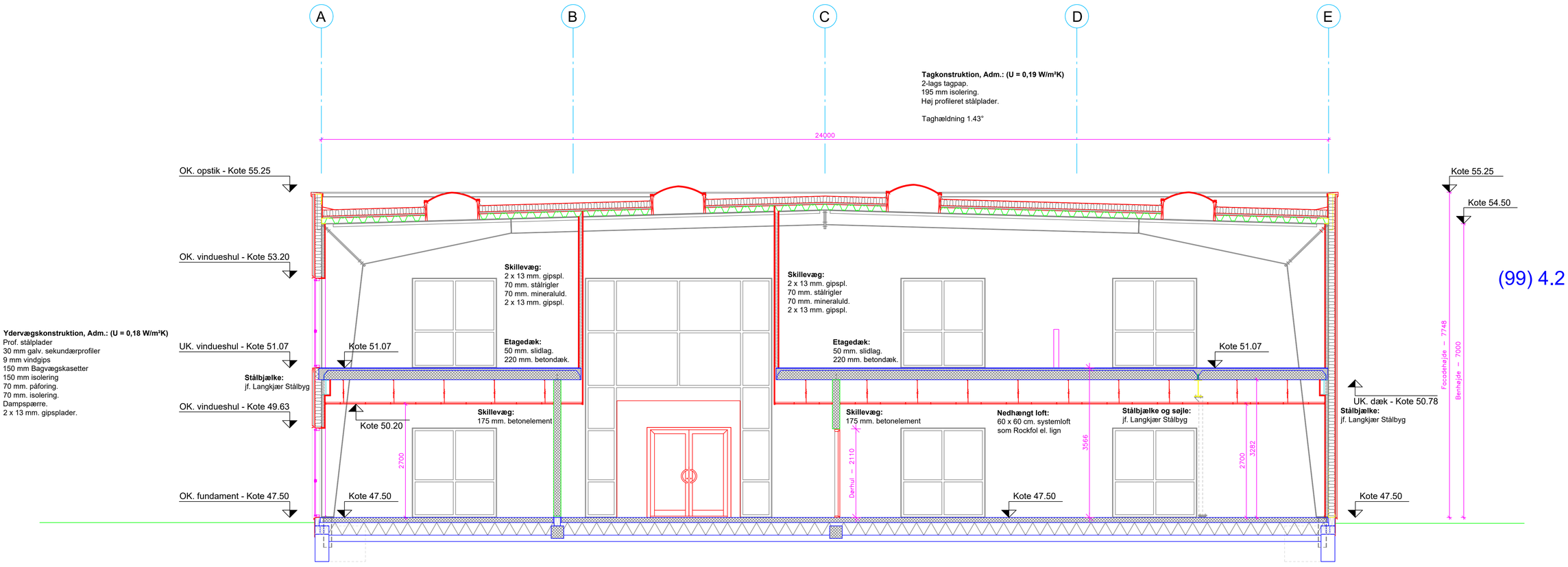
vejlevej 59 . dk-8700 horsens . tlf (+45) 75 64 23 66 . fax (+45) 75 64 39 20 . dh@danskhal.dk

(69) 3.2




Snit B:B

**Gulvkonstruktion, Adm.: (U = 0,11 W/m²K)**
120 mm maskinglittet armeret beton
300 mm Hård batts.
150 mm bundgrus

**Fundamenter:**
1 rk. 15 cm. Leca blokke.
1 rk. 33 cm. Lecaterm blok.
33 x 110 cm. stribefundamenter.
Punktfundamenter under rammeben og søjler.
Fundamenter udføres til min. frostfri.
Armering. jf. ingeniør

(99) 4.2

| REV. | DATO: | ÆNDRINGER |
|---|---|---|

BYGGESAG: Nyt Firmadomicil

BYGHERRE: Iceman - G.S. & Co. A/S

EMNE: Tværsnit B:B

SAGSNR.: 1583

TEGN. NR.

DATO: 27.09.2007 MÅL: 1:50 TEGN. AF: BP

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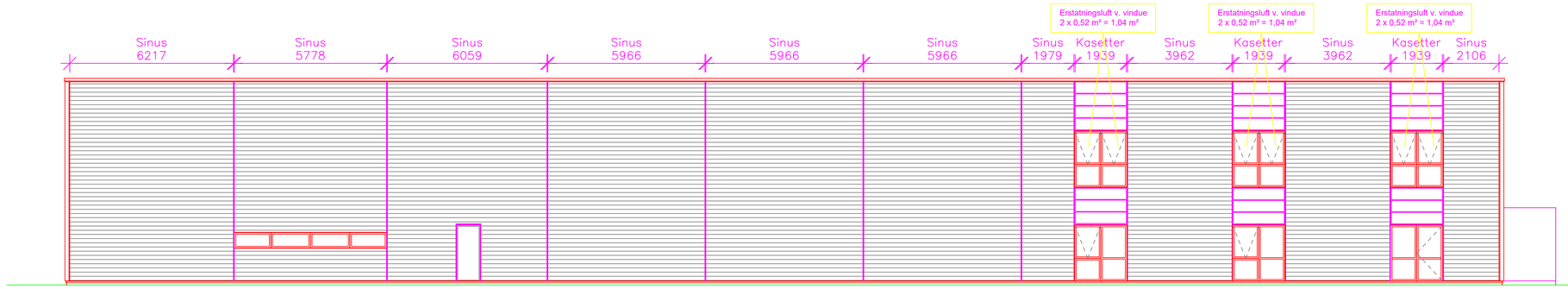
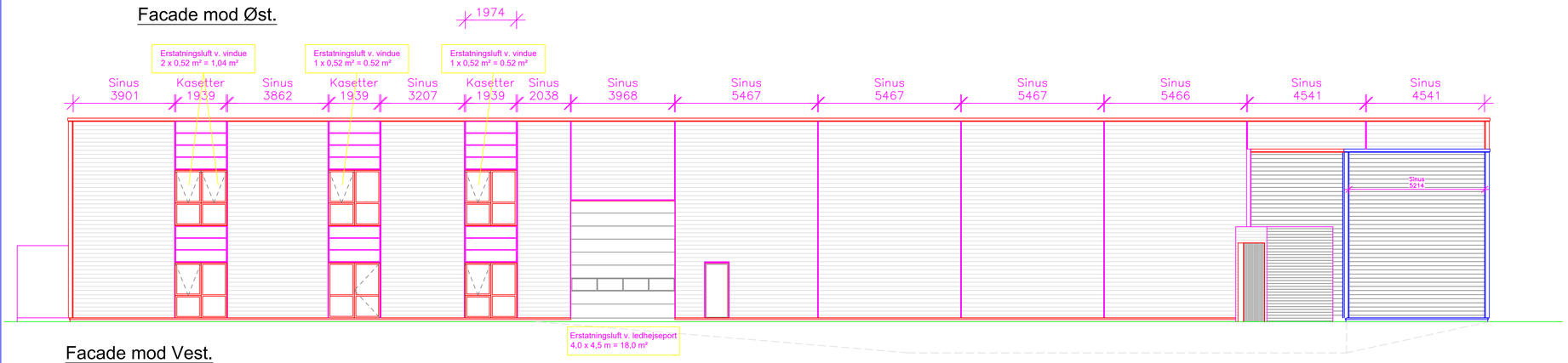
vejlevej 59 . dk-8700 horsens . tlf (+45) 75 64 23 66 . fax (+45) 75 64 39 20 . dh@danskhal.dk

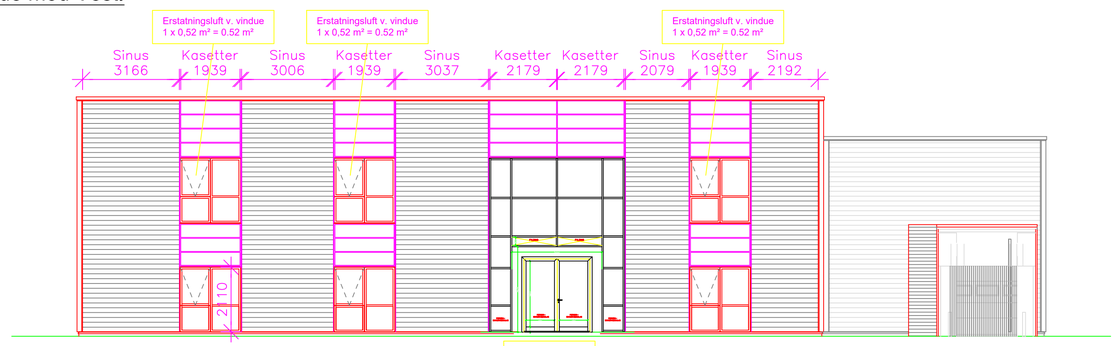
(99) 4.2



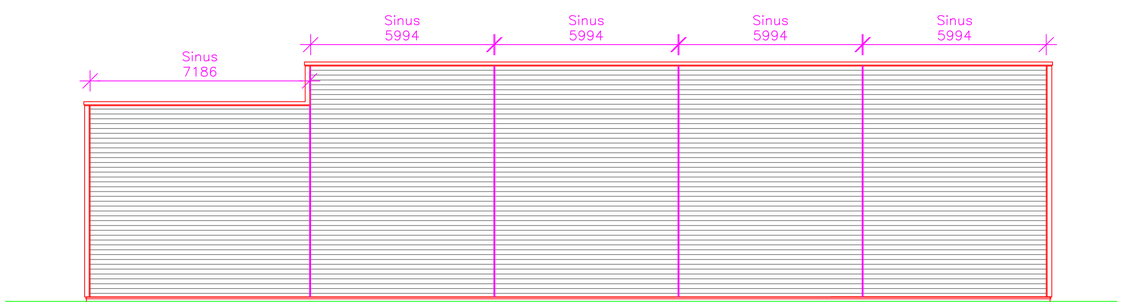

Facade mod Øst.




Facade mod Vest.




Facade mod Nord.




Facade mod Syd.

(99) 4.10

| | | | |
|---|---|---|---|
| REV. | C | 25.02.2008 | Ekstra vinduesparti er etableret |
| REV. | B | 15.01.2008 | Velfac vinduer ændret. |
| REV. | A | 19.11.2007 | Slusehus ændret |
| REV. | | DATO: | ÆNDRINGER |

BYGGESAG: Nyt Firmadomicil

BYGHERRE: Iceman - G.S. & Co. A/S

EMNE: Facader

SAGSNR.: 1583

TEGN. NR.

DATO: 27.09.2007 MÅL: 1:100 TEGN. AF: BP

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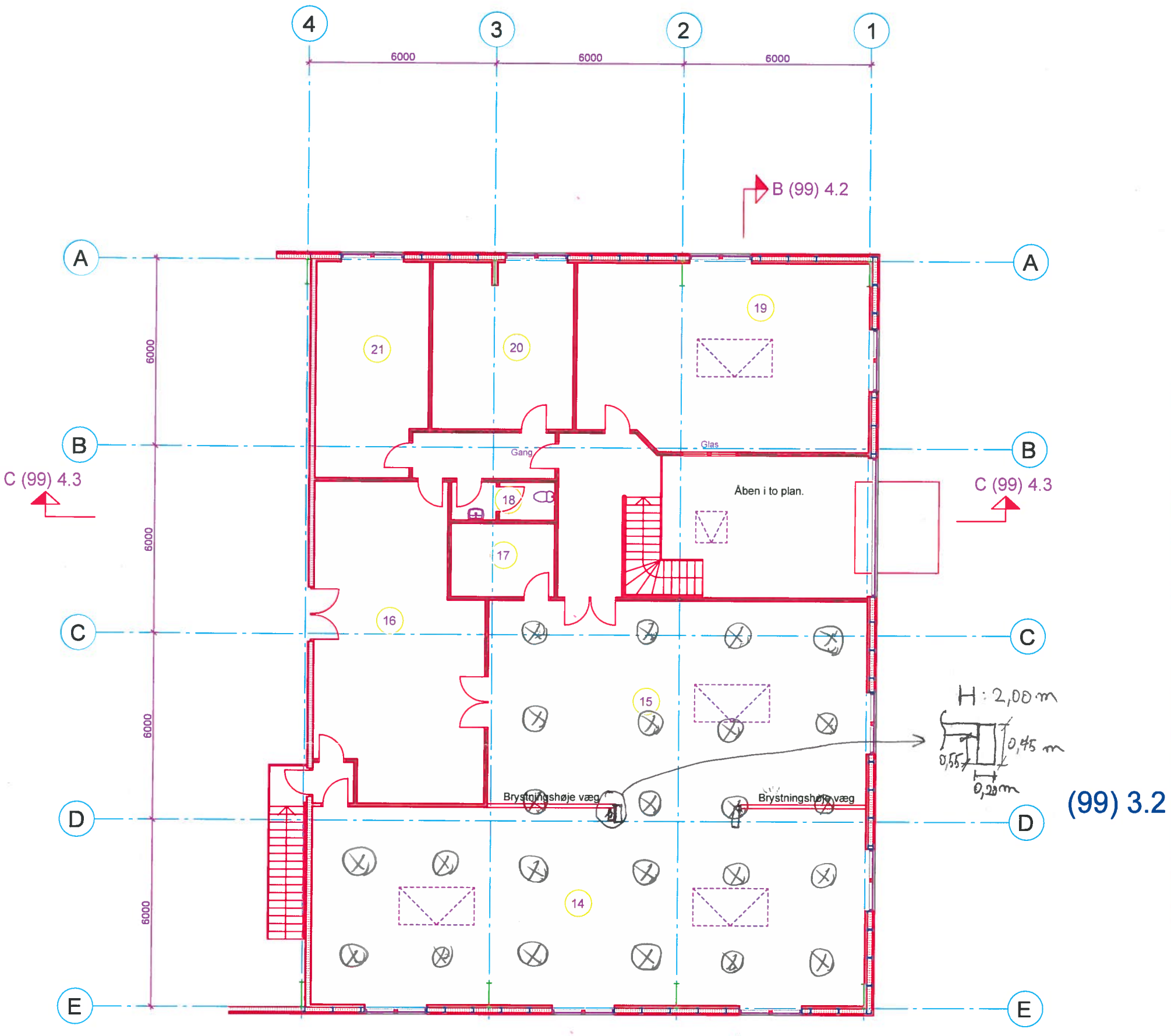
(99)4.10

# Appendix 4

Existing Lamps Positions




# Plan - 1. sal.

24 Pendant Lamps
Bulb Specifications: HL-CB-15-E27-830-F

| Rum nr.: | Betegnelse: | Netto areal: |
|---|---|---|
| 14 | Design | 110,0 m² |
| 15 | Indkøb / marketing | 81,1 m² |
| 16 | Kollekttionsprøver | 60,1 m² |
| 17 | Arkiv til labels m.v. | 7,8 m² |
| 18 | Toilet m. forrum | 4,0 m² |
| 19 | Showroom | 55,1 m² |
| 20 | Salgschef | 24,0 m² |
| 21 | Direktør kontor | 24,0 m² |

| REV. | DATO: | ÆNDRINGER |
|---|---|---|
| REV. | | |
| REV. | | |
| REV. | | |
| REV. A | 19.11.2007 | Diverse ændringer |

BYGGESAG: Nyt Firmadomicil

BYGHERRE: Iceman - G.S. & Co. A/S

EMNE: 1. sals plan

SAGSNR.: 1583

TEGN. NR.

DATO: 27.09.2007 MÅL: 1:100 TEGN. AF: BP

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(99) 3.2

# Appendix 5

Existing Light Source Specifications

# LED Industrial Bulb

## HL-CB-15-E27

**HeSaLight's LED Industrial Bulb is the most efficient and well-designed alternative to the traditional Incandescent bulb retrofit; Professional optics, selected components and consistency control as well as dimmable function make this bulb the ideal replacement choice.**

### LIGHT SPECIFICATIONS

| Color Temp(K) | Lumen (lm) | CRI (Ra) | SDCM | Efficiency (lm/W) | Beam angle (°) |
|---|---|---|---|---|---|
| 3000(+/-100) | 1170 | 80 | <5 | 78 | 360 |
| 4000(+/-150) | 1320 | 80 | <5 | 88 | 360 |

### POWER SPECIFICATIONS

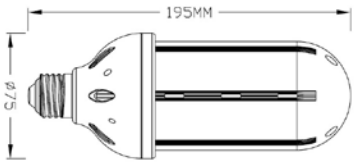
| Power (W) | Voltage (V) | Frequency (Hz) | Base | Dimmable | Power Factor |
|---|---|---|---|---|---|
| 15 | AC 85-265 | 50/60 | E27 | No | 0.5 |

### GENERAL SPECIFICATIONS

| LED source | Lifetime (hours) | Warranty (years) | PC Cover | Body Color | Material |
|---|---|---|---|---|---|
| Epistar SMD5050 | 50,000 | 5 | Frosted/Clear | White | Aluminum+Ceramic |

### DIMENSIONS

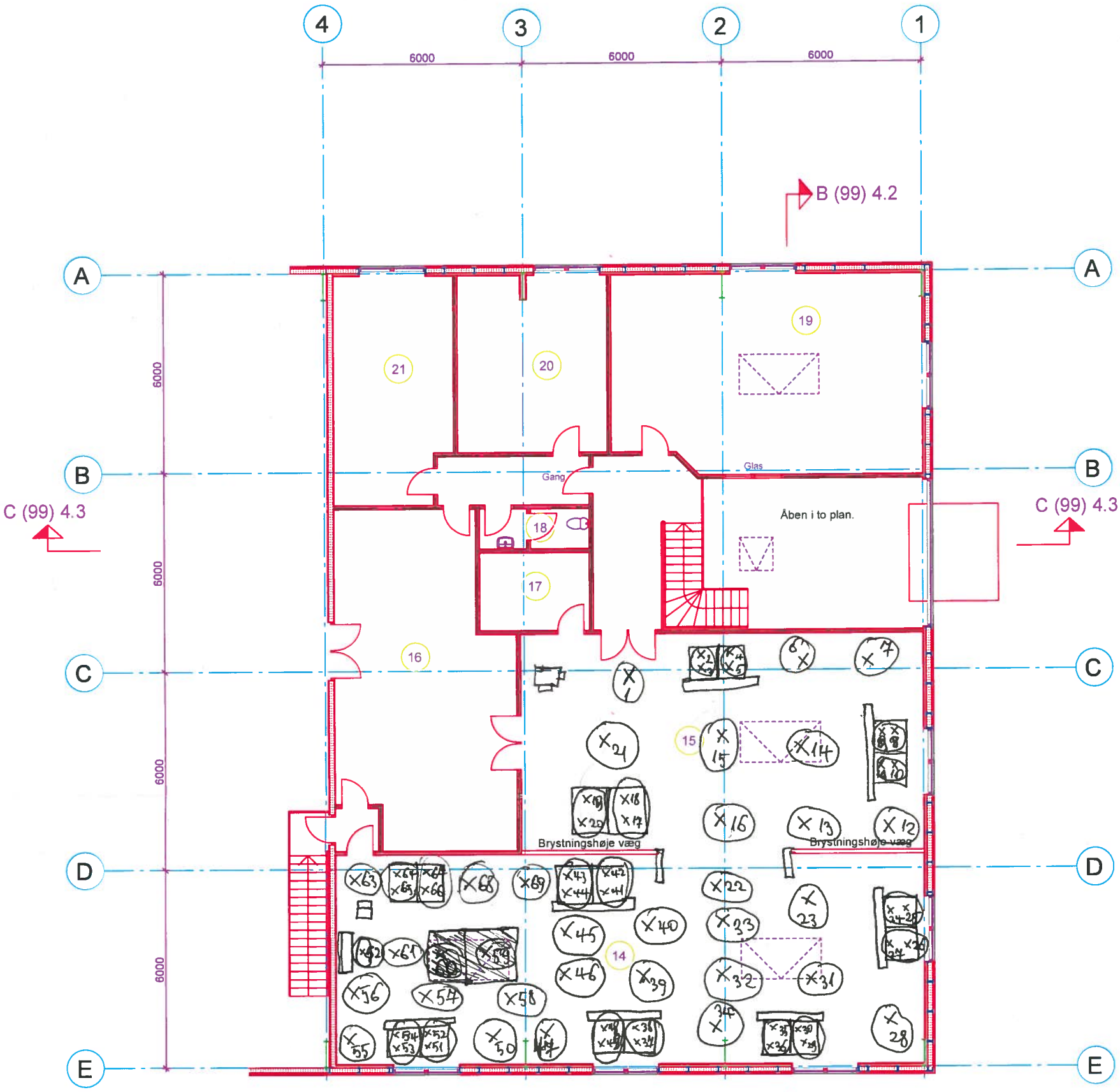
| Diameter (mm) | Height (mm) | Weight (kg) |
|---|---|---|
| Φ75 | 195 | 0.35 |




HeSaLight A/S – Lykkegaardsvej 9 4000 Roskilde Denmark– Tel: +45 3537 8888
www.hesalight.com email: info@hesalight.com

# Appendix 6

Daytime and Night-Time Horizontal Illuminance Measurements




## Plan - 1. sal.

05.05.2016 00:00 - 01:20
Night-time illuminance measurements
Electric light on
Outdoor contribution → low; can be ignored

26.04.2016 (16-17:00)
Daylight illuminance measurements
Electric light on
Cloudy day („constant" daylight)

| Rum nr.: | Betegnelse: | Netto areal: |
|---|---|---|
| 14 | Design | 110,0 m² |
| 15 | Indkøb / marketing | 81,1 m² |
| 16 | Kollekttionsprøver | 60,1 m² |
| 17 | Arkiv til labels m.v. | 7,8 m² |
| 18 | Toilet m. forrum | 4,0 m² |
| 19 | Showroom | 55,1 m² |
| 20 | Salgschef | 24,0 m² |
| 21 | Direktør kontor | 24,0 m² |

| REV. | | |
|---|---|---|
| REV. | | |
| REV. | | |
| REV. A | 19.11.2007 | Diverse ændringer |
| REV. | DATO: | ÆNDRINGER |

BYGGESAG: Nyt Firmadomicil

BYGHERRE: Iceman - G.S. & Co. A/S

EMNE: 1. sals plan

SAGSNR.: 1583

TEGN. NR.

DATO: 27.09.2007 MÅL: 1:100 TEGN. AF: BP

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(99) 3.2

| Daylight Horizontal Illuminance Measurements | | | |
|---|---|---|---|
| **Position** | **Height** | **Horizontal Illuminance** | **Average** |
| [-] | [m] | [lx] | |
| 1 | 0 | 147 | |
| 2 | 0.85 | 220 | 242 |
| 3 | 0.85 | 265 | |
| 4 | 0.85 | 267 | 327 |
| 5 | 0.85 | 386 | |
| 6 | 0 | 204 | |
| 7 | 0 | 188 | |
| 8 | 0.85 | 1195 | 804 |
| 9 | 0.85 | 413 | |
| 10 | 0.85 | 1370 | 1022 |
| 11 | 0.85 | 674 | |
| 12 | 0 | 315 | |
| 13 | 0 | 322 | |
| 14 | 0 | 622 | |
| 15 | 0 | 193 | |
| 16 | 0 | 280 | |
| 17 | 0.85 | 142 | 142 |
| 18 | 0.85 | 142 | |
| 19 | 0.85 | 122 | 126 |
| 20 | 0.85 | 129 | |
| 21 | 0 | 128 | |
| 22 | 0 | 547 | |
| 23 | 0 | 752 | |
| 24 | 0.85 | 1316 | 2165 |
| 25 | 0.85 | 3014 | |
| 26 | 0.85 | 2518 | 1903 |
| 27 | 0.85 | 1288 | |
| 28 | 0 | 851 | |
| 29 | 0.85 | 2067 | 2054 |
| 30 | 0.85 | 2040 | |
| 31 | 0 | 1024 | |
| 32 | 0 | 603 | |
| 33 | 0 | 572 | |
| 34 | 0 | 417 | |
| 35 | 0.85 | 543 | 444 |
| 36 | 0.85 | 344 | |
| 37 | 0.85 | 3535 | 2469 |
| 38 | 0.85 | 1403 | |
| 39 | 0 | 439 | |
| 40 | 0 | 267 | |
| 41 | 0.85 | 188 | 173 |
| 42 | 0.85 | 158 | |
| 43 | 0.85 | 128 | 124 |
| 44 | 0.85 | 119 | |
| 45 | 0 | 270 | |
| 46 | 0 | 296 | |
| 47 | 0 | 221 | |
| 48 | 0.85 | 560 | 1182 |
| 49 | 0.85 | 1803 | |
| 50 | 0 | 230 | |
| 51 | 0.85 | 2524 | 1648 |
| 52 | 0.85 | 773 | |
| 53 | 0.85 | 1166 | 940 |
| 54 | 0.85 | 715 | |
| 55 | 0 | 251 | |
| 56 | 0 | 246 | |
| 57 | 0 | 323 | |
| 58 | 0 | 324 | |
| 59 | 1 | 677 | |
| 60 | 1 | 749 | |
| 61 | 0 | 311 | |
| 62 | 0.25 | 277 | |
| 63 | 0 | 146 | |
| 64 | 0.85 | 189 | 306 |
| 65 | 0.85 | 423 | |
| 66 | 0.85 | 538 | 501 |
| 67 | 0.85 | 465 | |
| 68 | 0 | 353 | |
| 69 | 0 | 180 | |
| | | | |
| **To be correlated with the technical drawing** | | | |

| Night-time Horizontal Illuminance Measurements | | | |
|---|---|---|---|
| **Position** | **Height** | **Horizontal Illuminance** | **Average** |
| [-] | [m] | [lx] | [lx] |
| 1 | 0 | 55 | |
| 2 | 0.85 | 60 | 55 |
| 3 | 0.85 | 50 | |
| 4 | 0.85 | 40 | 40 |
| 5 | 0.85 | 40 | |
| 6 | 0 | 40 | |
| 7 | 0 | 53 | |
| 8 | 0.85 | 55 | 51 |
| 9 | 0.85 | 47 | |
| 10 | 0.85 | 55 | 58 |
| 11 | 0.85 | 61 | |
| 12 | 0 | 54 | |
| 13 | 0 | 63 | |
| 14 | 0 | 71 | |
| 15 | 0 | 61 | |
| 16 | 0 | 66 | |
| 17 | 0.85 | 84 | 77 |
| 18 | 0.85 | 70 | |
| 19 | 0.85 | 70 | 72 |
| 20 | 0.85 | 73 | |
| 21 | 0 | 50 | |
| 22 | 0 | 77 | |
| 23 | 0 | 58 | |
| 24 | 0.85 | 51 | 52 |
| 25 | 0.85 | 53 | |
| 26 | 0.85 | 54 | 51 |
| 27 | 0.85 | 47 | |
| 28 | 0 | 53 | |
| 29 | 0.85 | 50 | 53 |
| 30 | 0.85 | 55 | |
| 31 | 0 | 57 | |
| 32 | 0 | 66 | |
| 33 | 0 | 80 | |
| 34 | 0 | 57 | |
| 35 | 0.85 | 54 | 51 |
| 36 | 0.85 | 47 | |
| 37 | 0.85 | 57 | 60 |
| 38 | 0.85 | 62 | |
| 39 | 0 | 70 | |
| 40 | 0 | 65 | |
| 41 | 0.85 | 93 | 94 |
| 42 | 0.85 | 94 | |
| 43 | 0.85 | 64 | 59 |
| 44 | 0.85 | 54 | |
| 45 | 0 | 63 | |
| 46 | 0 | 54 | |
| 47 | 0 | 41 | |
| 48 | 0.85 | 64 | 59 |
| 49 | 0.85 | 53 | |
| 50 | 0 | 43 | |
| 51 | 0.85 | 41 | 44 |
| 52 | 0.85 | 47 | |
| 53 | 0.85 | 51 | 52 |
| 54 | 0.85 | 53 | |
| 55 | 0 | 40 | |
| 56 | 0 | 43 | |
| 57 | 0 | 25 | |
| 58 | 0 | 34 | |
| 59 | 1 | 77 | |
| 60 | 1 | 75 | |
| 61 | 0 | 28 | |
| 62 | 0.25 | 64 | |
| 63 | 0 | 36 | |
| 64 | 0.85 | 39 | 43 |
| 65 | 0.85 | 47 | |
| 66 | 0.85 | 34 | 31 |
| 67 | 0.85 | 28 | |
| 68 | 0 | 20 | |
| 69 | 0 | 40 | |
| | | | |
| **To be correlated with the technical drawing** | | | |

# Appendix 7

Daylight Factor Calculation Report

# HeSaLight Sales Office - Daylight Factor

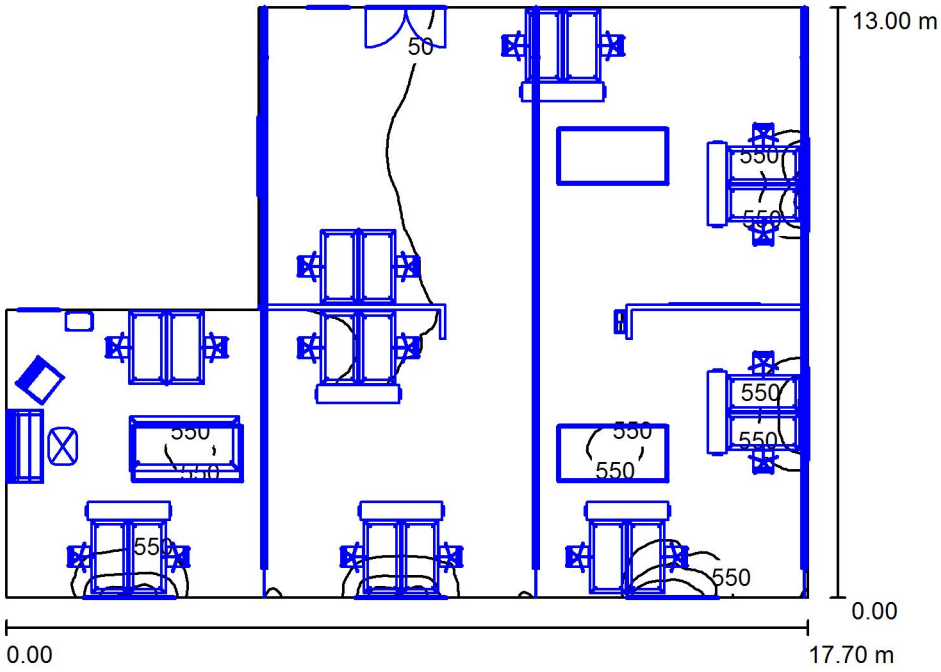
Date: 16.05.2016
Operator: Alexandru Daniel Vlas

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Table of contents

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Daylight / Summary




Height of Room: 3.750 m, Light loss factor: 0.90 Values in Lux, Scale 1:167

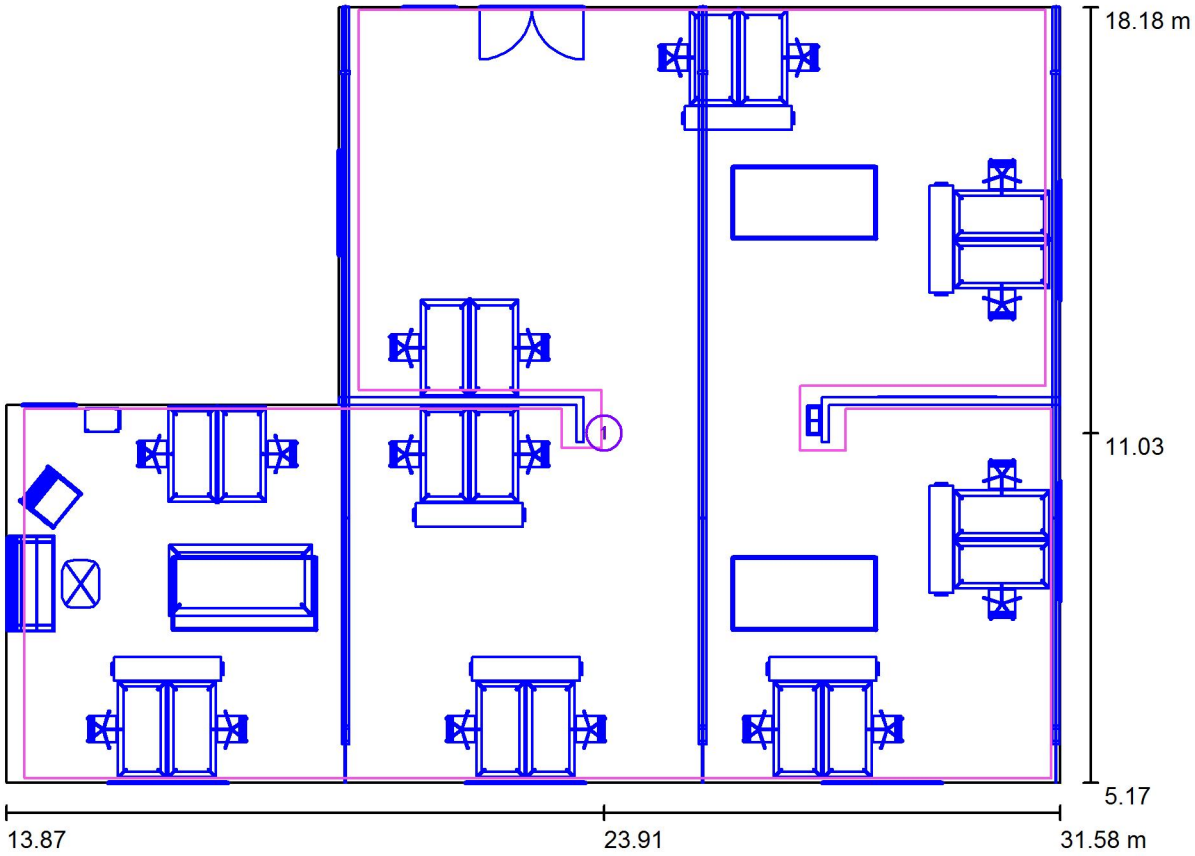
| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 261 | 11 | 2270 | 0.044 |
| Floor | 20 | 212 | 12 | 1524 | 0.056 |
| Ceiling | 70 | 0.91 | 0.81 | 1.06 | 0.888 |
| Walls (7) | 75 | 68 | 13 | 257 | / |

**Workplane:**
Height: 0.850 m
Grid: 128 x 128 Points
Boundary Zone: 0.000 m
Illuminance Quotient (according to LG7): Walls / Working Plane: - , Ceiling / Working Plane: - .

Pure daylight scene, no luminaires involved.

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Sales Office / Daylight / Daylight Factor Surfaces (Coordinates List)



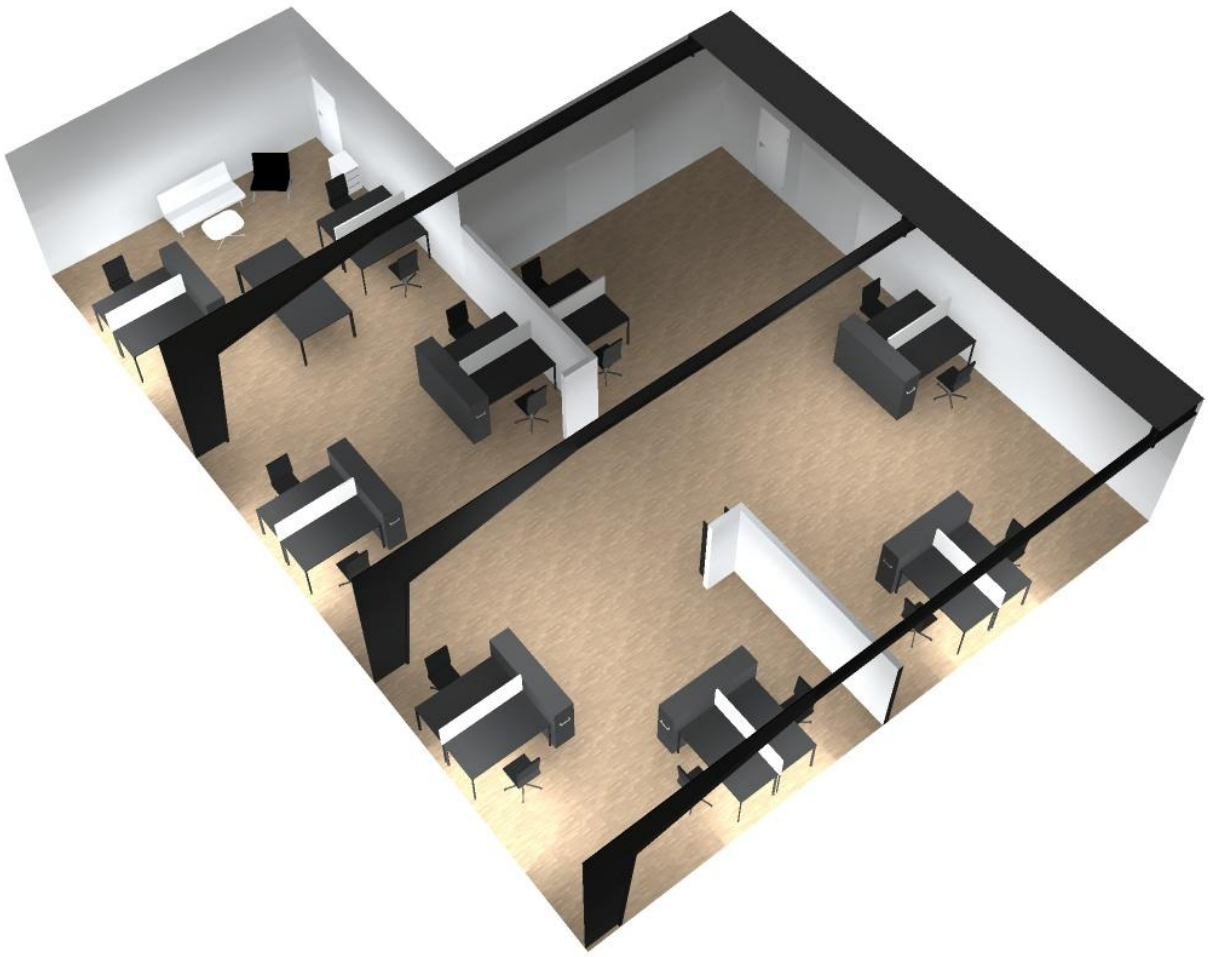

Scale 1 : 127

## Daylight factor surface list

| No. | Designation | Position [m] X | Y | Z | Size [m] L | W | Rotation [°] X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Daylight factor calculation surface 5 | 23.914 | 11.035 | 0.820 | 17.237 | 12.888 | 0.000 | 0.000 | 0.000 |

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

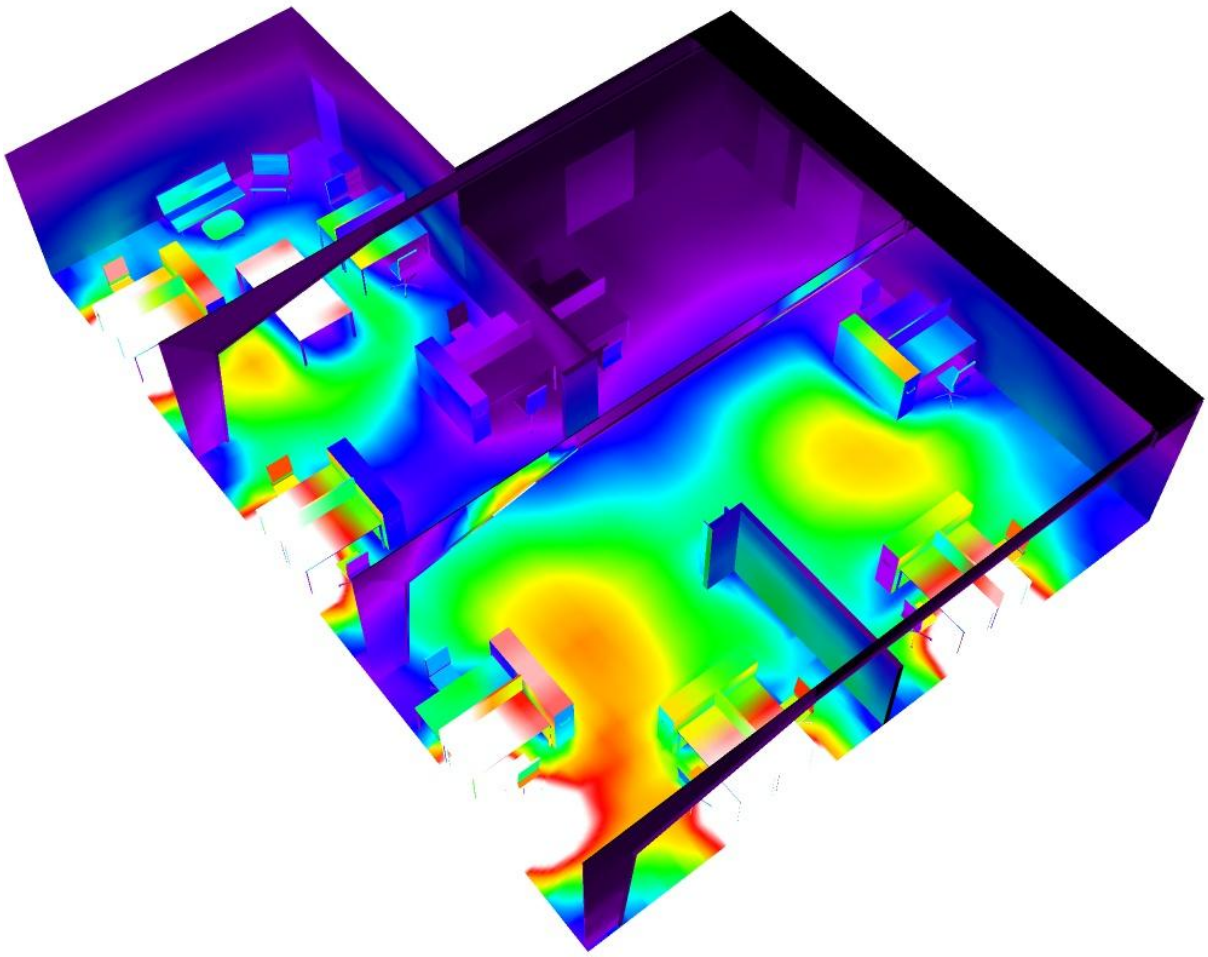
## Sales Office / Daylight / 3D Rendering



16.05.2016

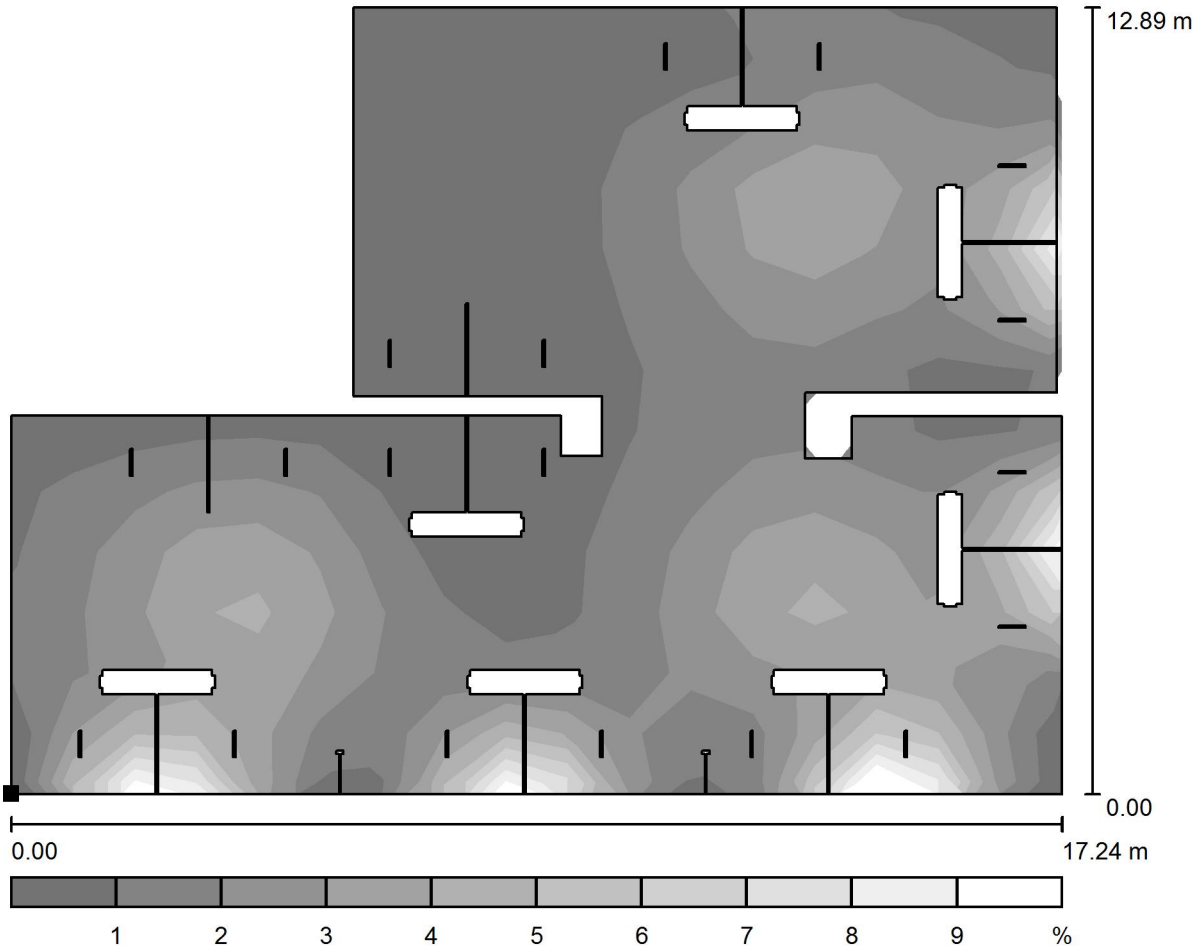
Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Daylight / False Color Rendering



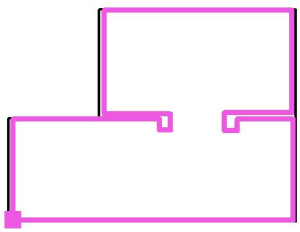
Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Daylight / Daylight factor calculation surface 5 / Greyscale (D)




Scale 1 : 124

Position of surface in room:
Marked point:
(14.181 m, 5.244 m, 0.820 m)



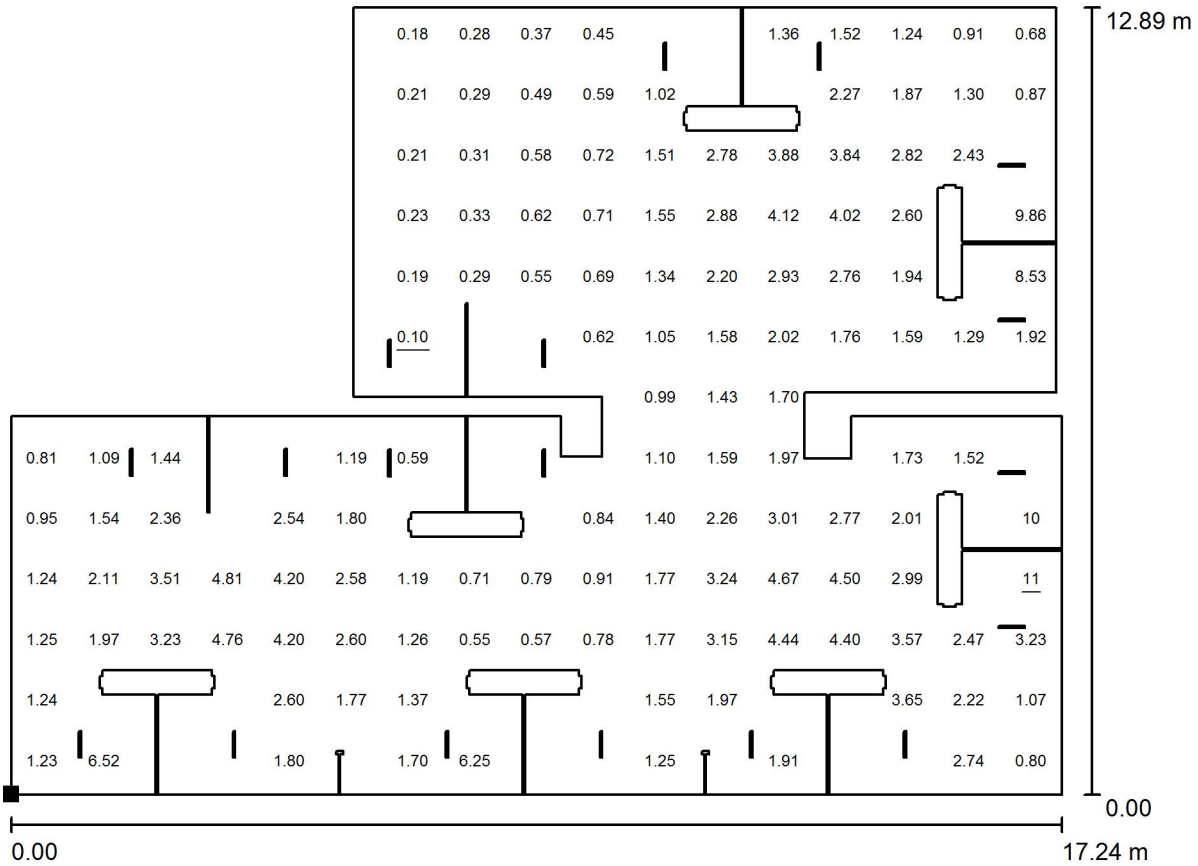
Grid: 17 x 13 Points

| $D_{av}$ [%] | $D_{min}$ [%] | $D_{max}$ [%] | $D_{min}$ / $D_{av}$ | $D_{min}$ / $D_{max}$ |
|---|---|---|---|---|
| 2.20 | 0.10 | 11 | 0.045 | 0.009 |

Horizontal illuminance outdoors $E_o$: 12209 lx

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

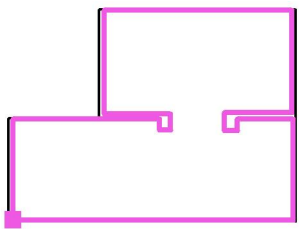
## Sales Office / Daylight / Daylight factor calculation surface 5 / Value Chart (D)




Scale 1 : 124

Not all calculated values could be displayed.

Position of surface in room:
Marked point:
(14.181 m, 5.244 m, 0.820 m)



Grid: 17 x 13 Points

| $D_{av}$ [%] | $D_{min}$ [%] | $D_{max}$ [%] | $D_{min}$ / $D_{av}$ | $D_{min}$ / $D_{max}$ |
|---|---|---|---|---|
| 2.20 | 0.10 | 11 | 0.045 | 0.009 |

Horizontal illuminance outdoors $E_o$: 12209 lx

# Appendix 8

Proposed Solution Calculation Report

Light Fixtures Specifications

# HeSaLight Sales Office - Proposed Solution

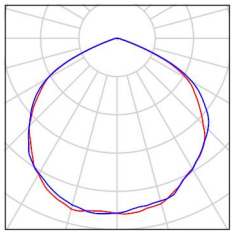
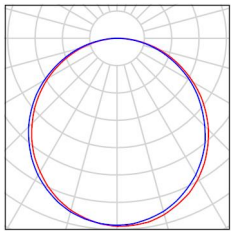
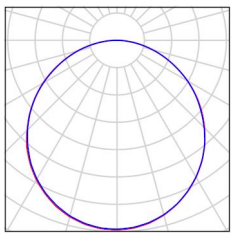
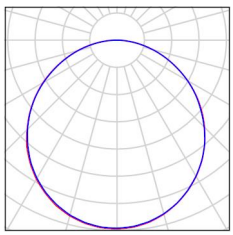
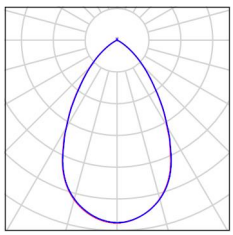
Date: 21.05.2016
Operator: Alexandru Daniel Vlas

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Table of contents

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## HeSaLight Sales Office - Proposed Solution / Luminaire parts list

| | | | |
|---|---|---|---|
| 6 Pieces | HeSaLight HL-HB-CALI-70-840-120D-OL<br>Article No.:<br>Luminous flux (Luminaire): 9000 lm<br>Luminous flux (Lamps): 9000 lm<br>Luminaire Wattage: 70.0 W<br>Luminaire classification according to CIE: 100<br>CIE flux code: 51 86 99 100 100<br>Fitting: 1 x User defined (Correction Factor 1.000). | See our luminaire catalog for an image of the luminaire. |  |
| 2 Pieces | HeSaLight HL-PL-AIKO-40-1195295-840<br>Article No.:<br>Luminous flux (Luminaire): 3796 lm<br>Luminous flux (Lamps): 3800 lm<br>Luminaire Wattage: 40.0 W<br>Luminaire classification according to CIE: 100<br>CIE flux code: 46 77 95 100 100<br>Fitting: 1 x Runlite SMD2835 (Correction Factor 1.000). | See our luminaire catalog for an image of the luminaire. |  |
| 4 Pieces | HeSaLight HL-PL-AIKO-40-595595-840<br>Article No.:<br>Luminous flux (Luminaire): 3796 lm<br>Luminous flux (Lamps): 3800 lm<br>Luminaire Wattage: 40.0 W<br>Luminaire classification according to CIE: 100<br>CIE flux code: 46 78 95 100 100<br>Fitting: 1 x Runlite SMD2835 (Correction Factor 1.000). | See our luminaire catalog for an image of the luminaire. |  |
| 6 Pieces | HeSaLight HL-PL-AIKO-45-595595-840<br>Article No.:<br>Luminous flux (Luminaire): 4270 lm<br>Luminous flux (Lamps): 4275 lm<br>Luminaire Wattage: 45.0 W<br>Luminaire classification according to CIE: 100<br>CIE flux code: 46 78 95 100 100<br>Fitting: 1 x Runlite SMD2835 (Correction Factor 1.000). | See our luminaire catalog for an image of the luminaire. |  |
| 6 Pieces | HeSaLight HL-RDLA-GABI2-24-R-165-840-60D<br>Article No.:<br>Luminous flux (Luminaire): 2313 lm<br>Luminous flux (Lamps): 2313 lm<br>Luminaire Wattage: 24.0 W<br>Luminaire classification according to CIE: 100<br>CIE flux code: 82 99 100 100 100<br>Fitting: 1 x undefined (Correction Factor 1.000). | See our luminaire catalog for an image of the luminaire. |  |

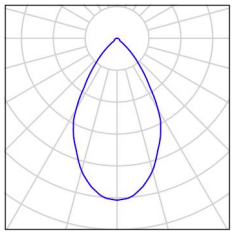
21.05.2016

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## HeSaLight Sales Office - Proposed Solution / Luminaire parts list

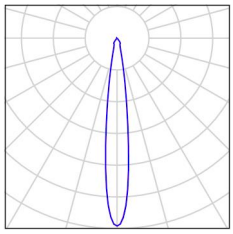
1 Pieces HeSaLight HL-TL-CATO CYL-12-B-930-60D
Article No.:
Luminous flux (Luminaire): 1004 lm
Luminous flux (Lamps): 1023 lm
Luminaire Wattage: 12.0 W
Luminaire classification according to CIE: 100
CIE flux code: 88 97 99 100 98
Fitting: 1 x undefined (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



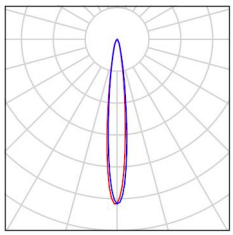
2 Pieces HeSaLight HL-TL-CATO-18-930-12D-A
Article No.:
Luminous flux (Luminaire): 1958 lm
Luminous flux (Lamps): 2000 lm
Luminaire Wattage: 12.0 W
Luminaire classification according to CIE: 100
CIE flux code: 100 100 100 100 98
Fitting: 1 x CLU024 (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



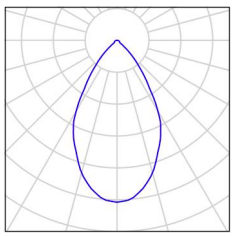
2 Pieces HeSaLight HL-TL-COSMO-18-940-W-15D
Article No.:
Luminous flux (Luminaire): 988 lm
Luminous flux (Lamps): 990 lm
Luminaire Wattage: 18.0 W
Luminaire classification according to CIE: 100
CIE flux code: 97 99 100 100 100
Fitting: 1 x NICHIA (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



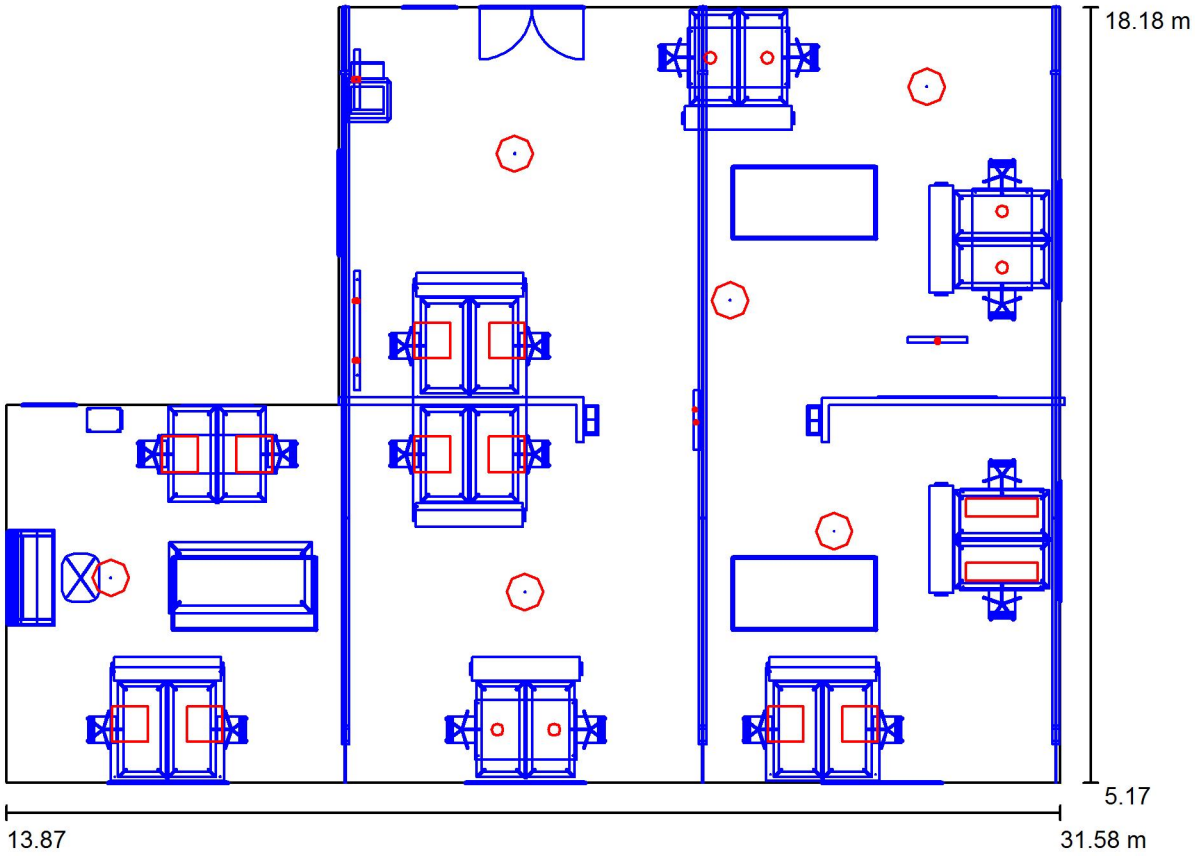
1 Pieces HeSaLight HL-TL-COSMO-18-940-W-60D
Article No.:
Luminous flux (Luminaire): 972 lm
Luminous flux (Lamps): 990 lm
Luminaire Wattage: 18.0 W
Luminaire classification according to CIE: 100
CIE flux code: 88 97 99 100 98
Fitting: 1 x NICHIA (Correction Factor 1.000).

See our luminaire catalog for an image of the luminaire.



Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

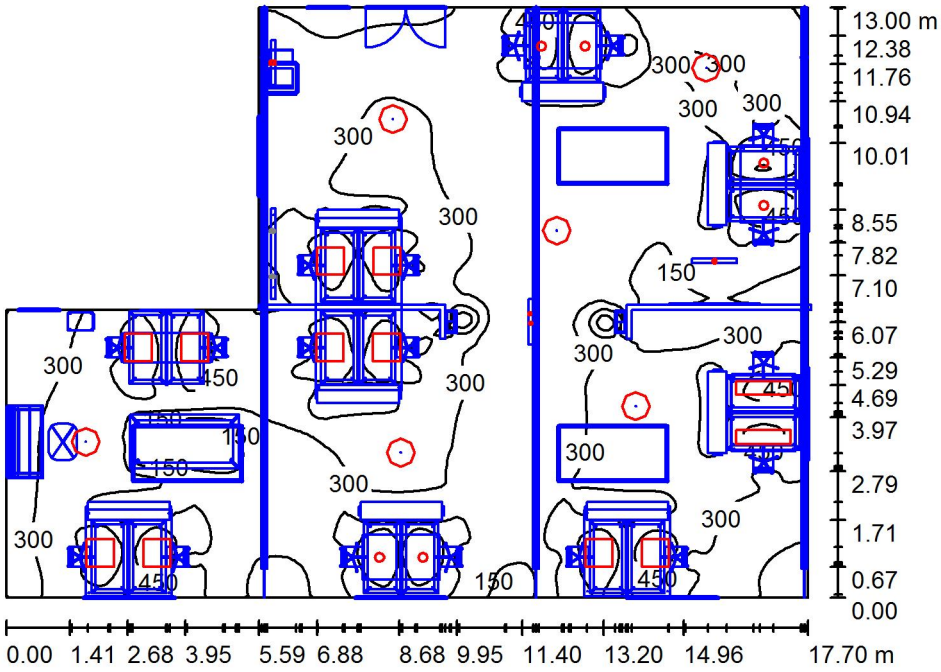
## Sales Office / Floor plan




Scale 1 : 127

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Night Work / Summary




Height of Room: 3.750 m, Light loss factor: 0.90 Values in Lux, Scale 1:167

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 301 | 23 | 738 | 0.078 |
| Floor | 20 | 188 | 17 | 366 | 0.092 |
| Ceiling | 70 | 1.93 | 0.94 | 6.87 | 0.485 |
| Walls (7) | 75 | 122 | 4.02 | 861 | / |

**Workplane:**

| | |
|---|---|
| Height: | 0.850 m |
| Grid: | 128 x 128 Points |
| Boundary Zone: | 0.000 m |

Illuminance Quotient (according to LG7): Walls / Working Plane: - , Ceiling / Working Plane: - .

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 6 | HeSaLight HL-HB-CALI-70-840-120D-OL (1.000) | 9000 | 9000 | 70.0 |
| 2 | 2 | HeSaLight HL-PL-AIKO-40-1195295-840 (1.000) | 3796 | 3800 | 40.0 |
| 3 | 4 | HeSaLight HL-PL-AIKO-40-595595-840 (1.000) | 3796 | 3800 | 40.0 |
| 4 | 6 | HeSaLight HL-PL-AIKO-45-595595-840 (1.000) | 4270 | 4275 | 45.0 |
| 5 | 6 | HeSaLight HL-RDLA-GABI2-24-R-165-840-60D (1.000) | 2313 | 2313 | 24.0 |
| 6 | 1 | HeSaLight HL-TL-CATO CYL-12-B-930-60D (1.000) | 1004 | 1023 | 12.0 |

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Night Work / Summary

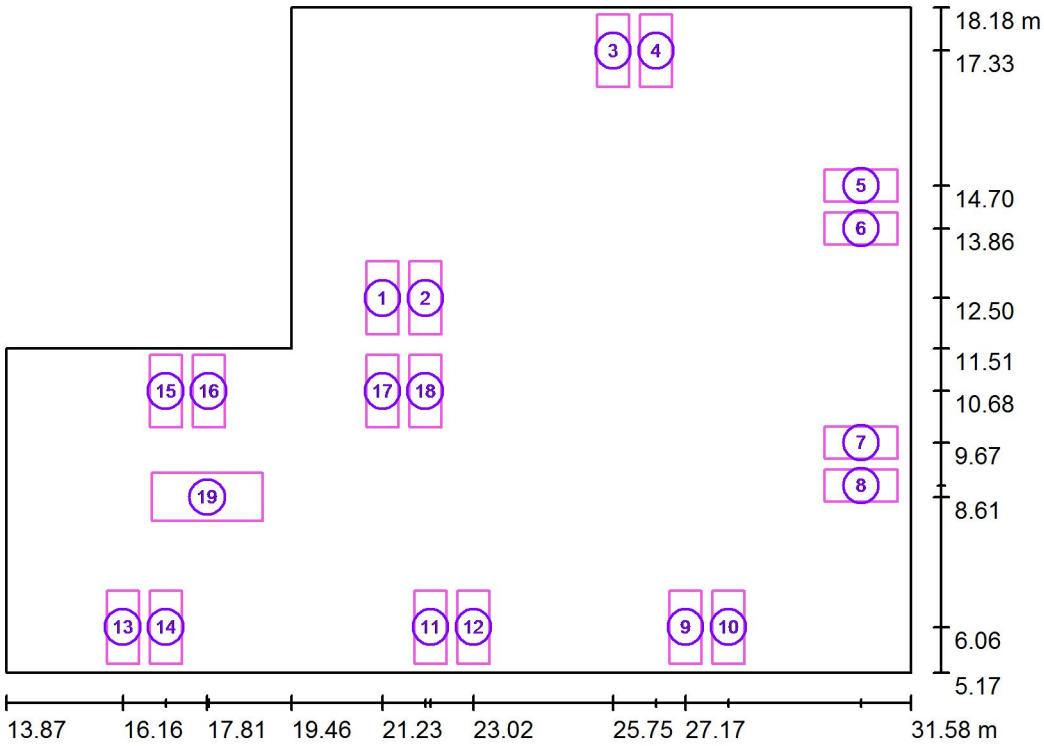
### Luminaire Parts List

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 7 | 2 | HeSaLight HL-TL-CATO-18-930-12D-A (1.000) | 1958 | 2000 | 12.0 |
| 8 | 1 | HeSaLight HL-TL-COSMO-18-940-W-60D (1.000) | 972 | 990 | 18.0 |
| | | | Total: 122160 | Total: 122341 | 1128.0 |

Specific connected load: 5.85 W/m² = 1.94 W/m²/100 lx (Ground area: 192.92 m²)

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Sales Office / Night Work / Calculation surfaces (results overview)




Scale 1 : 148

## Calculation Surface List

| No. | Designation | Type | Grid | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | Calculation Surface WA9/T1 | horizontal | 4 x 8 | 470 | 354 | 554 | 0.753 | 0.639 |
| 2 | Calculation Surface WA9/T2 | horizontal | 4 x 8 | 485 | 363 | 577 | 0.748 | 0.629 |
| 3 | Calculation Surface WA1/T1 | horizontal | 8 x 16 | 468 | 301 | 568 | 0.643 | 0.529 |
| 4 | Calculation Surface WA1/T2 | horizontal | 8 x 16 | 495 | 331 | 592 | 0.669 | 0.559 |
| 5 | Calculation Surface WA2/T1 | horizontal | 8 x 16 | 520 | 358 | 620 | 0.688 | 0.577 |
| 6 | Calculation Surface WA2/T2 | horizontal | 8 x 16 | 484 | 317 | 588 | 0.655 | 0.540 |
| 7 | Calculation Surface WA3/T1 | horizontal | 4 x 8 | 448 | 354 | 509 | 0.790 | 0.694 |
| 8 | Calculation Surface WA3/T2 | horizontal | 4 x 8 | 437 | 305 | 509 | 0.699 | 0.600 |
| 9 | Calculation Surface WA4/T1 | horizontal | 4 x 8 | 495 | 359 | 569 | 0.725 | 0.631 |

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Sales Office / Night Work / Calculation surfaces (results overview)

## Calculation Surface List

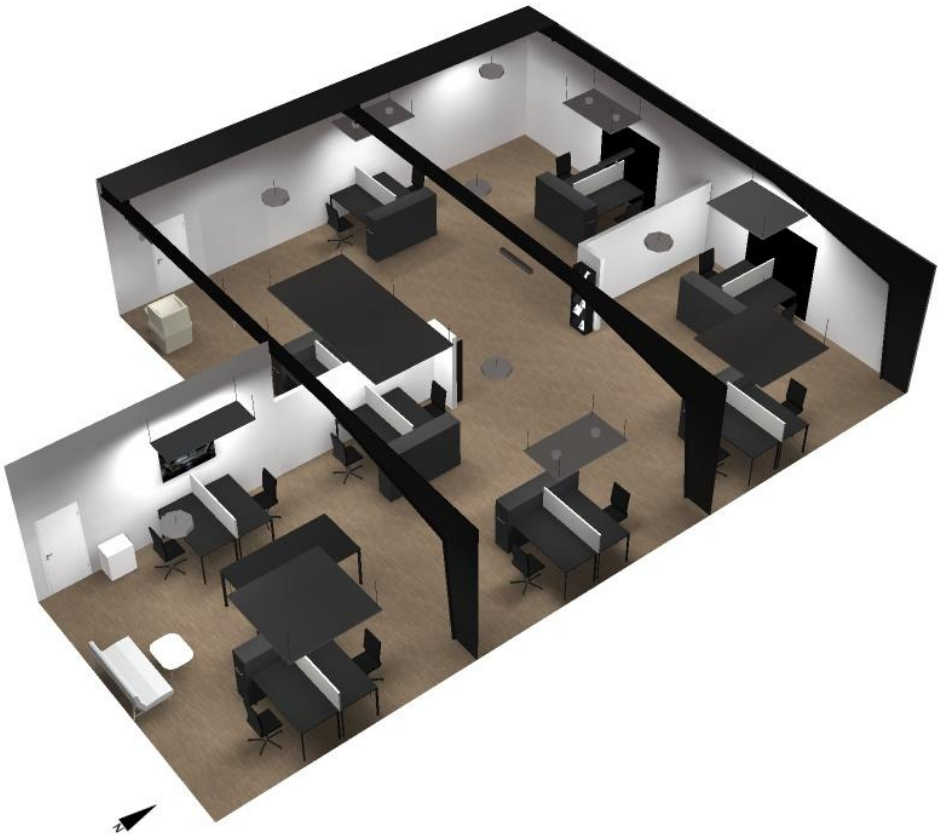
| No. | Designation | Type | Grid | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|---|---|
| 10 | Calculation Surface WA4/T2 | horizontal | 4 x 8 | 471 | 329 | 555 | 0.699 | 0.593 |
| 11 | Calculation Surface WA5/T1 | horizontal | 8 x 16 | 500 | 317 | 608 | 0.634 | 0.521 |
| 12 | Calculation Surface WA5/T2 | horizontal | 8 x 16 | 496 | 321 | 608 | 0.647 | 0.528 |
| 13 | Calculation Surface WA6/T1 | horizontal | 4 x 8 | 490 | 355 | 565 | 0.725 | 0.628 |
| 14 | Calculation Surface WA6/T2 | horizontal | 4 x 8 | 471 | 335 | 550 | 0.712 | 0.610 |
| 15 | Calculation Surface WA7/T1 | horizontal | 4 x 8 | 490 | 394 | 537 | 0.803 | 0.734 |
| 16 | Calculation Surface WA7/T2 | horizontal | 4 x 8 | 481 | 376 | 537 | 0.783 | 0.701 |
| 17 | Calculation Surface WA8/T1 | horizontal | 4 x 8 | 503 | 389 | 575 | 0.774 | 0.677 |
| 18 | Calculation Surface WA8/T2 | horizontal | 4 x 8 | 488 | 375 | 566 | 0.770 | 0.663 |
| 19 | Calculation Surface COM-TBL | horizontal | 16 x 8 | 326 | 242 | 412 | 0.743 | 0.588 |

## Summary of Results

| Type | Quantity | Average [lx] | Min [lx] | Max [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| horizontal | 19 | 465 | 242 | 620 | 0.52 | 0.39 |

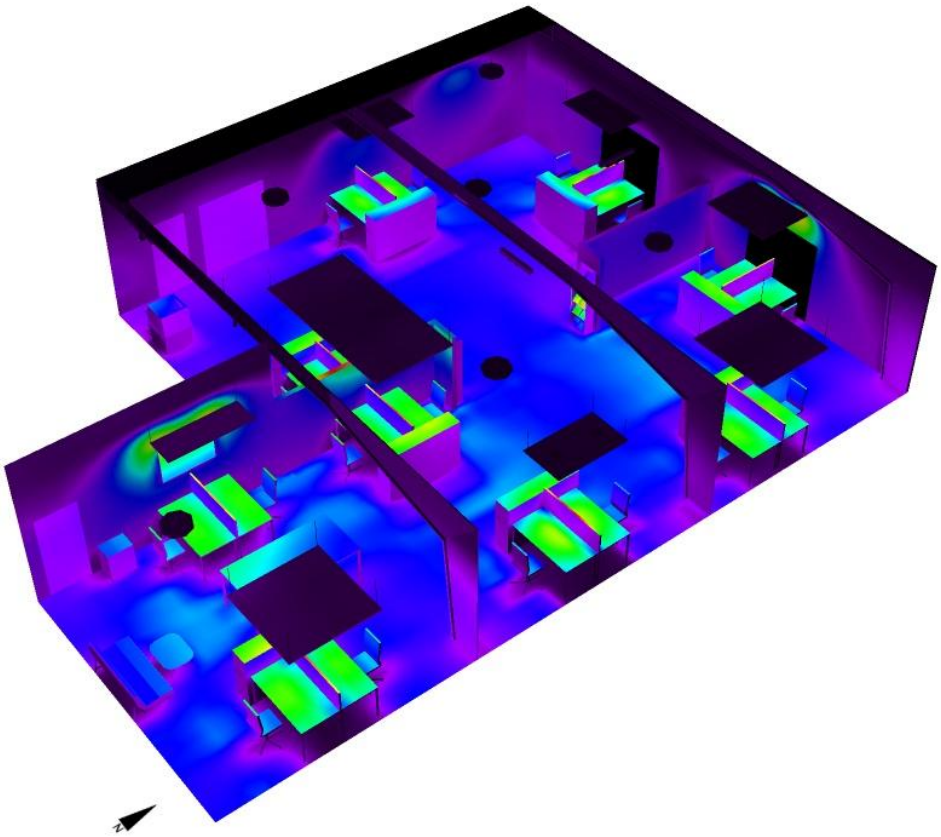
Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

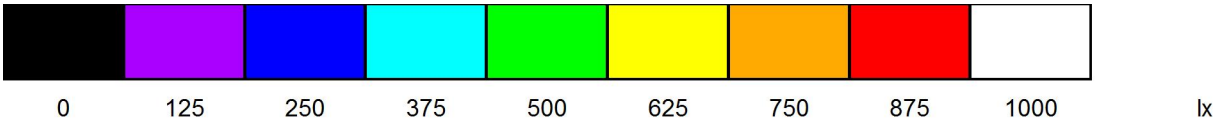
## Sales Office / Night Work / 3D Rendering



Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

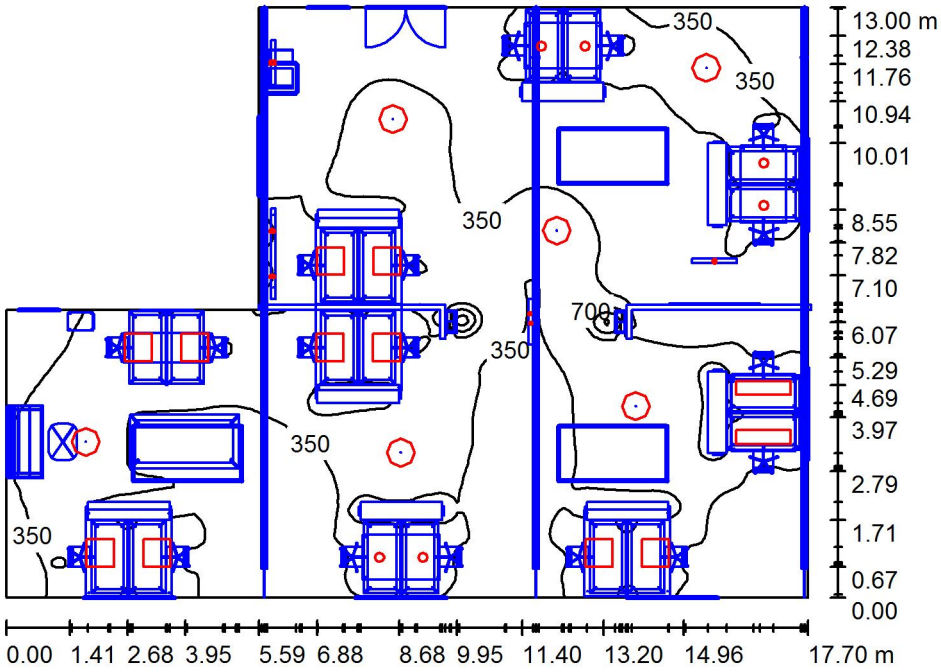
## Sales Office / Night Work / False Color Rendering





Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Showroom / Summary




Height of Room: 3.750 m, Light loss factor: 0.90 Values in Lux, Scale 1:167

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 366 | 27 | 1589 | 0.075 |
| Floor | 20 | 236 | 19 | 703 | 0.082 |
| Ceiling | 70 | 2.23 | 1.11 | 7.81 | 0.498 |
| Walls (7) | 75 | 147 | 4.75 | 1993 | / |

**Workplane:**

| | |
|---|---|
| Height: | 0.850 m |
| Grid: | 128 x 128 Points |
| Boundary Zone: | 0.000 m |

Illuminance Quotient (according to LG7): Walls / Working Plane: - , Ceiling / Working Plane: - .

**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 6 | HeSaLight HL-HB-CALI-70-840-120D-OL (1.000) | 9000 | 9000 | 70.0 |
| 2 | 2 | HeSaLight HL-PL-AIKO-40-1195295-840 (1.000) | 3796 | 3800 | 40.0 |
| 3 | 4 | HeSaLight HL-PL-AIKO-40-595595-840 (1.000) | 3796 | 3800 | 40.0 |
| 4 | 6 | HeSaLight HL-PL-AIKO-45-595595-840 (1.000) | 4270 | 4275 | 45.0 |
| 5 | 6 | HeSaLight HL-RDLA-GABI2-24-R-165-840-60D (1.000) | 2313 | 2313 | 24.0 |
| 6 | 1 | HeSaLight HL-TL-CATO CYL-12-B-930-60D (1.000) | 1004 | 1023 | 12.0 |

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Showroom / Summary

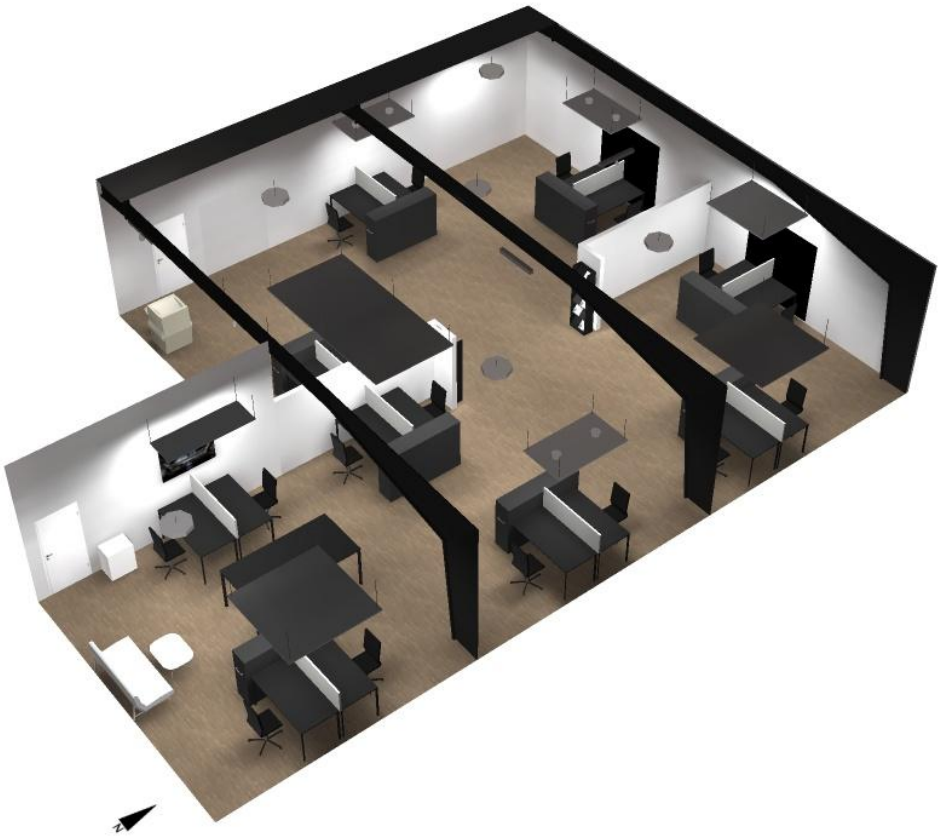
### Luminaire Parts List

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 7 | 2 | HeSaLight HL-TL-CATO-18-930-12D-A (1.000) | 1958 | 2000 | 12.0 |
| 8 | 2 | HeSaLight HL-TL-COSMO-18-940-W-15D (1.000) | 988 | 990 | 18.0 |
| 9 | 1 | HeSaLight HL-TL-COSMO-18-940-W-60D (1.000) | 972 | 990 | 18.0 |
| | | | Total: 124136 | Total: 124321 | 1164.0 |

Specific connected load: 6.03 W/m² = 1.65 W/m²/100 lx (Ground area: 192.92 m²)

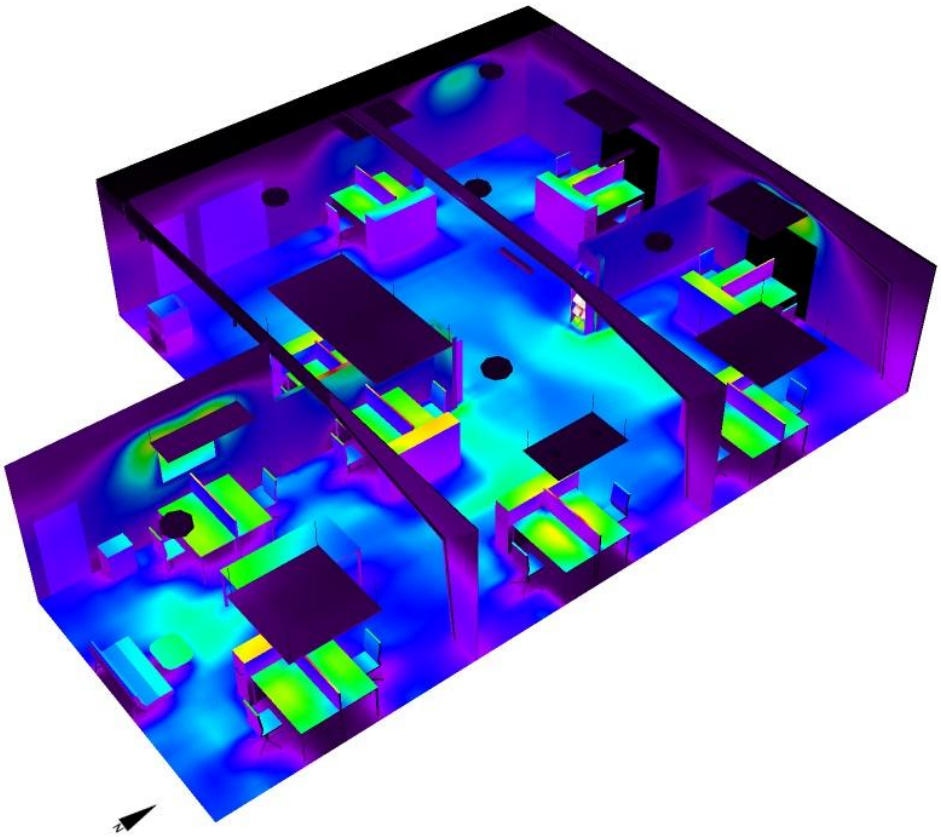
Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

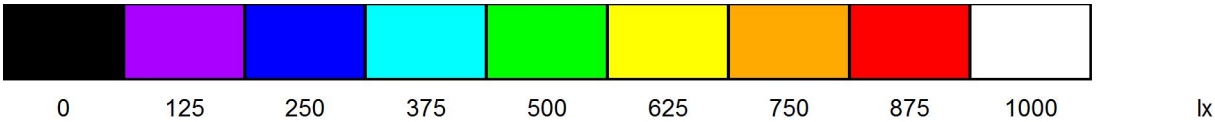
## Sales Office / Showroom / 3D Rendering



Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

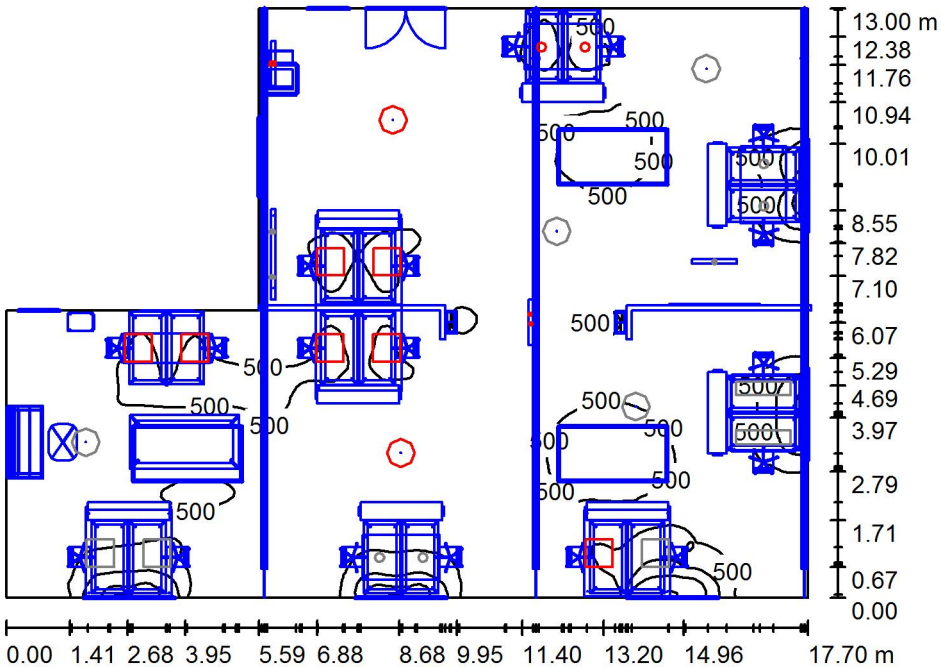
## Sales Office / Showroom / False Color Rendering





Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Sales Office / Daylight Work / Summary




Height of Room: 3.750 m, Light loss factor: 0.90 Values in Lux, Scale 1:167

| Surface | ρ [%] | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 |
|---|---|---|---|---|---|
| Workplane | / | 393 | 28 | 2314 | 0.072 |
| Floor | 20 | 302 | 31 | 1555 | 0.103 |
| Ceiling | 70 | 2.62 | 0.89 | 7.24 | 0.341 |
| Walls (7) | 75 | 117 | 16 | 733 | / |

**Workplane:**

| | |
|---|---|
| Height: | 0.850 m |
| Grid: | 128 x 128 Points |
| Boundary Zone: | 0.000 m |

Illuminance Quotient (according to LG7): Walls / Working Plane: - , Ceiling / Working Plane: - .

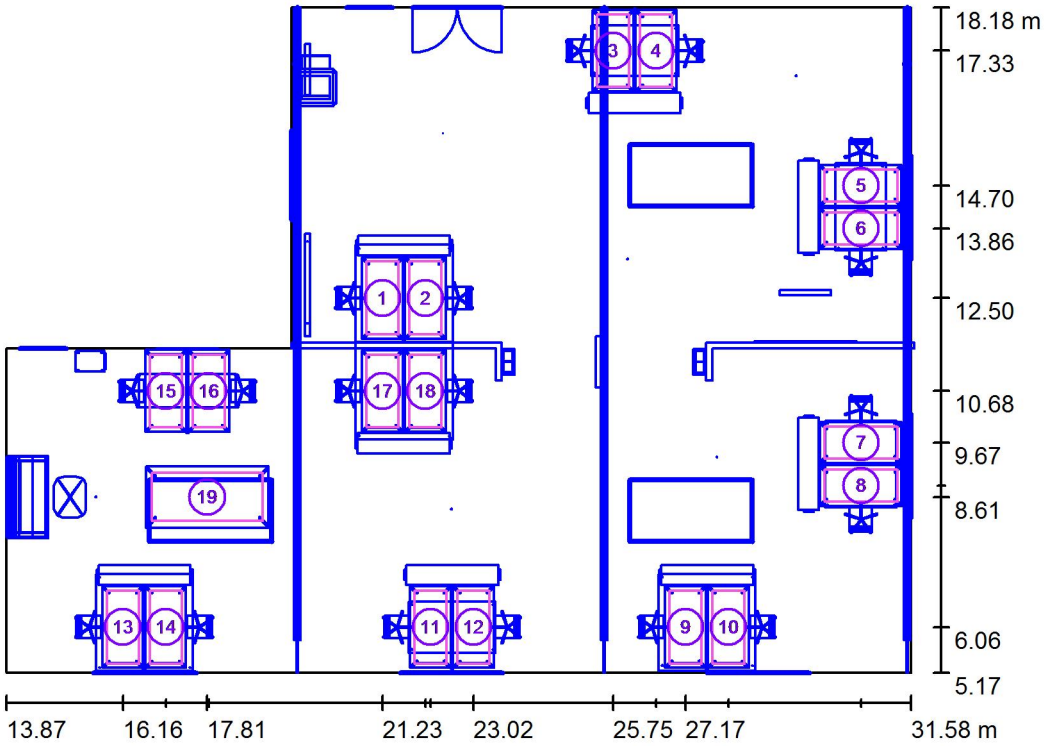
**Luminaire Parts List**

| No. | Pieces | Designation (Correction Factor) | Φ (Luminaire) [lm] | Φ (Lamps) [lm] | P [W] |
|---|---|---|---|---|---|
| 1 | 2 | HeSaLight HL-HB-CALI-70-840-120D-OL (1.000) | 9000 | 9000 | 70.0 |
| 2 | 1 | HeSaLight HL-PL-AIKO-40-595595-840 (1.000) | 3796 | 3800 | 40.0 |
| 3 | 6 | HeSaLight HL-PL-AIKO-45-595595-840 (1.000) | 4270 | 4275 | 45.0 |
| 4 | 2 | HeSaLight HL-RDLA-GABI2-24-R-165-840-60D (1.000) | 2313 | 2313 | 24.0 |
| 5 | 2 | HeSaLight HL-TL-CATO-18-930-12D-A (1.000) | 1958 | 2000 | 12.0 |
| 6 | 1 | HeSaLight HL-TL-COSMO-18-940-W-60D (1.000) | 972 | 990 | 18.0 |
| | | Total: | 56928 | Total: 57066 | 540.0 |

Specific connected load: 2.80 W/m² = 0.71 W/m²/100 lx (Ground area: 192.92 m²)

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Sales Office / Daylight Work / Calculation surfaces (results overview)




Scale 1 : 148

## Calculation Surface List

| No. | Designation | Type | Grid | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|---|---|
| 1 | Calculation Surface WA9/T1 | horizontal | 4 x 8 | 525 | 399 | 624 | 0.759 | 0.638 |
| 2 | Calculation Surface WA9/T2 | horizontal | 4 x 8 | 546 | 415 | 651 | 0.759 | 0.637 |
| 3 | Calculation Surface WA1/T1 | horizontal | 8 x 16 | 522 | 374 | 606 | 0.718 | 0.618 |
| 4 | Calculation Surface WA1/T2 | horizontal | 8 x 16 | 527 | 373 | 626 | 0.708 | 0.596 |
| 5 | Calculation Surface WA2/T1 | horizontal | 2 x 4 | 663 | 268 | 1228 | 0.404 | 0.218 |
| 6 | Calculation Surface WA2/T2 | horizontal | 2 x 4 | 662 | 253 | 1248 | 0.382 | 0.203 |
| 7 | Calculation Surface WA3/T1 | horizontal | 2 x 4 | 640 | 246 | 1215 | 0.384 | 0.202 |
| 8 | Calculation Surface WA3/T2 | horizontal | 2 x 4 | 692 | 274 | 1270 | 0.395 | 0.215 |
| 9 | Calculation Surface WA4/T1 | horizontal | 4 x 8 | 456 | 397 | 519 | 0.871 | 0.765 |

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

# Sales Office / Daylight Work / Calculation surfaces (results overview)

## Calculation Surface List

| No. | Designation | Type | Grid | $E_{av}$ [lx] | $E_{min}$ [lx] | $E_{max}$ [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|---|---|
| 10 | Calculation Surface WA4/T2 | horizontal | 4 x 8 | 994 | 472 | 1713 | 0.475 | 0.276 |
| 11 | Calculation Surface WA5/T1 | horizontal | 4 x 8 | 742 | 267 | 1418 | 0.359 | 0.188 |
| 12 | Calculation Surface WA5/T2 | horizontal | 4 x 8 | 729 | 267 | 1398 | 0.367 | 0.191 |
| 13 | Calculation Surface WA6/T1 | horizontal | 2 x 4 | 763 | 303 | 1440 | 0.396 | 0.210 |
| 14 | Calculation Surface WA6/T2 | horizontal | 2 x 4 | 837 | 380 | 1485 | 0.455 | 0.256 |
| 15 | Calculation Surface WA7/T1 | horizontal | 4 x 8 | 510 | 406 | 590 | 0.797 | 0.688 |
| 16 | Calculation Surface WA7/T2 | horizontal | 4 x 8 | 515 | 380 | 623 | 0.736 | 0.609 |
| 17 | Calculation Surface WA8/T1 | horizontal | 4 x 8 | 518 | 408 | 592 | 0.787 | 0.689 |
| 18 | Calculation Surface WA8/T2 | horizontal | 4 x 8 | 504 | 399 | 573 | 0.791 | 0.696 |
| 19 | Calculation Surface COM-TBL | horizontal | 8 x 4 | 728 | 665 | 773 | 0.914 | 0.861 |

## Summary of Results

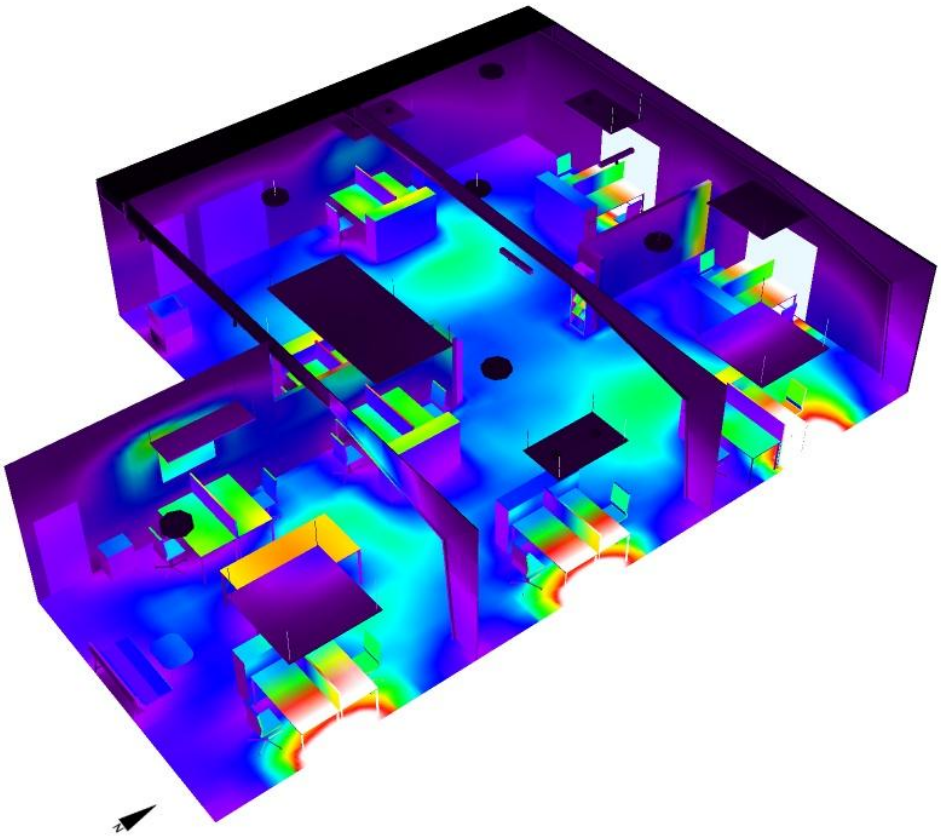
| Type | Quantity | Average [lx] | Min [lx] | Max [lx] | u0 | $E_{min}$ / $E_{max}$ |
|---|---|---|---|---|---|---|
| horizontal | 19 | 641 | 246 | 1713 | 0.38 | 0.14 |

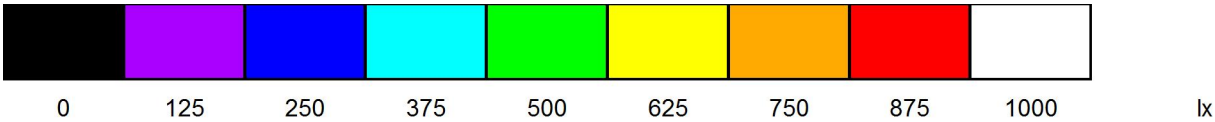
Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Daylight Work / 3D Rendering

Operator Alexandru Daniel Vlas
Telephone
Fax
e-Mail adv@hesalight.com

## Sales Office / Daylight Work / False Color Rendering





# Down Light Recessed Wide GABI2

## HL-DLR-GABI2-WIDE-24-R-165

**HeSaLight's GABI2 Down Light delivers incredible Softy a uniform light for retrofit and convention G24 lamp fixture; Anti-Glare designed with best selected components achieves excellent high quality To best replacement option**

### LIGHT SPECIFICATIONS

| Colour Temperature (K) | Lumen (lm) | CRI (Ra) | SDCM | Efficiency (lm/W) | Beam Angle (°) |
|---|---|---|---|---|---|
| 3000(+/-100) | 2150 | >83 | <5 | 90 | 60 |
| 4000(+/-150) | 2350 | >83 | <5 | 98 | 60 |

### POWER SPECIFICATIONS

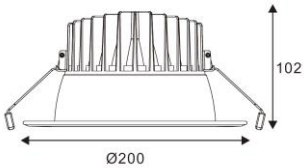
| Power (W) | Voltage (V) | Frequency (Hz) | Driver | Dimmable | Power factor | UGR |
|---|---|---|---|---|---|---|
| 24 | AC 220-240 | 50/60 | Lifud | Optional | >0.92 | <19 |

### GENERAL SPECIFICATIONS

| LED source | LifeTime (hours) | Warranty (years) | Body Color | Material | IP Rate |
|---|---|---|---|---|---|
| Samsung SMD5630 | 50,000 | 5 | Black | Magnesium Alloy+PMMA | IP44 |

### DIMENSIONS

| Outer Diameter (mm) | Height (mm) | Cutout Hole (mm) | Weight (kg) |
|---|---|---|---|
| Φ200 | 102 | Φ165 | 1.2 |

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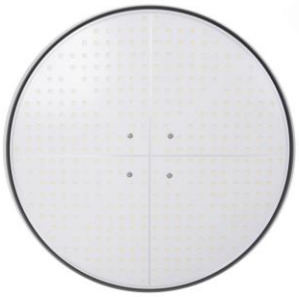
**www.hesalight.com** **email: info@hesalight.com**

# LED High Bay Light
## HL-HB-CALI-70

**This LED high bay light is an efficient and fully integrated lamp for illumination of high ceiling indoor areas. Application areas could be factories, warehouses, libraries, supermarkets, convention centers and more.**

**The durable and solid design combined with excellent lighting specifications is the trademark of these unique lamps.**



### LIGHT SPECIFICATIONS

| Colour temperature | Lumen (lm) | CRI (Ra) | Efficiency (lm/W) | Beam angle (°) |
|---|---|---|---|---|
| 3800-4100K | 9000 | 80 | 120 | 60, 120 |
| 5000-7000K | 9600 | 80 | 123 | 60, 120 |

### POWER SPECIFICATIONS

| Power (W) | Voltage (V) | Frequency (Hz) | Power factor | IP Grade |
|---|---|---|---|---|
| 70W | AC 90-305 | 50/60 | >0.90 | IP40 |

### GENERAL SPECIFICATIONS

| LED source | Lifetime (hours) | Warranty (years) | Colour | Material |
|---|---|---|---|---|
| LG Innotek | 100,000 | 5 | Metal | Aluminum Sheet |

### DIMENSIONS

| Height (mm) | Width (mm) | Weight (kg) |
|---|---|---|
| 20 | 600 | 6.5 |

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www.hesalight.com email: info@hesalight.com

# LED PANEL LIGHT
## HL-PL-40-595595

**HeSaLight's LED Panel Light Delivers Softy uniform and attractive light ideal for retrofit or conversion applications replacing fluorescent tubes fixtures**
**The latest LED technology and careful selection is adopted for this panel light in order to ensure both colour precision and consistency.**

### LIGHT SPECIFICATIONS

| Colour temperature (K) | Lumen (lm) | CRI (Ra) | SDCM | Efficiency (lm/W) | Beam angle (°) |
|---|---|---|---|---|---|
| 3000(+/-100) | 3600 | 80 | <5 | 90 | 120 |
| 4000(+/-150) | 3800 | 80 | <5 | 95 | 120 |

### POWER SPECIFICATIONS

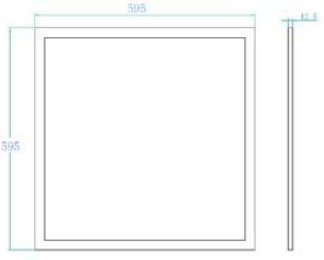
| Power (W) | Voltage (V) | Frequency (Hz) | LED Driver | Power factor | THD |
|---|---|---|---|---|---|
| 40 | 200-240 | 50/60 | Lifud Flicker free | >0.90 | <20 |

### GENERAL SPECIFICATIONS

| LED source | Lifetime (hours) | Warranty (years) | External Color | Material | IP Rate |
|---|---|---|---|---|---|
| Runlite SMD2835 | 50,000 | 5 | White /ALU RAL9003 | Aluminum/PC | IP20 |

### DIMENSIONS

| Dimension (mm) | Thickness (mm) | Weight (kg) |
|---|---|---|
| 595 x 595 | 12.5 | 4.5 |



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# LED PANEL LIGHT
## HL-PL-40-1195295

**HeSaLight's LED Panel Light Delivers Softy uniform and attractive light ideal for retrofit or conversion applications replacing fluorescent tubes fixtures**
**The latest LED technology and careful selection is adopted for this panel light in order to ensure both colour precision and consistency.**

### LIGHT SPECIFICATIONS

| Colour temperature (K) | Lumen (lm) | CRI (Ra) | SDCM | Efficiency (lm/W) | Beam angle (°) |
|---|---|---|---|---|---|
| 3000(+/-100) | 3600 | 80 | <5 | 90 | 120 |
| 4000(+/-150) | 3800 | 80 | <5 | 95 | 120 |

### POWER SPECIFICATIONS

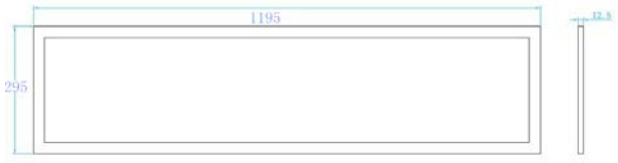
| Power (W) | Voltage (V) | Frequency (Hz) | LED Driver | Power factor | THD |
|---|---|---|---|---|---|
| 40 | 200-240 | 50/60 | Lifud Flicker free | >0.90 | <20 |

### GENERAL SPECIFICATIONS

| LED source | Lifetime (hours) | Warranty (years) | External Color | Material | IP Rate |
|---|---|---|---|---|---|
| Runlite SMD2835 | 50,000 | 3 | White /ALU RAL9003 | Aluminum/PC | IP20 |

### DIMENSIONS

| Dimension (mm) | Thickness (mm) | Weight (kg) |
|---|---|---|
| 1195 x 295 | 12.5 | 4.5 |

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www.hesalight.com email: info@hesalight.com

# LED PANEL LIGHT
## HL-PL-45-595595

**HeSaLight's LED Panel Light Delivers Softy uniform and attractive light ideal for retrofit or conversion applications replacing fluorescent tubes fixtures**
**The latest LED technology and careful selection is adopted for this panel light in order to ensure both colour precision and consistency.**

### LIGHT SPECIFICATIONS

| Colour temperature (K) | Lumen (lm) | CRI (Ra) | SDCM | Efficiency (lm/W) | Beam angle (°) |
|---|---|---|---|---|---|
| 3000(+/-100) | 4275 | 80 | <5 | 95 | 120 |
| 4000(+/-150) | 4275 | 80 | <5 | 95 | 120 |

### POWER SPECIFICATIONS

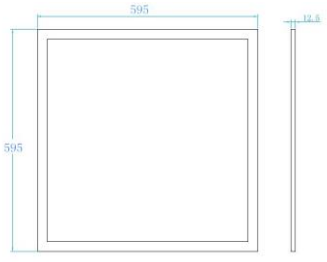
| Power (W) | Voltage (V) | Frequency (Hz) | LED Driver | Power factor | THD |
|---|---|---|---|---|---|
| 45 | 200-240 | 50/60 | Lifud Flicker free | >0.90 | <20 |

### GENERAL SPECIFICATIONS

| LED source | Lifetime (hours) | Warranty (years) | External Color | Material | IP Rate |
|---|---|---|---|---|---|
| Runlite SMD2835 | 50,000 | 5 | White /ALU RAL9003 | Aluminum/PC | IP20 |

### DIMENSIONS

| Dimension (mm) | Thickness (mm) | Weight (kg) |
|---|---|---|
| 595 x 595 | 12.5 | 4.5 |




HeSaLight A/S – Lykkegaardsvej 9 4000 Roskilde Denmark– Tel: +45 3537 8888
www.hesalight.com email: info@hesalight.com

# HL-TL-CATO-CON-18-TC

## Track Light CATO Conic 18W, Class II, True Color (high CRI)

- ✓ Modular, Flexible, Customizable LED Track Light, with Interchangeable Heads, Simple adjustment without tools
- ✓ Black or white exterior in aesthetic and slim design with all aluminum body.
- ✓ UV and IR free light with reduced heat generation that protects heat-sensitive objects.
- ✓ Precision optics makes this retail spot ideal to highlight your star products.
- ✓ True Color technology offer a great Color Rendering Index (CRI)
- ✓ 70 % energy saving compared with conventional halogen light sources.
- ✓ Developed for retail, shopping centers, cafes, art galleries and clothing stores.

### PHOTOMETRIC SPECIFICATIONS

| **Color Temperature** (K) | **Tolerance Range** (K) | **Lumen +/- 5%** (Lm) | **Color Index** (Ra) | **Efficiency** (Lm/W) |
|---|---|---|---|---|
| 3000<br>4000 | (+/-100)<br>(+/-150) | 1395<br>1445 | >97<br>>97 | 78<br>80 |

### ELECTRICAL SPECIFICATIONS

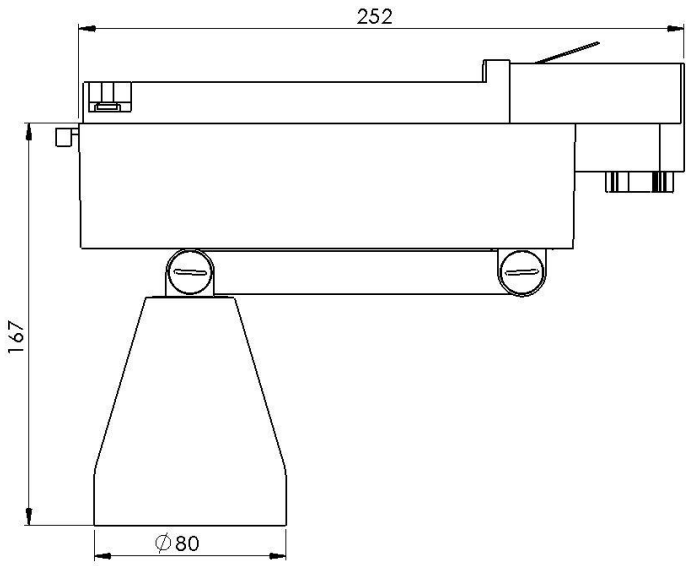
| **Consumption** (W) | **Voltage** (V) | **Frequency** (Hz) | **Power Factor** (COS) | **Forward Current** (mA) |
|---|---|---|---|---|
| 17,8 | 120-277 | 50/60 | 0,9 | 450 |

### GENERAL SPECIFICATIONS

| **Light Source** (Brand) | **Life Time** (H) | **Warranty (Y)** | **Installation Options** | **External Color** | **Material** |
|---|---|---|---|---|---|
| Citizen | 50,000 | 5 | 3 Phase Track Surface/Cieling Mounted | Black RAL 9004 White RAL 9003 | Aluminum |

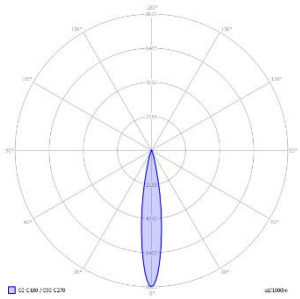
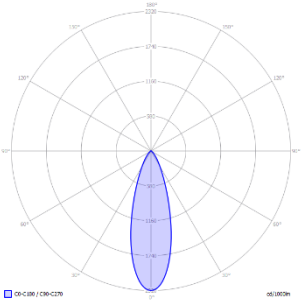
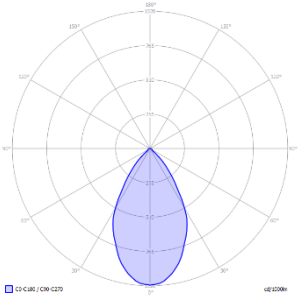
# HL-TL-CATO-CON-18-TC

## Track Light CATO Conic 18W, Class II, True Color (high CRI)




| DIMENSIONS | | | | | |
|---|---|---|---|---|---|
| **Full Length** (mm) | **Height** (mm) | **Box Depth** (mm) | **Weight** (kg) | **Diameter** (mm) | **Arm Length** (mm) |
| 252 | 162 | 36 | 0,80 | Ø80 | 138 |

## LIGHT DISTRIBUTIONS

| 16 Degrees | 35 Degrees | 60 Degrees |
|---|---|---|
|  |  |  |

# HL-TL-CATO-CYL-12-TC

## Track Light CATO Cylinder 12W, Class II, True Color (high CRI)

- ✓ Modular, Flexible, Customizable LED Track Light, with Interchangeable Heads, Simple adjustment without tools
- ✓ Black or white exterior in aesthetic and slim design with all aluminum body.
- ✓ UV and IR free light with reduced heat generation that protects heat-sensitive objects.
- ✓ Precision optics makes this retail spot ideal to highlight your star products.
- ✓ True Color technology offer a great Color Rendering Index (CRI)
- ✓ 70 % energy saving compared with conventional halogen light sources.
- ✓ Developed for retail, shopping centers, cafes, art galleries and clothing stores.

### PHOTOMETRIC SPECIFICATIONS

| Color Temperature (K) | Tolerance Range (K) | Lumen +/- 5% (Lm) | Color Index (Ra) | Efficiency (Lm/W) |
|---|---|---|---|---|
| 3000<br>4000 | (+/-100)<br>(+/-150) | 1034<br>1070 | >97<br>>97 | 86<br>89 |

### ELECTRICAL SPECIFICATIONS

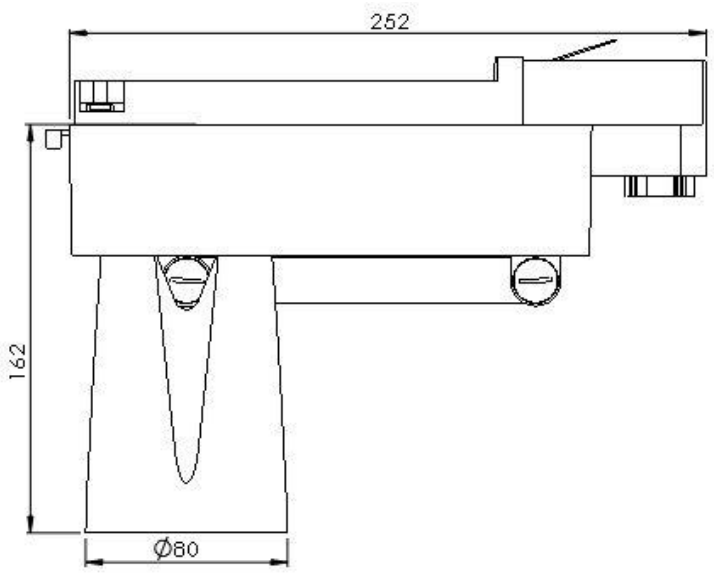
| Consumption (W) | Voltage (V) | Frequency (Hz) | Power Factor (COS) | Forward Current (mA) |
|---|---|---|---|---|
| 12 | 200-240 | 50/60 | 0,9 | 300 |

### GENERAL SPECIFICATIONS

| Light Source (Brand) | Life Time (H) | Warranty (Y) | Installation Options | External Color | Material |
|---|---|---|---|---|---|
| Citizen | 50,000 | 5 | 3 Phase Track Surface/Cieling Mounted | Black RAL 9004 White RAL 9003 | Aluminum |

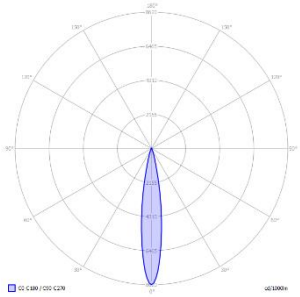
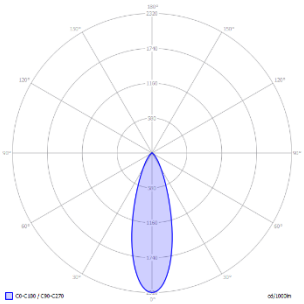
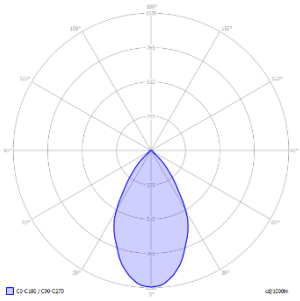
# HL-TL-CATO-CYL-12-TC

## Track Light CATO Cylinder 12W, Class II, True Color (high CRI)




| DIMENSIONS | | | | | |
|---|---|---|---|---|---|
| **Full Length** (mm) | **Height** (mm) | **Box Depth** (mm) | **Weight** (kg) | **Diameter** (mm) | **Arm Length** (mm) |
| 252 | 162 | 36 | 0,80 | Ø80 | 138 |

## LIGHT DISTRIBUTIONS

| 16 Degrees | 35 Degrees | 60 Degrees |
|---|---|---|
|  |  |  |

# Cosmo Spot
## HL-TL-COSMO-18-W

**HeSaLight's Cosmo Spot LED Track Light is the most efficient and Unique designed alternative to the traditional halogen lamp track light**

**Professional optic system design and well thermal management and the quality components make it to be ideal replacement choice.**

### LIGHT SPECIFICATIONS

| Colour temperature (K) | Lumen (lm) | CRI (Ra) | Efficiency (lm/W) | SDCM | Beam Angle (°) |
|---|---|---|---|---|---|
| 3000(+/-100) | 1530 | 80 | 85 | <3 | 15/25/35 |
| 4000(+/-150) | 1530 | 80 | 85 | <3 | 15/25/35 |
| 3000(+/-100) | 1260 | 90 | 70 | <3 | 15/25/35 |
| 4000(+/-150) | 1260 | 90 | 70 | <3 | 15/25/35 |

### POWER SPECIFICATIONS

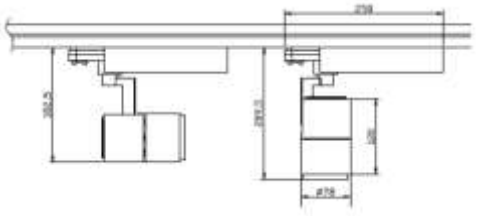
| Power (W) | Voltage (V) | Frequency (Hz) | Adapter | Power Efficiency | Power Factor |
|---|---|---|---|---|---|
| 18 | AC 220-240 | 50/60 | 3 phase | >90% | >0.95 |

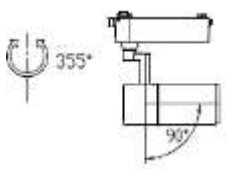
### GENERAL SPECIFICATIONS

| LED source | Lifetime (hours) | Warranty (years) | Color | Material |
|---|---|---|---|---|
| NICHIA | 50,000 | 5 | White | Aluminum/PC |

### DIMENSIONS

| Length (mm) | Height (mm) | Lamp Diameter | Weight (gr) |
|---|---|---|---|
| 250 | 182.5 | Φ78 | 900 |






HeSaLight A/S – Lykkegaardsvej 9 4000 Roskilde Denmark– Tel: +45 3537 8888
www.hesalight.com email: info@hesalight.com

# Appendix 9

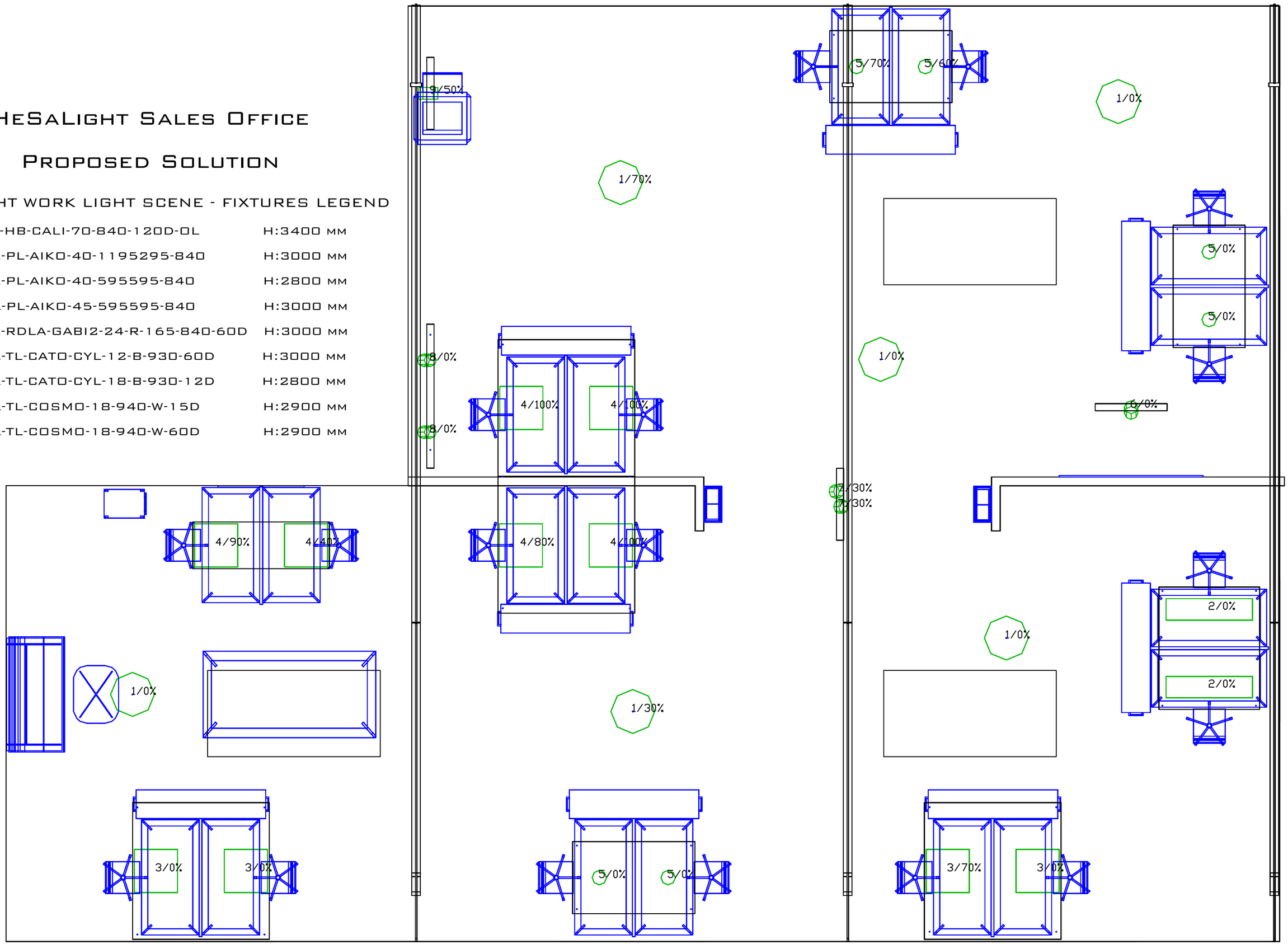
Proposed Solution Technical Drawings

# HeSaLight Sales Office

## Proposed Solution

### Daylight work light scene - fixtures legend

| | | |
|---|---|---|
| 1 | 6 x HL-HB-CALI-70-840-120D-OL | H:3400 mm |
| 2 | 2 x HL-PL-AIKO-40-1195295-840 | H:3000 mm |
| 3 | 4 x HL-PL-AIKO-40-595595-840 | H:2800 mm |
| 4 | 6 x HL-PL-AIKO-45-595595-840 | H:3000 mm |
| 5 | 6 x HL-RDLA-GABI2-24-R-165-840-60D | H:3000 mm |
| 6 | 1 x HL-TL-CATO-CYL-12-B-930-60D | H:3000 mm |
| 7 | 2 x HL-TL-CATO-CYL-18-B-930-12D | H:2800 mm |
| 8 | 2 x HL-TL-COSMO-18-940-W-15D | H:2900 mm |
| 9 | 1 x HL-TL-COSMO-18-940-W-60D | H:2900 mm |

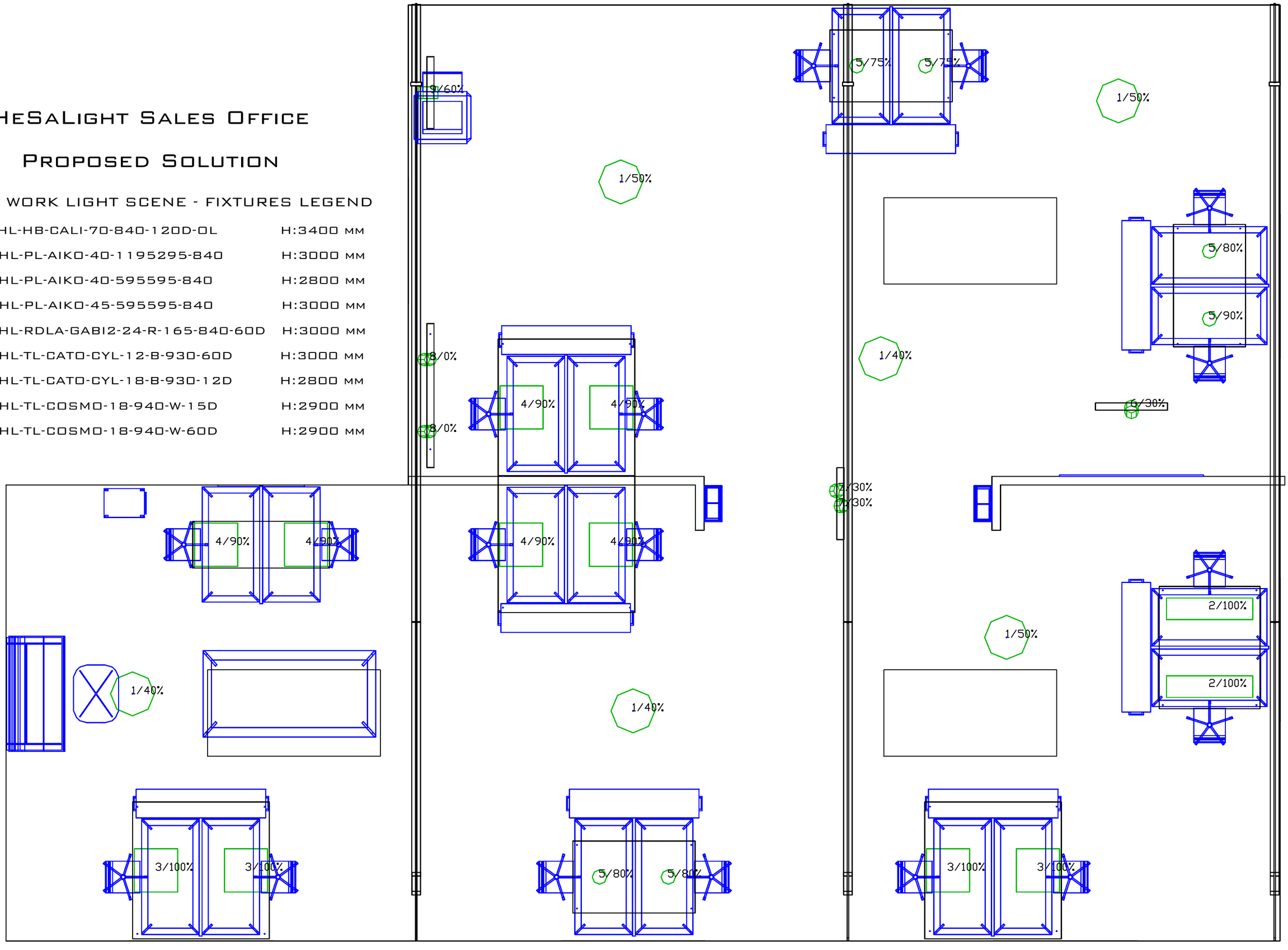


# HeSaLight Sales Office

## Proposed Solution

### NIGHT WORK LIGHT SCENE - FIXTURES LEGEND

| | | |
|---|---|---|
| 1 | 6 x HL-HB-CALI-70-840-120D-OL | H:3400 mm |
| 2 | 2 x HL-PL-AIKO-40-1195295-840 | H:3000 mm |
| 3 | 4 x HL-PL-AIKO-40-595595-840 | H:2800 mm |
| 4 | 6 x HL-PL-AIKO-45-595595-840 | H:3000 mm |
| 5 | 6 x HL-RDLA-GABI2-24-R-165-840-60D | H:3000 mm |
| 6 | 1 x HL-TL-CATO-CYL-12-B-930-60D | H:3000 mm |
| 7 | 2 x HL-TL-CATO-CYL-18-B-930-12D | H:2800 mm |
| 8 | 2 x HL-TL-COSMO-18-940-W-15D | H:2900 mm |
| 9 | 1 x HL-TL-COSMO-18-940-W-60D | H:2900 mm |

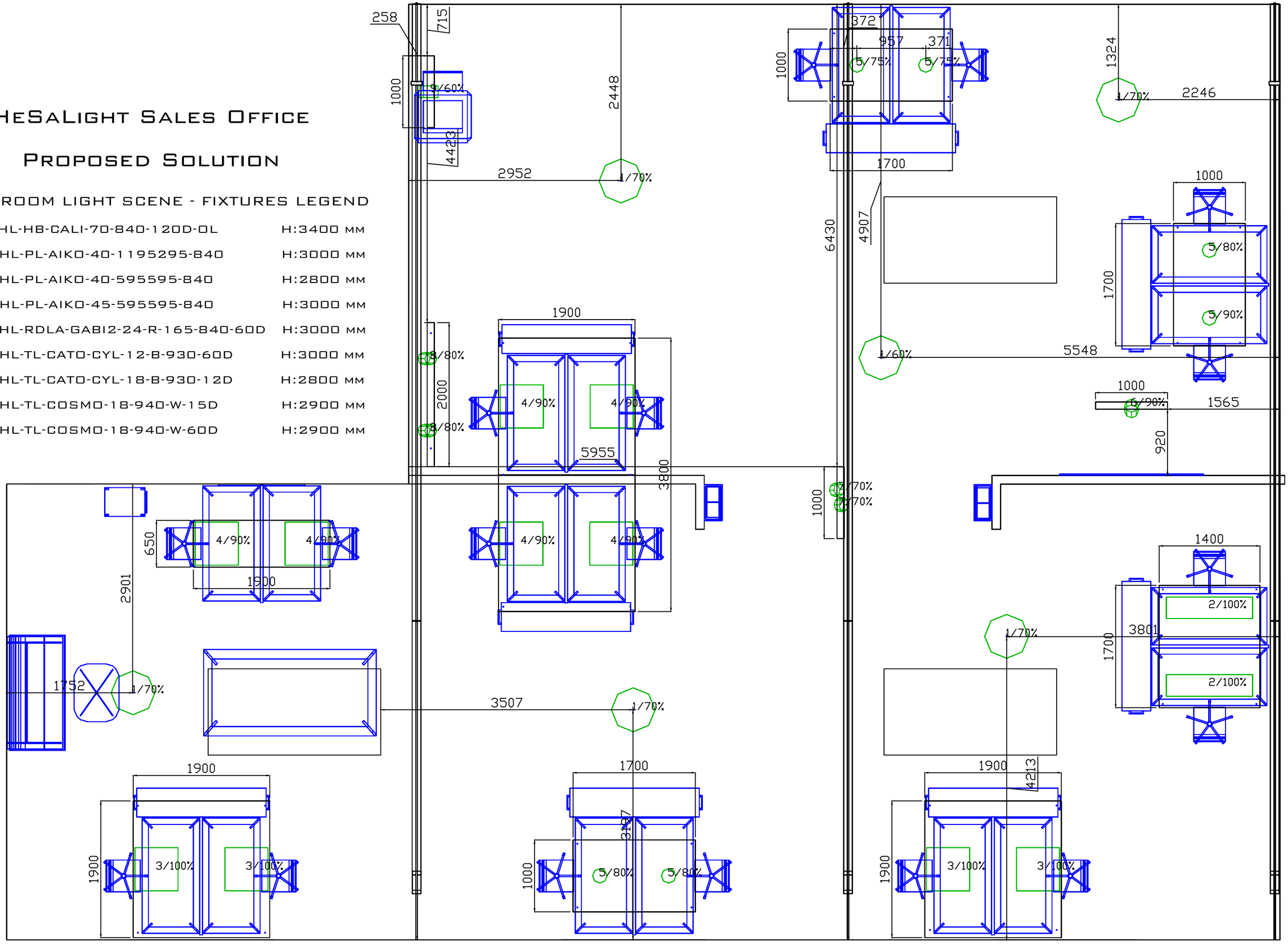


# HeSaLight Sales Office

## Proposed Solution

### SHOWROOM LIGHT SCENE - FIXTURES LEGEND

| | | |
|---|---|---|
| 1 | 6 x HL-HB-CALI-70-840-120D-0L | H:3400 mm |
| 2 | 2 x HL-PL-AIKO-40-1195295-840 | H:3000 mm |
| 3 | 4 x HL-PL-AIKO-40-595595-840 | H:2800 mm |
| 4 | 6 x HL-PL-AIKO-45-595595-840 | H:3000 mm |
| 5 | 6 x HL-RDLA-GABI2-24-R-165-840-60D | H:3000 mm |
| 6 | 1 x HL-TL-CATO-CYL-12-B-930-60D | H:3000 mm |
| 7 | 2 x HL-TL-CATO-CYL-18-B-930-12D | H:2800 mm |
| 8 | 2 x HL-TL-COSMO-18-940-W-15D | H:2900 mm |
| 9 | 1 x HL-TL-COSMO-18-940-W-60D | H:2900 mm |



# Appendix 10

Proposed Solution Renderings

Fig.1 General View - Daylight Work Scenario

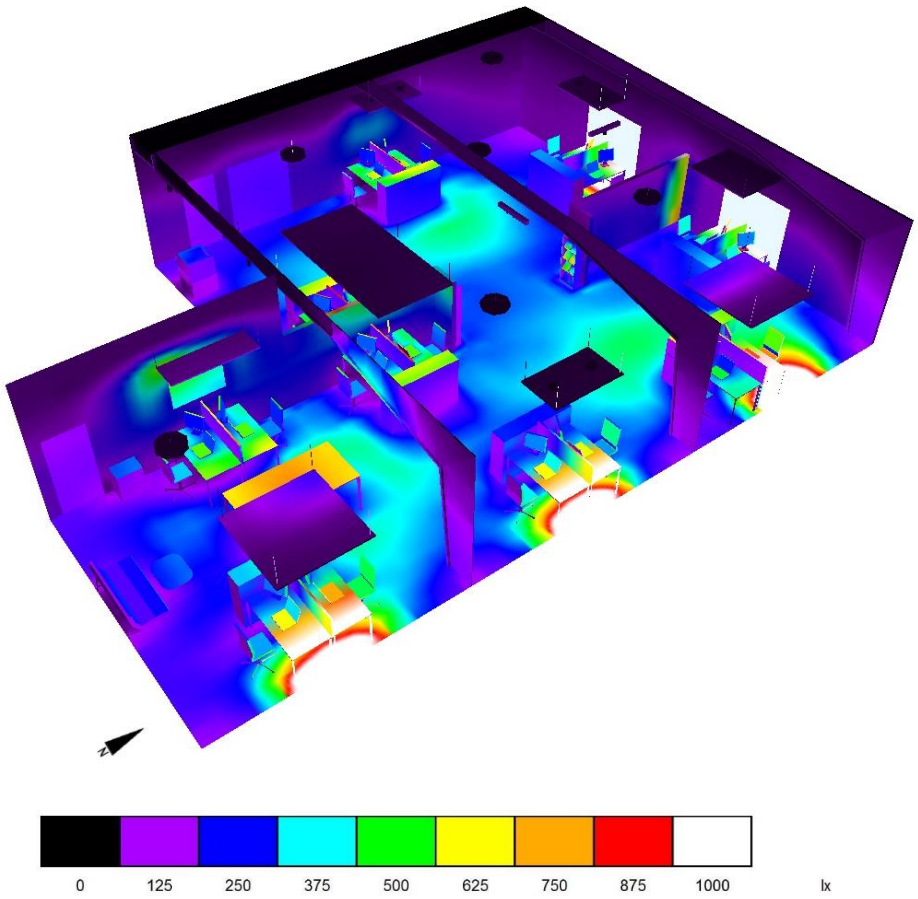



Fig.2 General View - Daylight Work Scenario (False Colors)

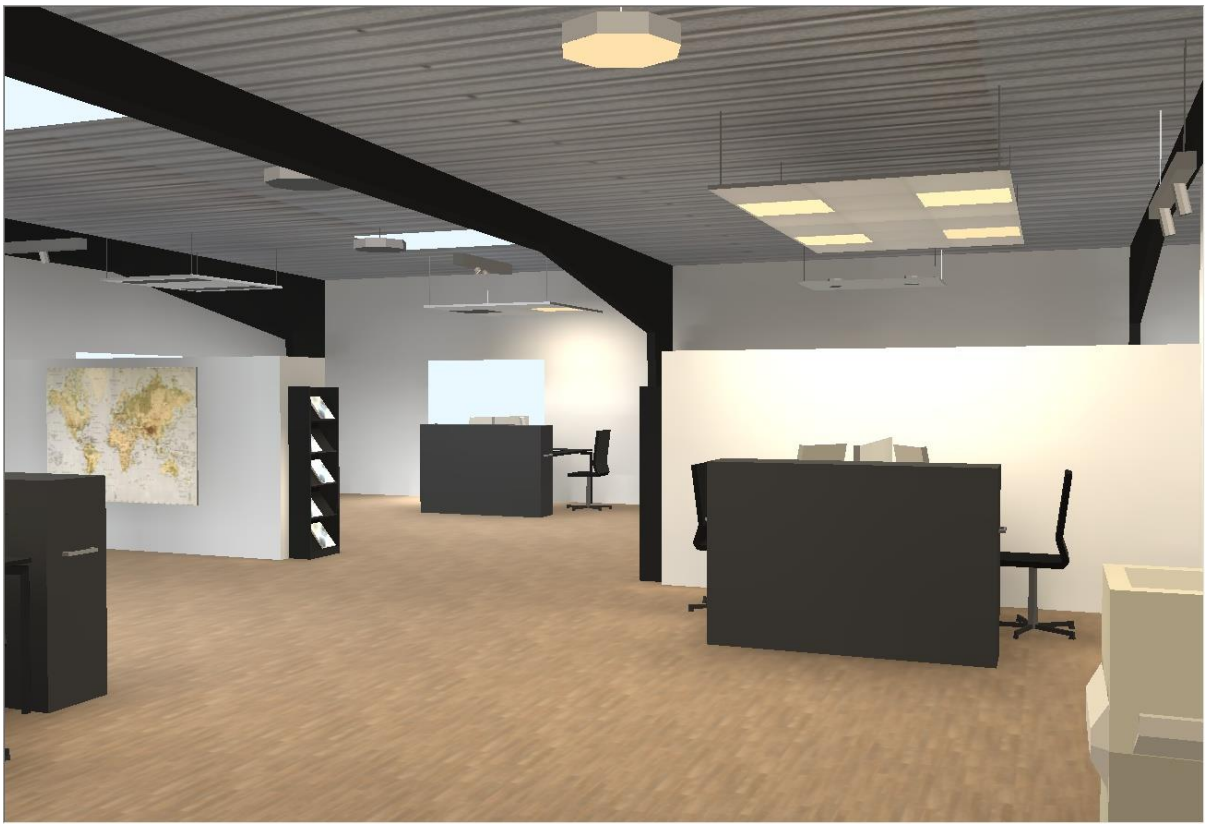


Fig.3 Entrance View – Daylight Work Scenario

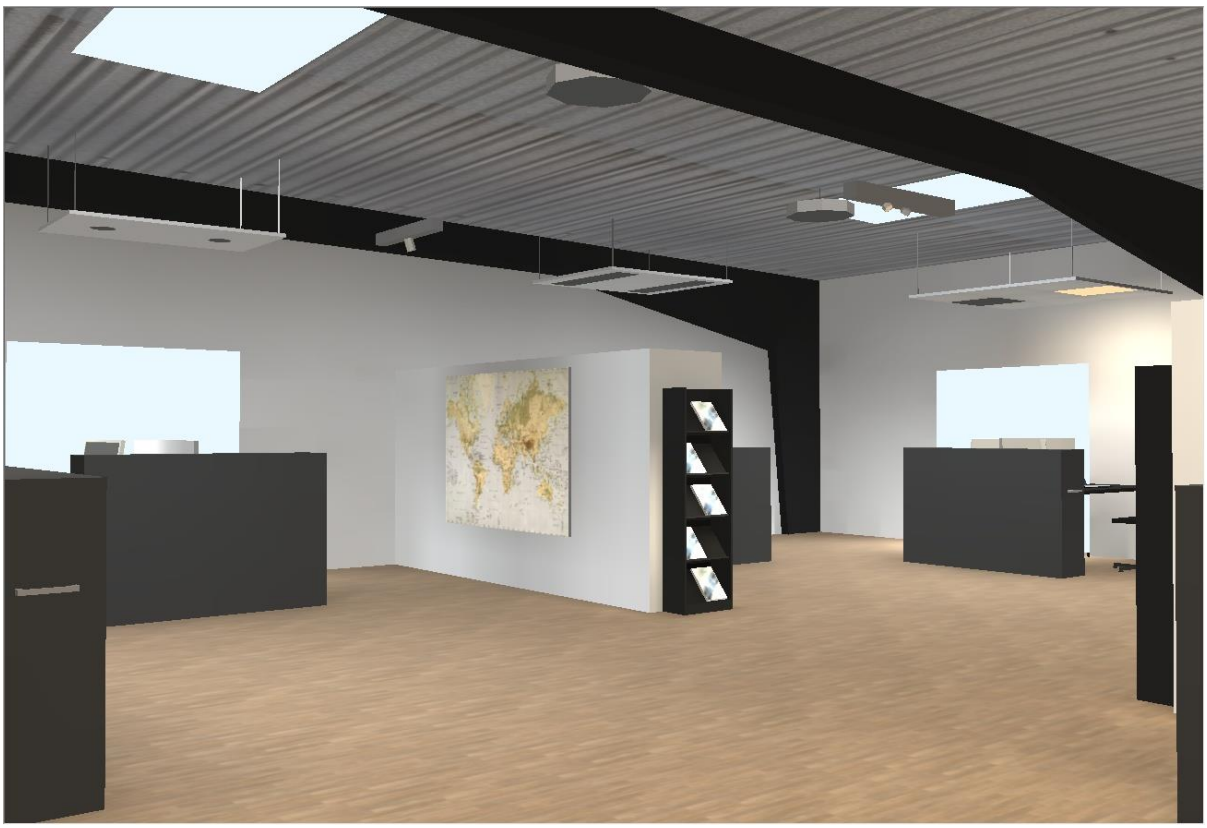


Fig.4 North Façade View – Daylight Work Scenario

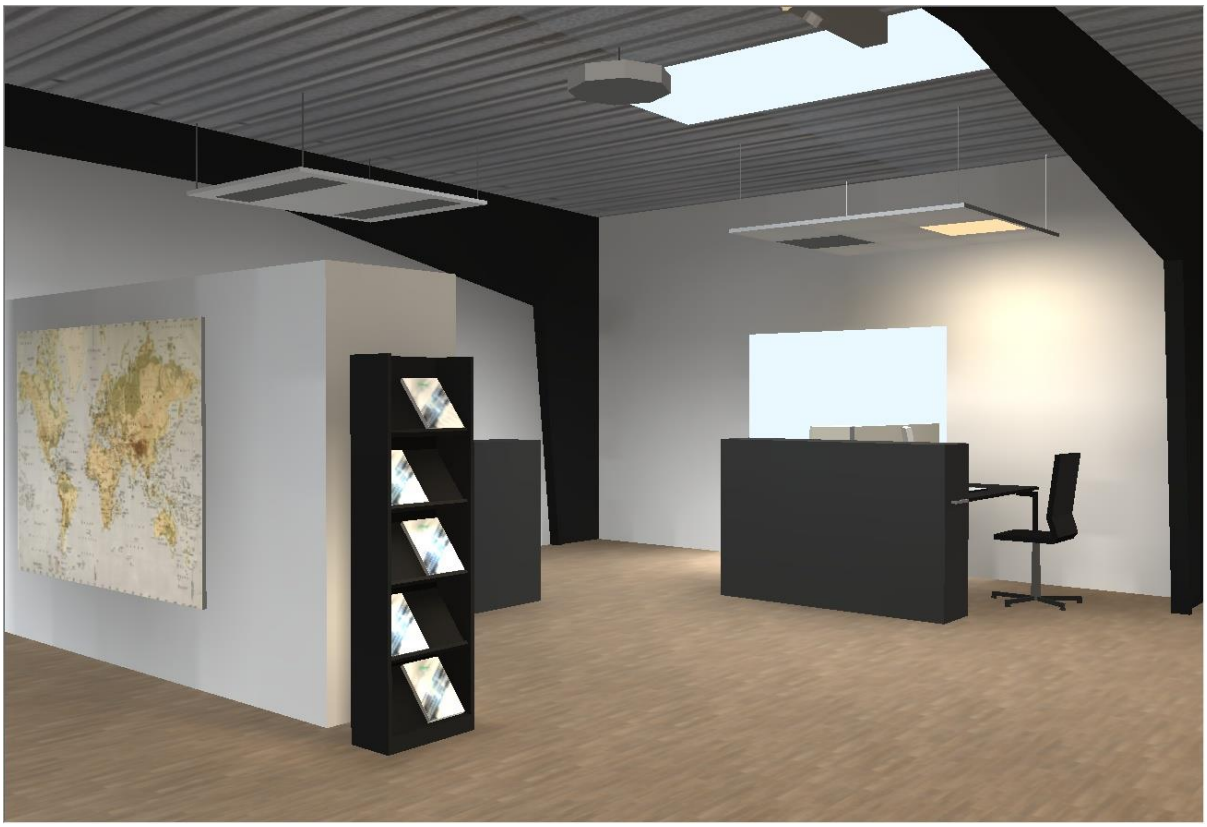


Fig.5 Close-up view of the catalogue stand – Daylight Work Scenario

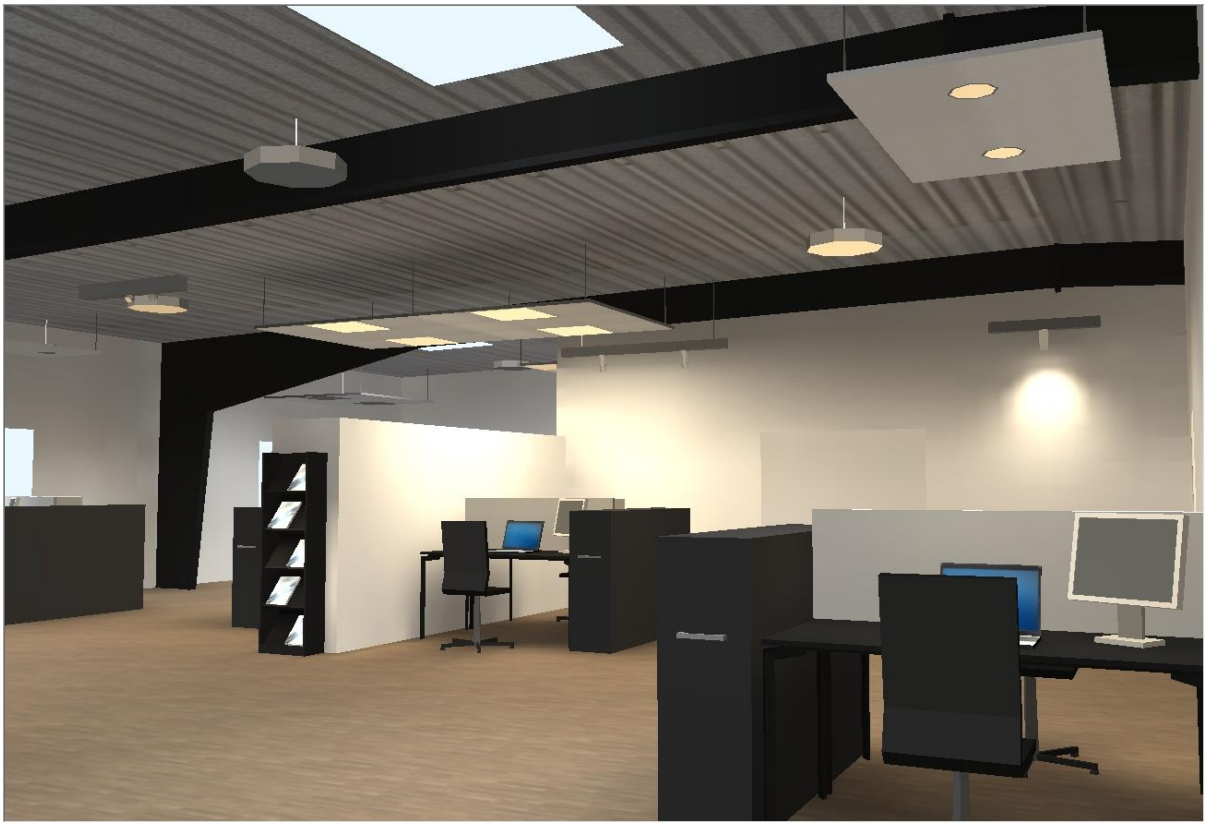


Fig.6 View from the North Façade – Daylight Work Scenario

Fig.7 Work Area on the North Façade – Daylight Work Scenario

Fig.8 Work Areas in the middle of the space – Daylight Work Scenario

Fig.9 View from the South Wall – Daylight Work Scenario

Fig.10 East Façade View – Daylight Work Scenario

Fig.11 General View – Showroom Scenario

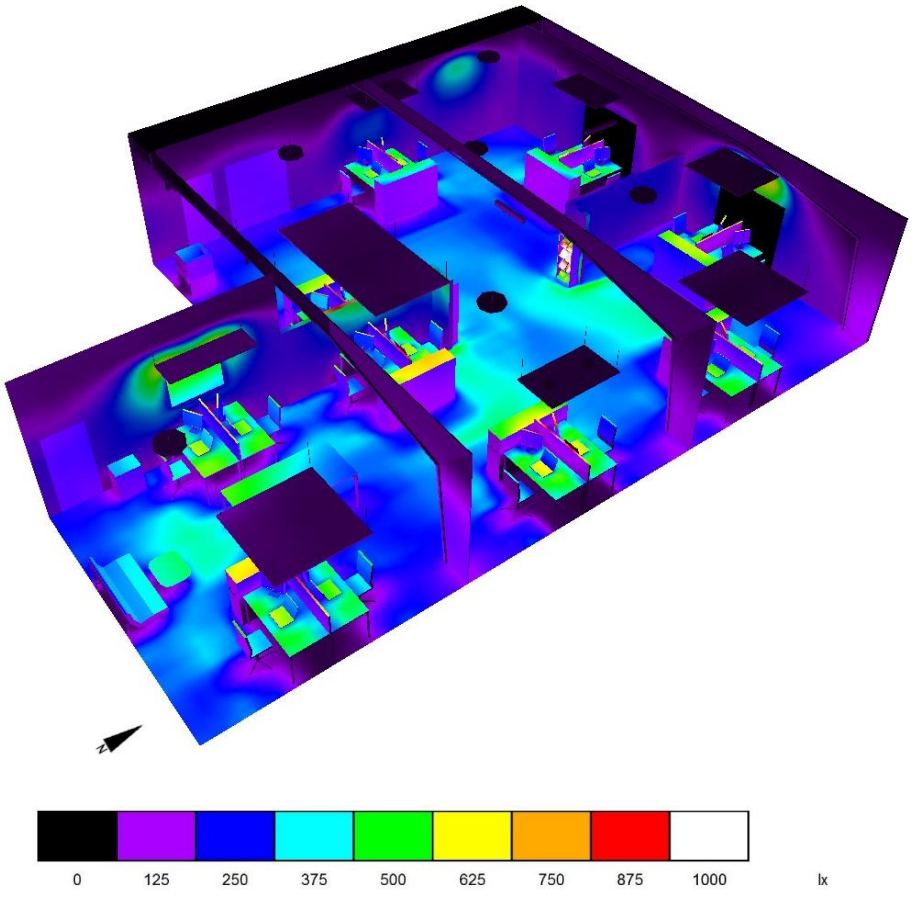



Fig.12 General View – Showroom Scenario (False Colors)

Fig.13 Entrance View – Showroom Scenario

Fig.14 North Façade View – Showroom Scenario

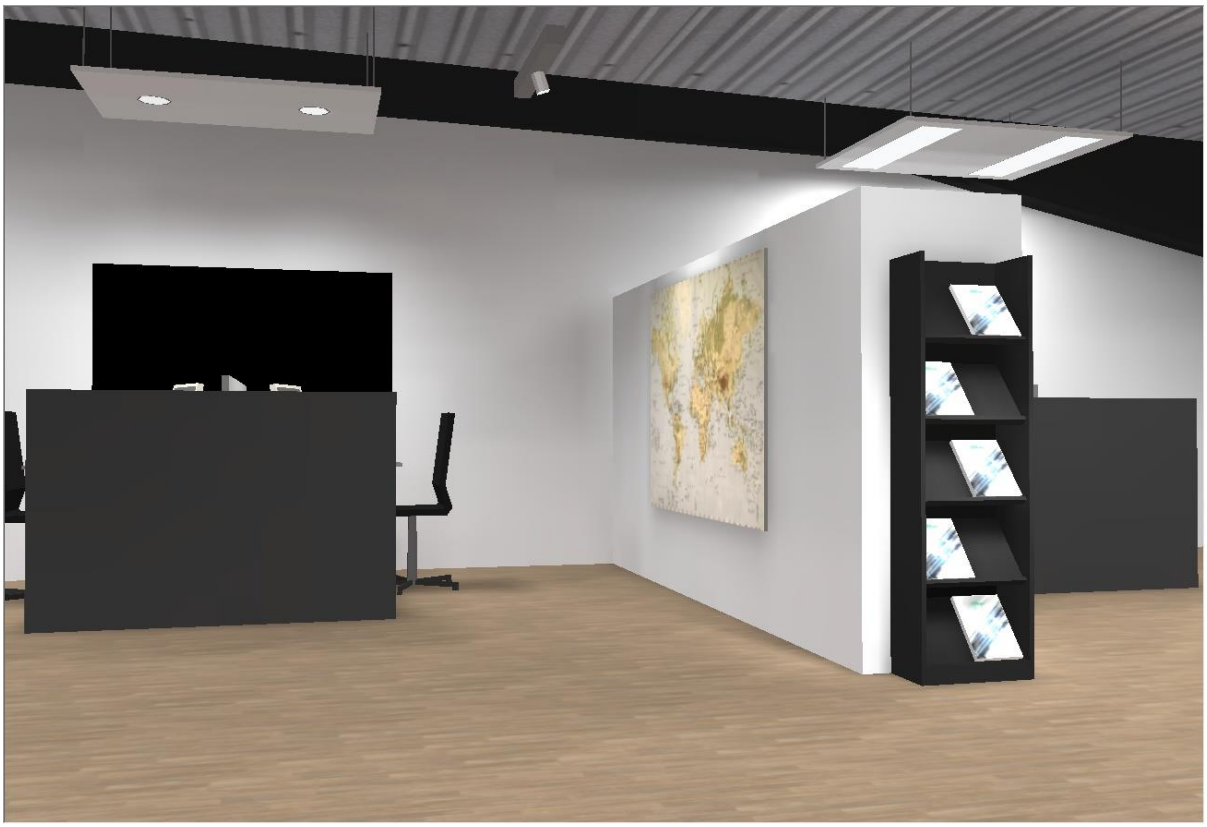


Fig.15 Close-up view of the catalogue stand – Showroom Scenario

Fig.16 View from the North Façade – Showroom Scenario

Fig.17 Work Areas in the middle of the space – Showroom Scenario

Fig.18 View from the East Façade – Showroom Scenario