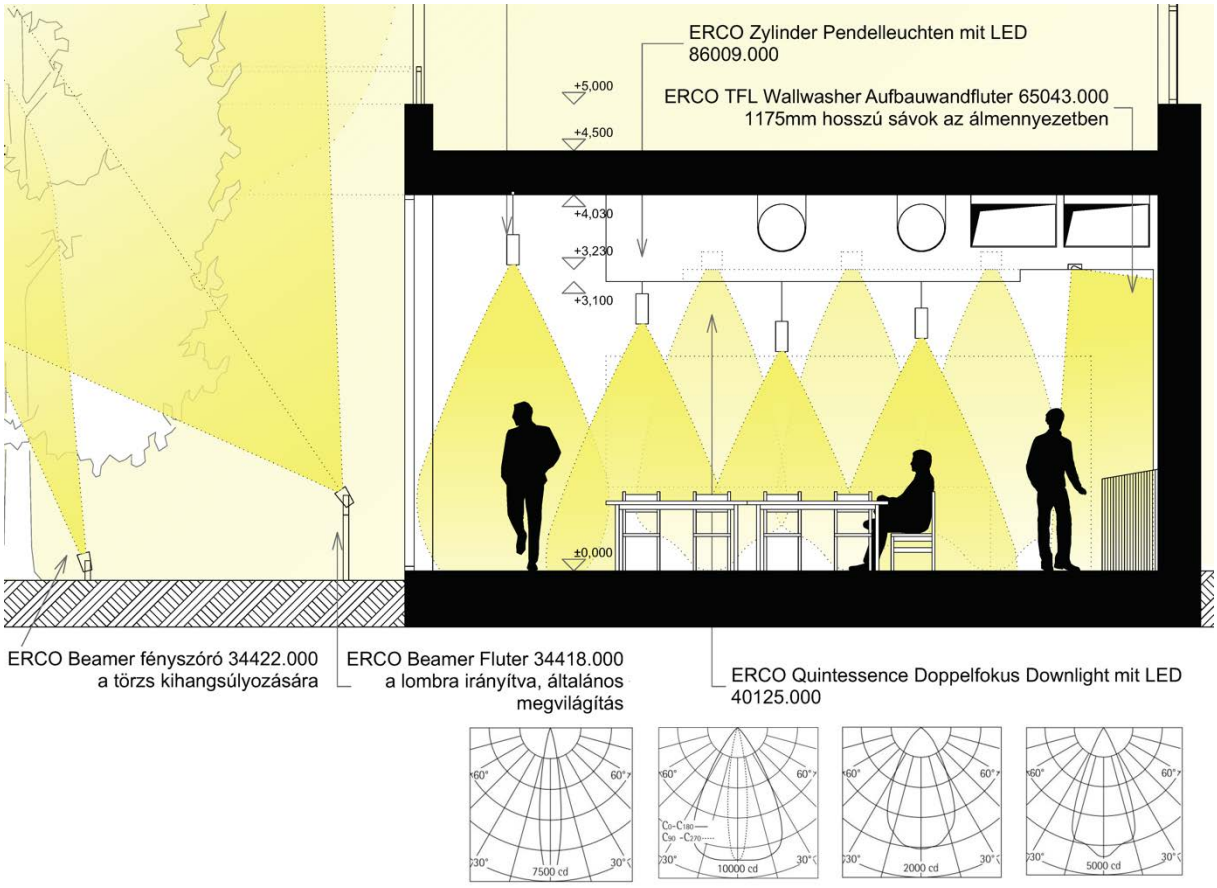
Budapesti Műszaki és Gazdaságtudományi Egyetem, Építészmérnöki Kar
Épületenergetikai és Épületgépészeti Tanszék, www.egt.bme.hu

LIGHTING OF BUILDINGS

Complex 2 Design Aid



Artificial light source distribution diagrams and lamp distribution indicated on a building section (Borbála Birges)

Levente Filetóth

2018. January

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SCOPE OF THE DESIGN TASK

This design aid was created to help the lighting and luminaire design related tasks - as part of the comprehensive design project - of the students of the Faculty of Architecture of the Budapest University of Technology and Economics.

The task of the Comprehensive Design 2 semester design project is to create "working drawing sets" ready to be used during construction. In case of lighting and luminaire design the goal is to create and illustrate the artificial lighting in the selected interior spaces of the building and to suggest corresponding daylighting schemes for the architectural design.

The goal of the building lighting task is to **design the articial lighting** (define lighting type, lamps, their position and luminaire types) of the selected interior spaces.

Please select the areas and spaces of your project to consider for artifical lighting design with your consultant!

CONTENT OF THE SUBMITTED TASKS

Please submit an A4 booklet and drawing layouts with the following content:

- **Booklet** explaining the selected lighting methods, luminaire and light source types including manufacturer specific luinaire data. Please also include calculations clarifying the type and the number of the designed luminaires and light sources.
- **Floor plan or suspended ceiling plan(s)** (scale 1:50 or larger), cross- or longitudinal section indicating the position of the selected luminaires.
- **Interior elevation(s)** indicating the textures of the internal surfaces and furniture (this might also be a 3D hand- or computer-made sketch, capturing the selected interior from eye-level).

1. Artificial Lighting in Buildings

The artificial illumination design is usually created by teams of engineers, at the tender or construction documentation stage of the design process. The **input data** for the illumination design is provided **by the architect**.

To be able to design the layout of the luminaires and specify light sources, we must know the exact **function** and **geometry** of the areas and rooms and have an idea about the **surfaces**, **glazed** areas, **windows** and planned shading devices and their orientation as well as of the **furnishing** of the interior.

Interior elevation indicating lamps, furnishing and surface textures (Anna Hertel)

When creating articial illumination for buildings we must ensure adequate level of **illuminance, E [lux]** considering the **functions** and **typical usage** of the building. It is also important to comply with all the lighting regulations and standards including luminance distribtion **L** [cd/m2], colour-rendering **Ra** [-], color-temperature **T** [K]. It is also imporant to validate and **balance artificial lighting and daylighting** in the interor and ensure that not only the **visual comfort requirements** but also the building **energetics** and **maintenance** costs are controled.

Artificial lighting is not only about illumination in the interior but its also part of **interior design**, csonsidering the shape, size and design of the lamps.

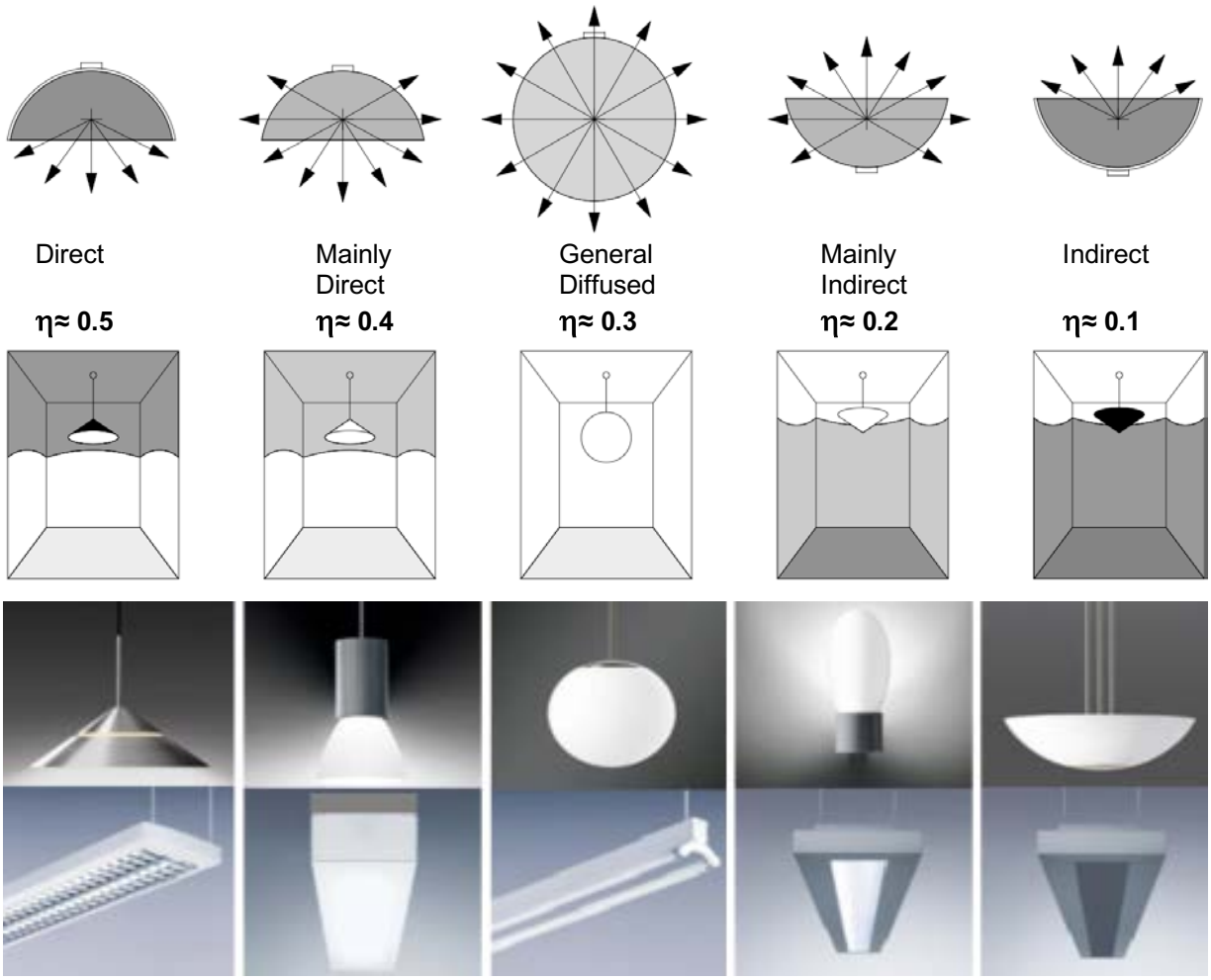
2. Artificial Lighting Design

This design aid presents a **simplified calculation method** to estimate the number and power of the luminaires considering the **function** of the interior, the required **illuminance** level and the **light distribution** of the lamp.

This simplified method does not consider the reflectance of the surfaces, the furnishing of the interior. Lighting designers usually use a computer software and consider manufacturer specific light sources and luminaire data.

2.1. Light Distribution of Luminaires

The light distribution - and the corresponding efficiency - of luminaires are divided into five main categories by the regulations and standards; as presented on the table bellow. The most appropriate luminaires should be selected for the individual tasks and areas.



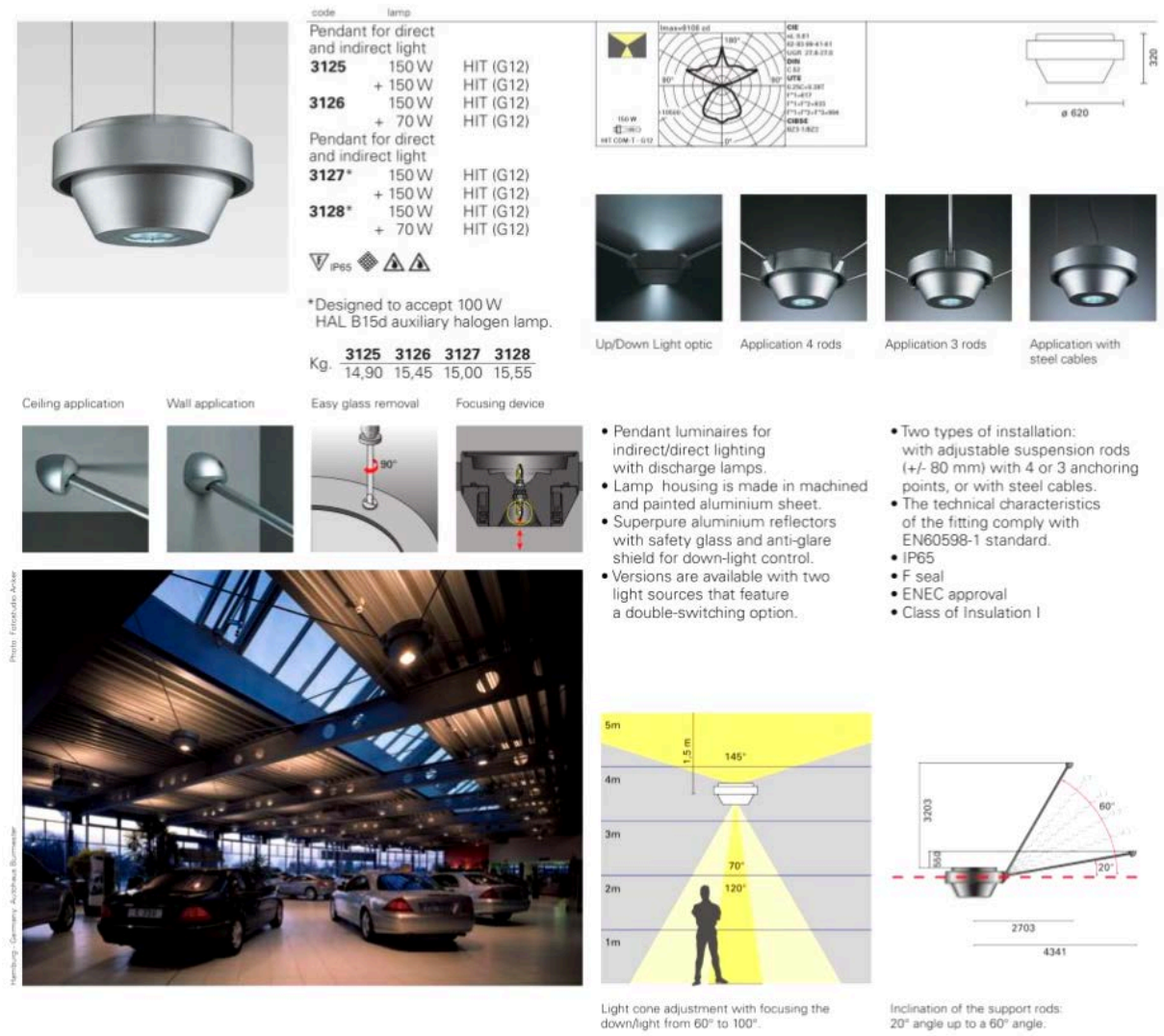
Light distribution and efficiency of luminaires

The **η [-] efficiency** values desribe the amount of light provided by the various light distribution schemes: **direct** lighting**: 0,5**, **mainly direct** lighting: **0,4**, **general diffused** lighting**: 0,3, mainly indirect** lighting**: 0,2, indirect** lighting: **0,1**.

Please select the most appropriate luminaire distribution methid for the specific lighting tasks with the help of the consultant!

2.2. Lamps

It's important to select such a lamp that corresponds to the previously defined light distribution mode. Manufacturer cataloges can be use dto select a lamp, these catalogues usually display photos about interiors where a spacific lamp is recommended for.



iGuzzini GREENWICH pendant luminaire design by Norman Foster

Please check out these manufacturers and download their product catalogs:

- **iGuzzini** www.iguzzini.com
- **Artmeide** www.artemide.com
- **Philips** www.philips.hu
- **ERCO** www.erco.com
- **Zumtobel** www.zumtobel.com
- **BEGA** www.bega.de
- **Faeluce** www.faelluce.com
- **OSRAM** www.osram.com
- **Holux** www.holux.hu
- **Ridi** www.ridi.de
- **Fagerhult** www.fagerhult.com
- **iN** www.performanceinlighting.com

Most of the manufacturers' catalogues displays photos of building interiors where a lamp had been installed. Such photos provide help to make sure that the selected lamp can be used in your building design and function.

For further interior lighting design examples categorized by function please visit the egt.pagem.hu site where you may find ideas and inspiration for your design.

2.3. Light Sources

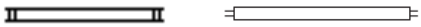
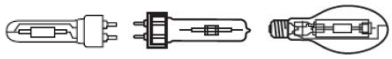
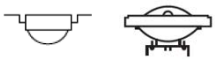
There are various artificial light sources are available using different technology optimized for different lighting tasks. Some have small sizes and require little space for installation (eq. bookshelves) but require considerable to operate. Some have considerable power and can be used in large spaces (eq. concert halls) but can not be dimmed. Some may have low opeartional costs but bad color rendering and so on.

Halogen lamps (point-like light sources) require about 5-6 times more energy to opearte than LEDs. However they have small sizes and their color temperature is warm. Halogen lamps are still used in interior spaces where the lamp-target distance is not more than 3 - 4,00 meters.

Fluorescent tubes (linear light sources) and **compact fluorescent tubes** (point-like lightsources) are low-cost to operate and to install. Their color temperature is natural or cold and they are ideal for public buildings for spaces not higher than 5 - 6,00 meters.

Metal halide lamps (point-like light sources) are low-cost to operate and can have high capacities. These are ideal for lighting of concert halls, stadions, etc.

LED light sources (point-like or linear light sources) are low-cost to operate and can be used for all lighting scenarios.

Light Source	Energy Efficiency	Catalog Icons
Halogen lamp	η^* = 25 lm/W	
Compact flourescent tube	η^* = 70 lm/W	
Flourescent tube	η^* = 80 lm/W	
Metal halide lamp	η^* = 90 lm/W	
Natrium lamp	η^* = 130 lm/W	
LED light sources	η^* = 90 lm/W	

Lumen efficiency and symbols of lamps

2.4. Calculations

The following simplified calculation method can be used to forecase the **number of luminaires** and the required **power of light sources**. This equation uses the data described and presented on the previous pages of this design aid.

First we must calculate the "**required luminous flux**", Φ [lm]. This defines the **amount** of light that the lamp should eventually provide for a specific task.

$$\Phi = k (E \cdot A) / \eta \text{ [lm]}$$

Next, we will define **P** [W] that is the "**built-in performance**" of lighting in the interior. This will help us to determine the number of luminaires and the power of light sources necessary to provide the Φ [lm] amount of light calculated above.

$$P = \Phi / \eta^* \text{ [W]}$$

Here's a short explanation and help to calculate the required Φ [lm] luminous flux:

- **k [-] is the environmental factor**: it's typical value is **k = 1,25** for "clean" interior. In case of interiors with constant dust and pollution pls consider k = 1,6 (cement factory, saw machinery room, etc.).
- **E [lx] illuminance**: typical values are **100 lx < E < 500 lx** (storage, toilet: 100 lx, corridors, passages: 200 lx, reception hall: 300 lx, workspaces: 500 lx). In case of exterior lighting 10...50 lx may also be adequte, yet please consider 750...2000 lx for TV studios and performance halls.
- **A [m^2] area**: this is the area of the lighting task. This may by the floor are of a corridor, but may also be the area of a painting, table or a service desk.
- η [-] **Light distribution efficiency**: direct: **0,5,** mainly direct: **0,4**, general diffused: **0,3**, mainly indirect: **0,2**, indirect: **0,1.**

The only unknow in the built-in-performance formula **P** [W] is the energy efficiency of the selected light source:

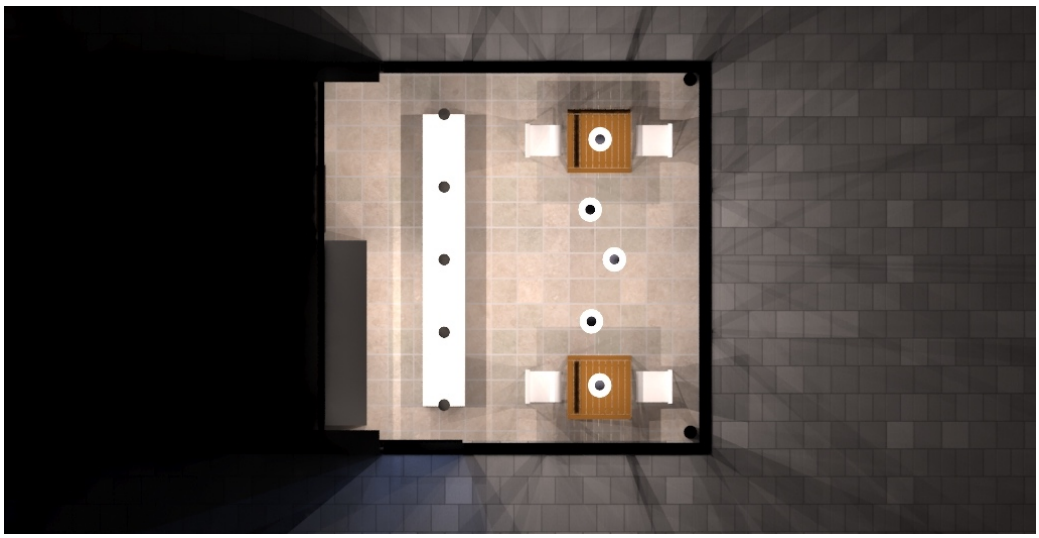
- η^* **[lm/W]** lumen-efficiency of the light source: **halogén** 25 lm/W, **fluorescent** tube and **compact fluorescent** tube: 70-80 lm/W, **metal halid** lamp and **LED** 90 lm/W.

Using the P [W] built-in performace you may choose to install less number of lamps having higher capacity of light sources and vice versa. It is imporatnt to select the number of lamps so, that even light distribution is provided in the interior while all visual comfort requirements are also met!

Please discuss the number and distribution of the selected lamps with your consultant!

3. Lighting Design Examples

Perspective view and floor plan detail presenting lamp distribution (Dávid Kerekes)



6. KÁVÉZÓ MESTERSÉGES MEGVILÁGÍTÁS TERVE

3 fajta funkció:

- Társalgó/étkező/előtér
- Eladó pult, pénztár, tálalás
- Mosogató, konyhai előkészítő műveletek

Társalgó, étkező, előtér:

1. Alap adatok:
   terület:
   A = 17 m²
   környezeti tényező:
   K = 1,25
2. Világítási mód: szórt fényű → η = 0,3
3. Szükséges megvilágítási érték: E = 200lx
4. Fényforrás: kompakt fénycső → η* = 70lm/W
5. Lámpatest: Bega függesztett gömb test /66 704/
6. Beépítendő fényáram: $\Phi = k(E \cdot A)/\eta$

$$\Phi = 1{,}25(200 \cdot 17)/0{,}3$$

$$\Phi = 14066\ lm$$

Beépített teljesítmény:

P = Φ / η*

P = 14066 / 70

P = 202,4 W

→ 5db 42W-os izzóval ellátott lámpatest kerül betervezésre.

Eladó pult, pénztár/tálalás:

1. Alap adatok
   terület:
   A = 8 m²
   környezeti tényező:
   K = 1,25
2. Világítási mód: közvetlen → η = 0,5
3. Szükséges megvilágítási érték? E = 500lx
4. Fényforrás: LED → η* = 90lm/W
5. Lámpatest: ERCO quintessence 85792.000
6. Beépítendő fényáram:

$$\Phi = 1{,}25(500 \cdot 8)/0{,}5$$

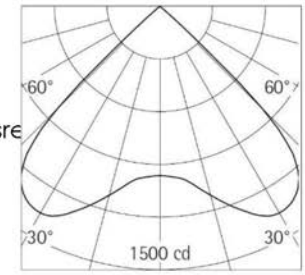
$$\Phi = 10000\ lm$$

Beépített teljesítmény:

P = 10000 / 90

P = 111,1 W

→ 5db 24W-os LED izzóval ellátott lámpatest kerül betervezésre



LED 24W 3300lm 4000K neutral white

5

Mosogató, konyhai előkészítő műveletek:

1. Alap adatok:
   terület:
   A = 2,5 m²
   környezeti tényező:
   K = 1,25
2. Világítási mód: közvetlen → η = 0,5
3. Szükséges megvilágítási érték: E = 300lx
4. Fényforrás: LED szalag→ η* = 90lm/W
5. Lámpatest: Philips pentura mini led
6. Beépítendő fényáram:

$$\Phi = 1{,}25(300 \cdot 2{,}5)/0{,}5$$

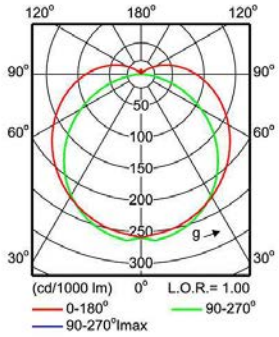
$$\Phi = 1875\ lm$$

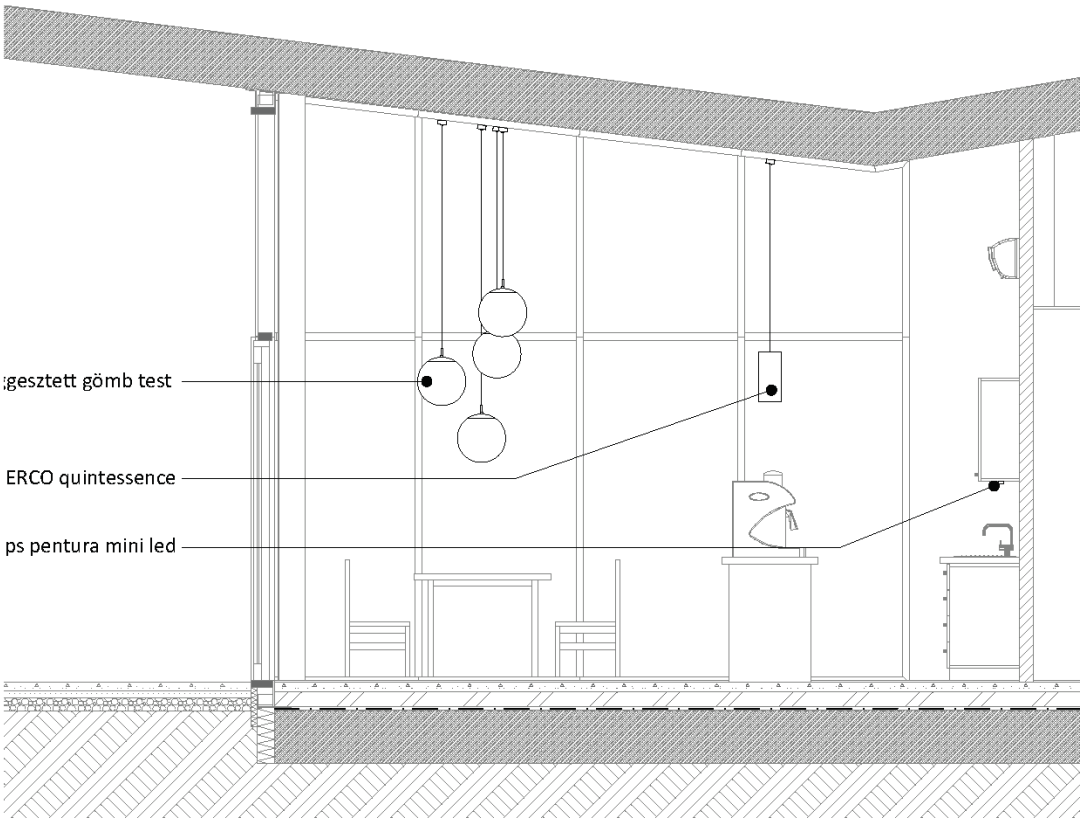
Beépített teljesítmény:

P = 1875 / 90

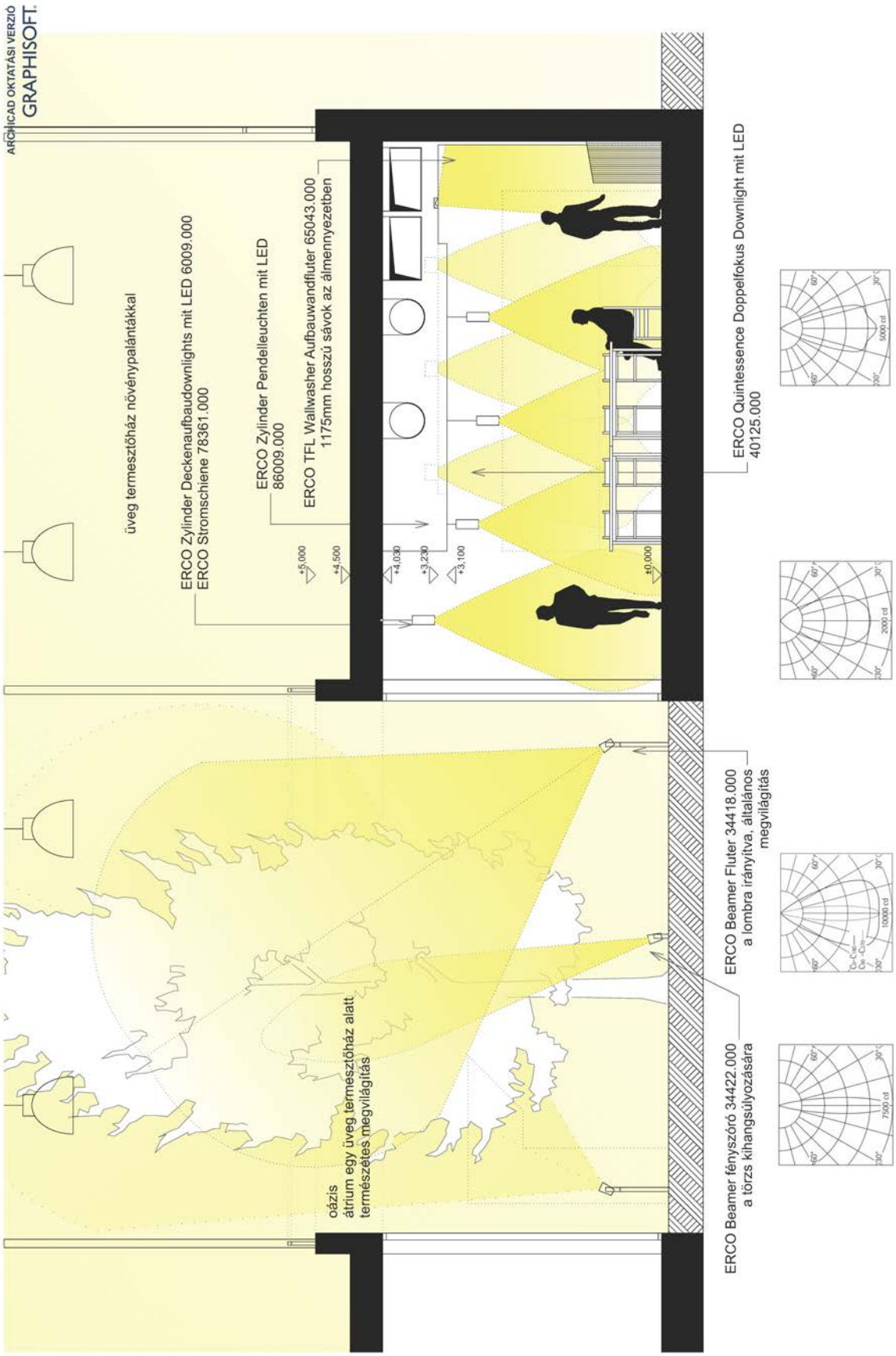
P = 20,8 W

→ 2db 10,8 W-os Led lámpatest kerül betervezésre.

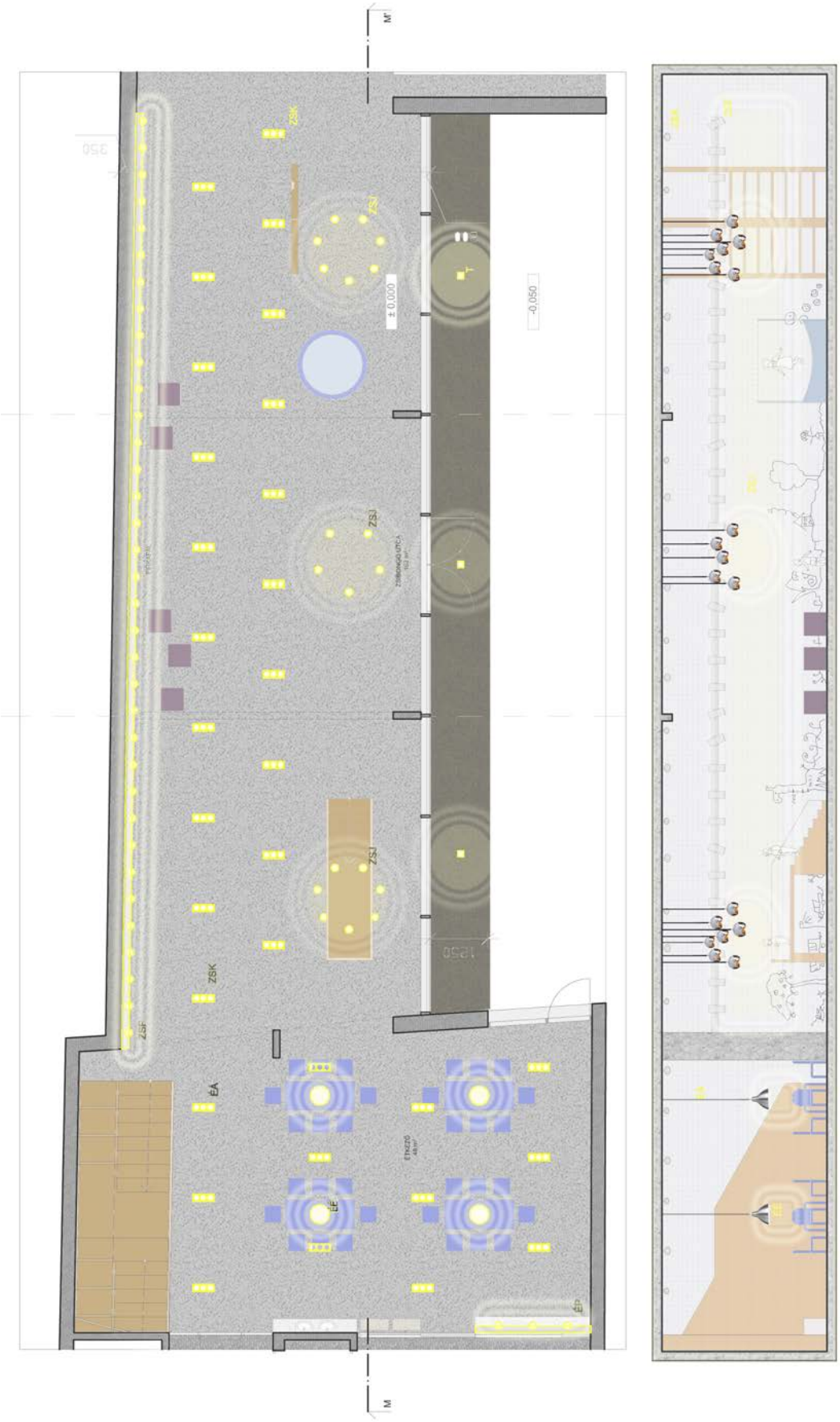




Calculations using manufacturer specific luminaires and light sources



Section and Floor Plan (next page) views with luminaires (Dorottya Vajda)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