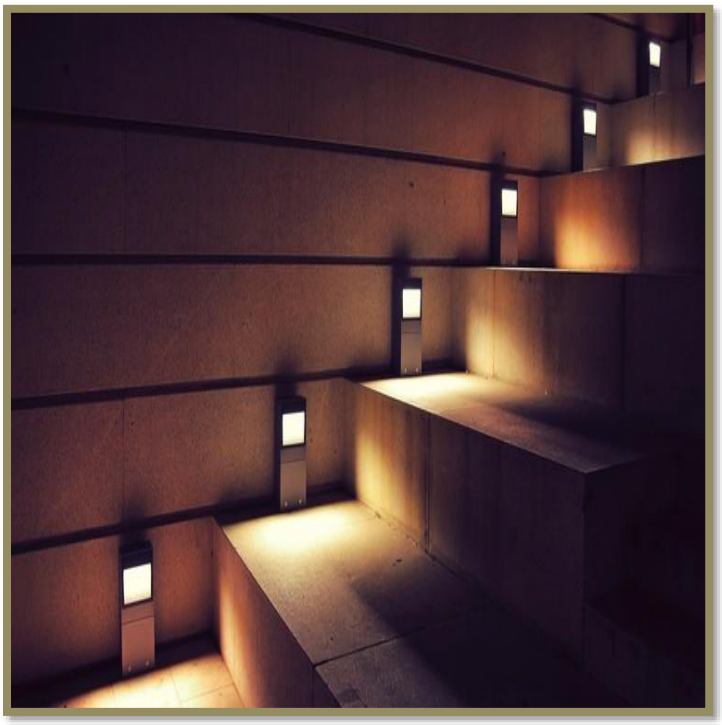

LIGHTING DESIGN

A Complex Engineering Problem

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Abstract

This report details a proposal for a residential lighting scheme and cable installation as the final project for the Electrical Power Distribution and Utilization (EE-359) course of NEDUET's B.E. Electrical Engineering undergraduate program.

An apartment's floor plan was used to model it in DIALux Evo v. 8.2.1 which used standardized average illumination levels for different rooms to create a preliminary lighting scheme with selected luminaires. After modifying the preliminary lighting scheme for economic feasibility and improved uniformity in average illumination levels, its data was combined with the results of a load survey to model the apartment as an electrical load in the form of a single line diagram (SLD). Finally, the power consumption data were used to select appropriate cables for power distribution and design a distribution board based on standard operating procedure.

Project Requirements

Introduction

One of the responsibilities of an electrical engineer is the design and analysis of cabling and lighting schemes for electrical installations. The process of devising such a scheme involves accounting for a plethora of factors such as total power consumption, standardized illumination levels, cable selection and sizing based on environmental conditions, to name a few.

Deliverables

To gain insight into this process, an electrical cabling and lighting scheme was devised for a 1,700 sq. ft, 3 bedroom apartment powered by a 3 phase, 220V 50 Hz supply from K-Electric. The technical requirements or deliverables this proposal aims to address are

- list of luminaires or lighting fixtures for different areas of the apartment, along with their associated illumination levels, quantities, and other relevant data.
- lighting scheme showing the placement of these luminaires, optimized for maintaining standardized average illumination levels and space-height ratios.
- load table summarizing the results of a load survey to quantify the electrical power consumption requirements of the apartment.
- single line diagram (SLD) modeling the distribution of power from the metering panel to the terminal loads in the apartment.
- distribution board layout to provide an overview of the circuit breakers used for each load.

Technical Requirements: Floor Plan

Figure 01 shows the floor plan of the apartment unit for which the cable installation and lighting scheme are to be proposed. The apartment has three bedrooms with attached bathrooms, a lounge/dining area, a kitchen, a guest room with an attached bathroom, a balcony, a store, and a drawing room with an adjacent bathroom. The different sections of the house along with their areas and corresponding expected loads are shown in Table 1.

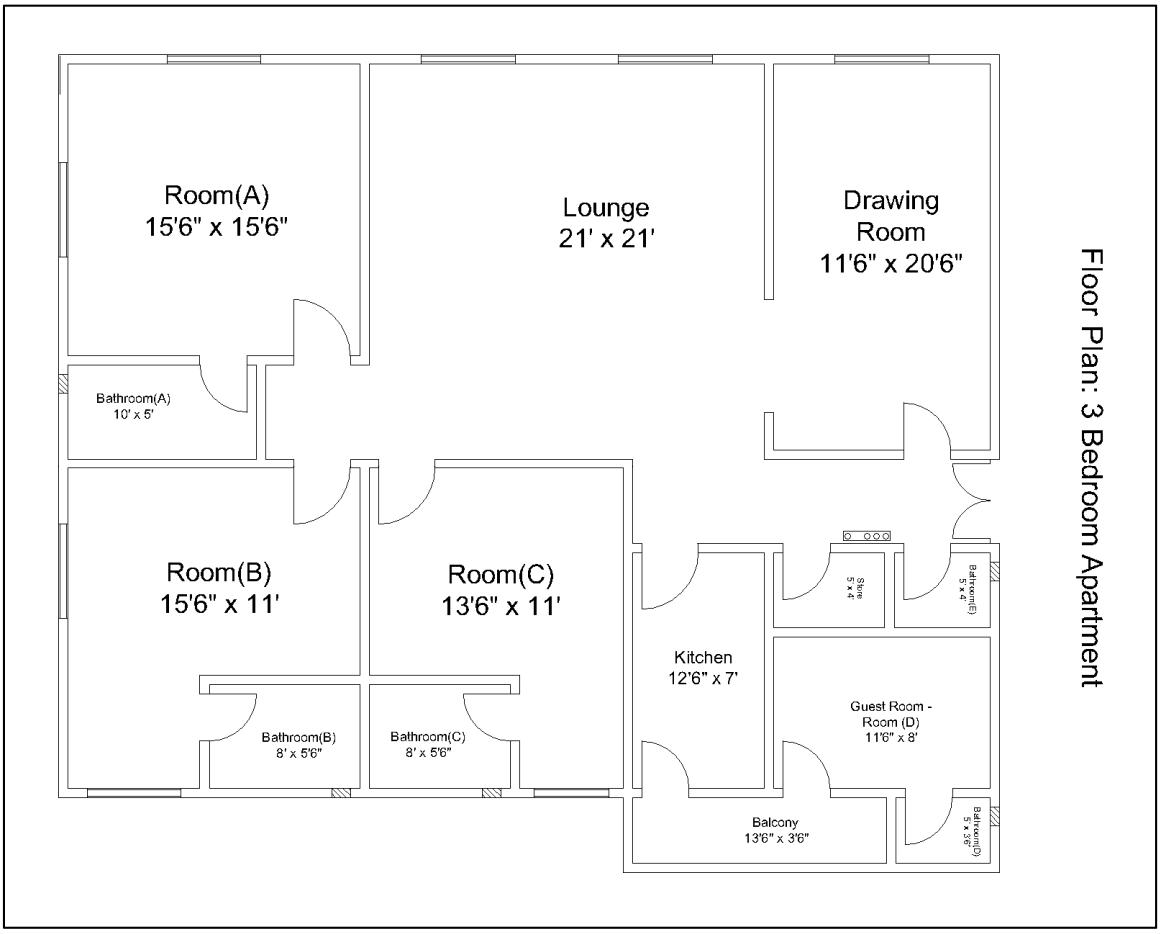


Figure 1: Floor Plan of 3 Bedroom Apartment

Section	Dimensions	Area (sq ft)	Expected Load
Room (A)	$15'6" \times 15'6"$	240.25	Air Conditioner, Lighting, Ceiling Fan
Bathroom (A)	$10' \times 5'$	50	Exhaust Fan, Lighting
Room (B)	$15'6" \times 11'$	170.5	Air Conditioner, Lighting, Ceiling Fan, Power
Bathroom (B)	$8' \times 5'6"$	44	Exhaust Fan, Lighting
Room (C)	$13'6" \times 11'$	148.5	Air Conditioner, Lighting, Clothes Iron, Ceiling Fan, Power
Bathroom (C)	$8 \times 5'6"$	44	Exhaust Fan, Lighting
Lounge	$21' \times 21'$	441	Lighting, Ceiling Fans, Refrigerator

Drawing Room	$20'6" \times 11'6"$	235.75	Lighting, Ceiling Fan
Passageway	$12' \times 4'6"$	54	Lighting, Electrical Panel
Kitchen	$12'6" \times 7'$	87.5	Lighting, Ceiling Fan, Exhaust, Microwave
Room (D)	$11'6" \times 8'$	92	Lighting, Ceiling Fan
Bathroom (D)	$5' \times 3'6"$	17.5	Exhaust Fan, Lighting,
Balcony	$13'6" \times 3'6"$	47.25	Lighting, Washing Machine
Bathroom (E)	$5' \times 4'$	20	Exhaust Fan, Lighting

Table 1: Apartment Area Distribution & Preliminary Load Assessment

Analysis of Preliminary Load Assessment

- Most load is lighting with the largest non-lighting loads being air conditioners.
- The power factor of a residential unit such as this apartment will therefore likely be close to 1, as heavy inductive machinery is not a part of the load.
- To achieve a robust power distribution scheme, the loads must be distributed equally across all three phases to the apartment unit.
- For greater fault tolerance and robustness, the load on each phase should be varied: powering all the lighting fixtures or air conditioners in the apartment with a single phase is a poor design choice.

Technical Requirements – Estimated Cabling Distances

The apartment is located on the top floor of a 7 floor building (excluding the ground floor), with 4 apartments on each floor. The apartment receives a 3 phase, 220 V, 60 Hz sinusoid power supply from a local K-Electric substation situated approximately 85 m ( ) away. The substation delivers power to many apartment blocks on the same street and terminates in a metering panel situated underneath the stairwell on the ground floor of each building. A vertical cable tray then delivers power to each individual apartment in the building.

Substation to Metering Panel

It is unlikely that a UGC will be laid in a straight line between the substation and the metering panel. As shown in Figure 2, an arrangement in which the UGC has been laid parallel to the street, branching into each apartment building. Thus, the total cable length between the substation and the metering panel is estimated to be $\approx$ 120 m (392 ft).

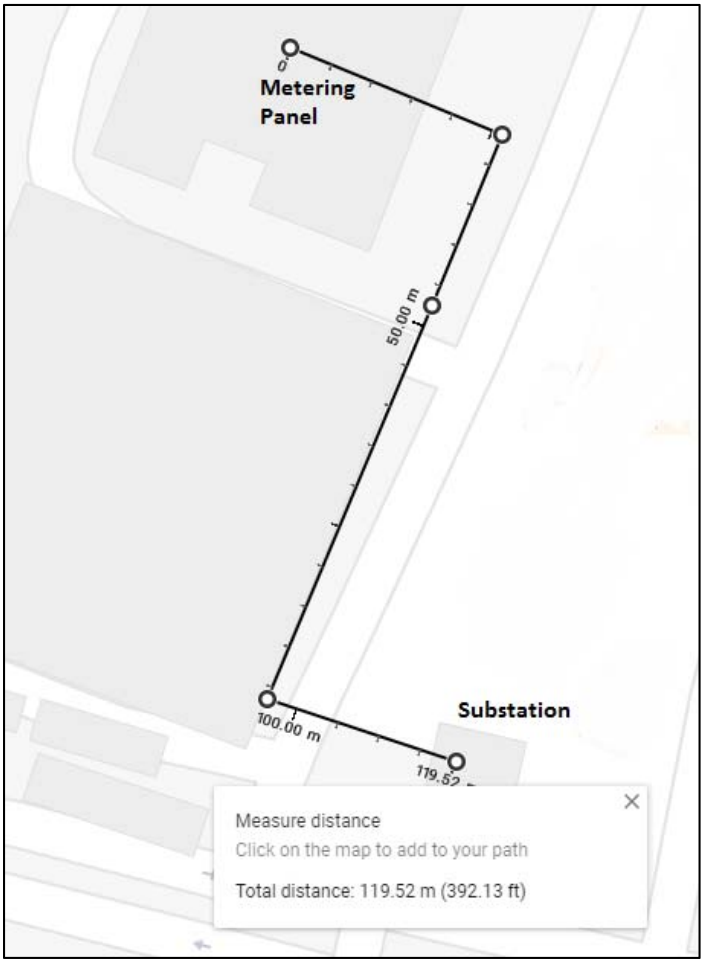


Figure 2: Substation to Metering Panel Distance

Metering Panel to Apartment

As the floor-to-ceiling height of each level in the apartment building is 10 ft, and the thickness of the concrete floor between levels is ≈1 ft, the total vertical distance between the metering panel and the apartment on the seventh floor is

$$Vertical\ Distance = Number\ of\ Floors \times (Floor\ Height + Floor\ Thickness)$$
$$Vertical\ Distance = 7 \times (1\ ft + 10\ ft) = 7 \times 11 ft = 77\ ft$$

Accounting for the horizontal distance between the metering panel and the distribution board (12 ft) and also accommodating tolerance levels, the total distance between the metering panel and the apartment's distribution board is ≈ 27 m (90 ft).

Technical Requirements: Illumination Levels

Guidelines in The Lighting Handbook recommend specific average illumination levels for both general and task lighting schemes depending on the nature of the area being illuminated. These values are used as target illumination levels in the design of the lighting scheme. The relevant values are listed in Table 2.

Location	Lighting Scheme	Average Illumination (Lux)	Location	Lighting Scheme	Average Illumination (Lux)
Bedroom (Adult)	General	100 – 300	Kitchen	General	300
	Task	500		Countertop	750
Bedroom (Child)	General	500	Bathroom	General	300
	Task	800		Shave/Makeup	300 - 750
Laundry/ Utility	General	200	Hall or Landing	General	100 - 500
Home Office	General	500	Living Room	General	300
	Task	800		Task	500
Dining Room	General	200	Family Room	General	300
				Task	500

Table 2: Standardized Illumination Levels

Analysis of Illumination Levels and Lighting Scheme Types

- Recommended illumination levels are average values only: the actual illumination at any given point in a room may exceed or fall short of the average value.
- General lighting will be used in all areas as part of this proposal, primarily because of its uniformity and flexibility.
- The uniformity makes the analysis and computation of a lighting scheme more tractable, as the illumination produced by a general lighting is roughly uniform.
- The general lighting scheme is also flexible: it can adequately facilitate the purposes of both ambient illumination and a variety of tasks, without being exclusive to a specific task.
- However, task lighting is more energy efficient, and can help achieve up to $\frac{2}{3}$ of the general lighting scheme's energy savings.

- The availability of power outlets in the cable installation (see Load Assement) means the system can still accommodate task lighting in the form of table lamps or similar luminaires.

Summary of Technical Requirements

- Three phase, 220 V, 50 Hz sinusoid power supply.
- General lighting scheme for a 1,700 sq. ft residential unit.
- Standardized average illumination level is 300 lux for most areas.
- Load is mostly lighting, with some slightly inductive appliances such as air conditioners and refrigerators.
- Power factor of the system is approximately 1.
- Cable from metering panel to distribution board is $\approx$ 27 m through a vertical cable shaft. Can use moderate amounts of armouring/protection, if funds allow.
- Cable from local substation to metering panel is $\approx$ 120 m through an underground cable tray. Will need armouring to protect against environmental stresses.

Lighting Scheme Proposal

The lighting scheme for the apartment was designed by importing the floor plan into DIALux Evo v. 4.1. Windows, doors, furniture, and other calculation objects were added to the model in DIALux to make the lighting scheme model as accurate a representation of an actual apartment as possible. Luminaires were selected from Philips Product Selector Database, which provides a complete catalog of digital models of Philips Lighting products to simulate a lighting scheme in DIALux, 3DS Max, and other modeling software.

Luminaire Selection Criteria

- Luminaires were selected on the basis of their lumen-wattage ratios or Lamp Efficiency η_L. The higher this ratio, the greater the amount of electrical energy converted to luminous energy. The goal is to achieve the maximum possible illumination for a given input power, to maximize illumination simultaneously while minimizing power consumption.

- The luminaire selection consists entirely of fluorescent lighting, with no incandescent lamps being used. This is because despite the relatively better power factor of the former, long term economic losses are high because of poor efficiency.

- Incandescent luminaires were also not chosen because of their poor maintenance factor, as they are more susceptible to overheating/moisture damage than their fluorescent counterparts.

- For consistency, the same correlated color temperature (CCT) was chosen for all luminaires. The CCT was between 3,000 K (soft/warm white) and 3,500 K (natural/cool white respectively).

- Very little accent or task lighting was used in the design of the lighting scheme, primarily to reduce expenditure and improve model tractability.

List of Selected Luminaires

Please refer to Appendix A: DIALux Report for a list of all luminaires used in the lighting scheme. The list provides information about various luminous parameters of each luminaire, including the luminous efficacy, luminaire flux, lamp flux, power consumption, and model number, to name a few.

Luminaire Selection Analysis

- Fluorescent lamps placed in recessed lamp holders have significantly higher lamp efficiency or luminous efficacy than fluorescent tube lights.
- All luminaires have a CCT of a 3,000 K, which is a warm white light that is suitable for residential installations.
- Examining the polar curves generated by DIALux Evo for each luminaire shows that lamps provide direct or semi-direct illumination, whereas tube lights are better suited to indirect or semi-indirect illumination.
- This would also explain why the luminous efficacy of the lamps is higher than that of the tube lights.
- The average luminous efficacy of the entire luminaire list is 96 lm/W.

Luminaire Placement

Please refer to Appendix A: DIALux Lighting Scheme Report for a complete overview of the placement of luminaires in the apartment, the associated lux distribution in the form of isolux contour maps, and other relevant data.

Analysis of Luminaire Placement

Table 3 shows the average luminous flux in each section of the apartment as derived from the proposed lighting scheme modeled in DIALux Evo. The target luminous flux values for the same sections, as outlined in the technical requirements section, are also listed in the table.

Section	**Target Average Luminous Flux (*Lumens/Lux*)**	**Actual Average Luminous Flux (*Lumens/Lux*)**	**Error (%)**
Bedroom (1)	349	300	16.3
Bathroom (1)	310	300	3.3
Bedroom (2)	303	300	1.0
Bathroom (2)	308	300	2.7
Bedroom (3)	348	300	16.0
Bathroom (3)	335	300	11.7
Bedroom (4)	317	300	5.7
Bathroom (4)	316	300	5.3
Drawing Room	320	300	6.7
Bathroom (5)	353	300	17.7
Kitchen	207	200	3.5

Balcony	270	250	8.0
Dining and Lounge	264	200	32.0
Store	244	150	62.7

Table 3: Lighting Scheme Luminous Flux Data

- The average percentage error between the target average lux and the average lux achieved with the proposed lighting scheme is 13.8%.
- In all sections of the house, the proposed luminous flux exceeds the target lux, albeit by different amounts.
- The highest deviation from target lux is observed in the store, dining and lounge, and bathroom 5, possibly due to the presence of reflective surfaces or calculation points in the DIALux model.
- All lighting calculations done with the room's floor as the working plane.

Connected Load Assessment

The lighting scheme data (types, quantities, and power ratings of luminaires) constitutes only a part of the total power consumption requirements of the apartment. A load assessment was carried out to account for non-lighting loads such as ceiling fans, refrigerators, ventilators, and air conditioners. The electrical appliances in each room were counted and their power ratings collated to calculate the total real power consumed by each room. The results of the load assessment are shown in Table 4.

Room A						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Room A	Recessed LED Lights	Surface Mounted	Lighting	21.5	4	86
	Television		Lighting	100	1	100
	Tube lights	Wall Mounter	Lighting	55	2	110
	Air Conditioner		Cooling	1250	1	1250
	Two-pin electrical outlet		Power	5	3	15
	Ceiling Fan		Cooling	150	1	150
Bathroom 1	Exhaust Fan	In attached bath	Cooling	75	1	75
	LED Lamp	Surface mounted	Lighting	21.5	1	21.5
					Total Power in W	**1807.5**

Room B						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Room B	Recessed LED Lights	Surface Mounted	Lighting	21.5	3	64.5
	Ceiling Fan		Heating/Cooling	75	1	75

	Tube Lights	Wall Mounted	Lighting	55	2	110
	Air Conditioner		Heavy/Heating/Cooling	1500	1	1500
	Computer Monitor		-	34	1	34
	Small LED Study Light	Wall Mounted	Lighting	4	1	4
	LaserJet Printer		Heavy/Motor	150	1	150
	PC		Heating/ Cooling	250	1	250
Bathroom 2	Exhaust Fan		Heating/Cooling	75	1	75
	LED Lamp	Surface Mounted	Lighting	18.8	1	18.8
					Total Power in W	**2281.3**

Room C						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Room C	Tube Light	Wall Mounted	Lighting	55	2	110
	Recessed LED Lights	Surface mounted	Lighting	21.5	3	64.5
	Ceiling Fan		Heating/Cooling	75	1	75
	Clothes Iron		Heavy/Heating	800	1	800
Bath 3	LED Lamp	Surface Mounted	Lighting	18.8	1	18.8
	Exhaust Fan	In attached bath	Heating/Cooling	75	1	75
	Two-pin Electrical Outlet	5A Fuse	-	5	2	10
					Total Power in W	**1153.3**

Kitchen						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Kitchen	LED Lamps	Surface Mounted	Lighting	18.8	2	37.6
	Ceiling Fan		Heating/ Cooling	75	1	75
	Deep Freezer		Heating/ Cooling	500	1	500
	Exhaust Fan		Heating/ Cooling	75	1	75
	Electric Chimney		Heating/ Cooling	75	1	75
	Microwave Oven		Heating/ Cooling	1200	1	1200
	Electric Kettle		Heating/ Cooling	250	1	250
					Total Power in W	**2212.6**

Lounge, Dining, Entrance Hallway						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Lounge, Dining, Entrance Hallway	Recessed LED Lights	Surface Mounted	Lighting	21.5	2	43
	LED Lamps	Surface Mounted	Lighting	18.8	3	56.4
	Focused LED Lamp	Hanging	Lighting	36	1	36
	Tube Lights	wall Mounted	Lighting	55	2	110
	Ceiling Fan		Heating/ Cooling	75	2	150

	Refrigerator	W/stabilizer	Heating/ Cooling	800	1	800
	Water Cooler		Heating/ Cooling	60	1	60
	Television			150	1	150
	Telephone	mW load. Negligible		0	1	0
	WiFi Router			5.4	1	5.4
	Doorbell	mW load. Negligible		10	1	10
					Total Power in W	**1420.8**

Guest Room and Bathroom 4						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Guest Room	Tube Light	Wall Mounted	Lighting	55	1	55
	Focused LED Lamp	Hanging	Lighting	36	1	36
Bathroom 4	LED Lamp	Surface Mounted	Lighting	11.6	1	11.6
					Total Power in W	**102.6**

Drawing Room						
	Load	**Comment**	**Type**	**Power Rating**	**Quantity**	**Total Power**
Drawing Room	Ceiling Fan		Cooling	75	1	75
	Recessed LED Lights	Surface Mounted	Lighting	21.5	4	86
					Total Power in W	**161**

Store and Bathroom 5

	Load	Comment	Type	Power Rating	Quantity	Total Power
Store	LED Tube Lights	Wall Mounted	Lighting	37.5	2	75
Bath 5	LED Lamps	Surface mounted	Lighting	11.6	2	23.2
					Total Power in W	**98.2**

Balcony						
	Load	**Comments**	**Type**	**Power Rating (Watts)**	**Quantity**	**Total Power**
Balcony	LED Lamps	Surface Mounted	Lighting	18.8	1	18.8
	Exhaust Fan		Heating/Cooling	75	1	75
	Washing Machine		Motor/Heavy	800	1	800
	Two-pin Outlets	5A Rated	Lighting	5	1	5
					Total Power in W	**898.8**

Table 4: Connected Load Assessment

Summary of Connected Load Assessment

- Coincident Connected Peak Load is 10.136 kW, although the power being drawn from the supply at any given time is likely to be lower.
- Difficult to calculate non-coincident peak load without data to analyse utilization factor.
- The kitchen, Room B (with attached bath), and Room A (with attached bath) have the highest power consumption. All three have highly inductive (microwave in kitchen and air conditioner in Room A) or highly resistive (clothes Iron in Room C) loads.
- Majority of the balcony and guest room's load is due to the highly inductive washing machine present in the section.
- Adding 150 W and 250 W for each non-connected load (powered through electrical outlet) in each bathroom and bedroom respectively, the power consumption is $\approx$ 11.8 kW.

Cable Sizing Proposal

Introduction

With the help of the finalized lighting scheme and load assessment data, power distribution cables have been selected for delivering power

- from the apartment's distribution panel to each section of the apartment.
- from the metering panel on the apartment building's ground floor to the distribution panel in the apartment on the 7th floor.

Manual Cable Sizing – Metering Panel to Distribution Board

This section performs calculations to choose a size for the cable between the metering panel on the ground floor of the apartment building and the distribution board within the apartment.

The relevant parameters, as derived in the load assessment and technical requirements section, are:

$$Total\ Load = 11.8\ kW$$

$$Phase\ Voltage = 220\ V$$

$$Total\ Load\ Current = I_L = 53.63\ A\ \approx 54\ A$$

Current Carrying Capacity I_{ccc}

To find the current carrying capacity, relevant correction factors must be applied on the load current. As a multicore (4 core) cable is being used to deliver power, the corresponding tables for 4 core cables are used to decide the corrections factors. Average ambient temperature is assumed to be $45℃$ hence the temperature correction factor is $K_c = 0.79$.

Also, the main cable is grouped in a bundle therefore the grouping factor is $K_g = 0.85$. Multiplying both the factors will result in the final correction factor to be

$$K = 0.78 \times 0.85 = 0.663$$

Hence

$$I_{ccc} = \frac{I_L}{K} = \frac{54}{0.663}$$

$$\boldsymbol{I_{ccc} = 81.44\ A}$$

The reference method chosen for this cable was "reference Method E" which dictates that the cable is travelling in a vertical perforated duct with a group of other cables having a suitable space between them. Hence, the cable size can be found by referring to **IEC table B.52.10**.

The required cable size for this application was found from the 3 loaded conductors column and is

$$\boldsymbol{Cable\ Size = 25\ mm^2}$$

With base cable capacity of 101 A.

Automated Cable Sizing – Cable Sizer Web Application

The very same results were produced by an online cable sizing service name "Cable Sizer" which follows the International Electrotechnical Commission (IEC) cable sizing and grading standards and was used to calculate sizes for the rest of the cables. A link to the service is mentioned below

http://www.cablesizer.com

Since in Pakistan IEC standards are followed for electrical installations and cable gauging therefore all the cable calculations are based on tables found in the IEC Cable Booklet. Furthermore, "Pakistan Cables Ltd" follows IEC standards for manufacturing cables, hence any product of the same specifications from their catalogue can be used for this design scheme.

Cable length for the metering panel-distribution board line has been estimated as part of the technical requirements. Lengths of all other cables are estimated based on the floor plan of the apartment and the distance of each load cluster from the apartment's distribution board.

IEC Cable Sizing Report – Metering Panel to Distribution Board

The following is a cable sizing report generated by Cable Sizer for the main power supply cable that brings power from the metering panel to the distribution board via a vertical cabling shaft.

Basic Information

The following basic cable specification was selected:

Conductor material	Copper
Insulation type	PVC
Number of cores	Multicore

The following load parameters were selected

Number of Phases	Three Phase
Nominal Load Voltage	220 V
Full Load Power Factor	1 p.u
Full Load Current	54 A

Voltage Drop Considerations

I is the full load current = 54 A

L is the total cable length = 30 m

R_c is the cable ac resistance = 0.884 Ω/km (based on typical values)

X_c is the cable ac reactance = 0.0853 Ω/km (based on typical values)

Result: The voltage drop across the 25 mm^2 cable is $\mathbf{V_{3\Phi}}$ **= 2.4804 V** (or equivalently 1.1275 % of nominal voltage)

Ampacity Considerations

Reference Installation Method	E
Ambient Temperature	45°C
Installation Type	Vertical Perforated Cable Tray (Spaced)
Number of Layers	3
Number of Grouped Cables	9

Given the cable installation, the relevant derating factors are

Ambient Temperature	**0.79** (IEC 60364-5-52 Table B.52.14)
Grouping Derating	**0.85** (IEC 60364-5-52 Table B.52.20)
Total Derating Factor	**0.6715**

Short Circuit Adiabatic Temperature Rise

Based on initial and final conductor temperatures $\theta_i = 75$ °C and $\theta_f = 160$ °C

$$\boldsymbol{k = 111.329}$$

Result: Minimum cable size based on short circuit temperature rise is

$$\boldsymbol{A = 15.5579\, mm^2}$$

IEC Cable Sizing Report: In-house Wiring

The following is a cable sizing report generated by Cable Sizer for the cables that are to deliver power from the distribution board to each load cluster. The data has been grouped according to each phase.

Basic Information

The following basic cable specification was selected:

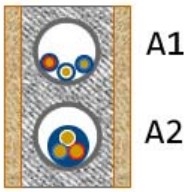
Conductor material	Copper	**Number of Phases**	Single Phase
Insulation type	PVC	**Nominal Load Voltage**	220 V
Number of cores	Single core	**Full Load Power Factor**	1 p.u

Voltage Considerations

R_c is the cable ac resistance = 16.5 Ω/km (based on typical values)

X_c is the cable ac reactance = 0.172 Ω/km (based on typical values)

Ampacity Considerations

	**Reference Installation Method**	A1 (For all cables used in house wiring)
	Ambient Temperature	45°C
	Number of Grouped Cables	1

Given the cable installation, the relevant derating factors are

Ambient Temperature	**0.79** (IEC 60364-5-52 Table B.52.14)
Grouping Derating	**1.0** (IEC 60364-5-52 Table B.52.17)
Total Derating Factor	**0.79**
Cable Base Ampacity	(IEC 60364-5-52 Table B.52.2)

Short Circuit Considerations

Based on initial and final conductor temperatures $\theta_i = 75$ °C and $\theta_f = 160$ °C

$$\boldsymbol{k = 111.329}$$

Tables 5 – 7 summarise the results of Cable Sizer for the cables used in all three phases. Cable base ampacity can be related from IEC 60364-5-52 Table B.52.2**

Phase 'R'					
Breaker Number	**1**	**2**	**3**	**4**	**5**
Load Allotted	***Spare***	***AC (A)***	***L&F(A)***	***Balcony***	***Fridge***
Load Rating (W)		1250	857.5	900	800
Load Current (A)		5.7	3.9	4.09	3.7
Cable Size (mm²)		1.5	1.5	1.5	1.5
Base Ampacity (A)		14.5	14.5	14.5	14.5
Rerated Ampacity (A)		11.455	11.455	11.455	11.455
Voltage Drop (%)		2.08	1.64	2	0.20
Conductor Length (m)		24.4	28.04	25	4.6

Table 5: Cable Sizes - Phase R

Phase 'B'					
Breaker Number	**6**	**7**	**8**	**9**	**10**
Load Allotted	***Spare***	***L&F(B)***	***AC (B)***	***Iron (C)***	***L&F(C)***
Load Rating (W)		743.3	1500	1000	443
Load Current (A)		3.4	6.818	4.545	2.015
Cable Size (mm²)		1.5	1.5	1.5	1.5

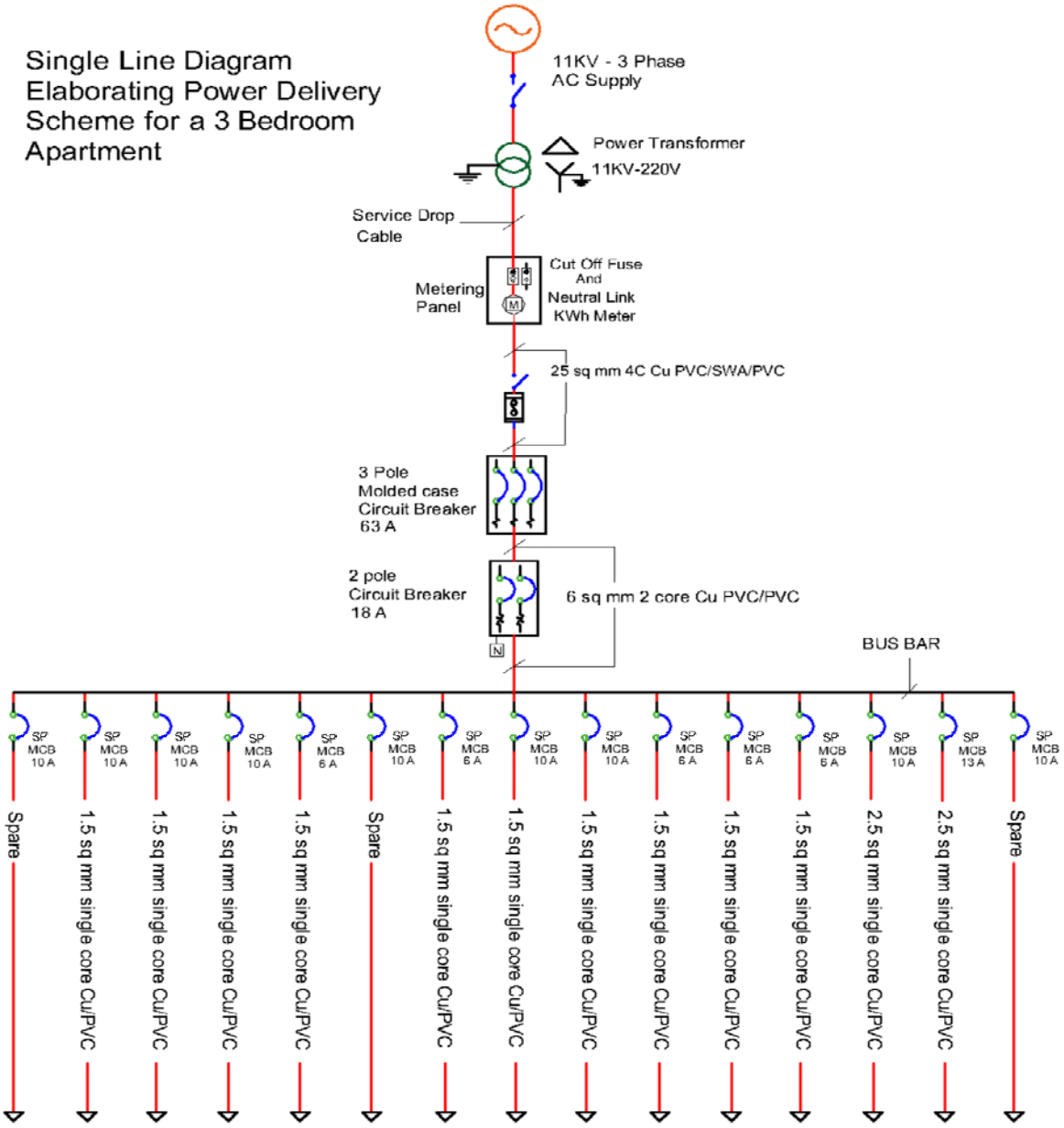
Base Ampacity (A)		14.5	14.5	14.5	14.5
Rerated Ampacity (A)		11.455	11.455	11.455	11.455
Voltage Drop (%)		0.66	0.84	0.52	0.22%
Conductor Length (m)		13	23	7.5	7

Table 6: Cable Sizes - Phase B

Phase' 'Y'					
Breaker Number	**11**	**12**	**13**	**14**	**15**
Load Allotted	***L&F – Drawing Room***	***Store + guest room +Bath 4 & 5***	***Lounge & kitchen***	***Freezer, Micro wave***	***Spare***
Load Rating (W)	361	352	1568	2000	
Load Current (A)	1.64	1.6	7.12	9.1	
Cable Size (mm^2)	1.5	1.5	2.5	2.5	
Base Ampacity (A)	14.5	14.5	19.5	19.5	
Rerated Ampacity (A)	11.455	11.455	11.692	13.25	
Voltage Drop (%)	0.28	0.22	0.83	0.46	
Conductor Length (m)	9.2	7.8	7.2	8	

Table 7: Cable Sizes - Phase Y

Single Line Diagram (SLD)



	Phase 'R'					Phase 'B'					Phase' 'Y'				
Breaker Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Load Alloted	Spare	AC in Room A	L & F Room A + Bath	Balcony	Fridge	Spare	L&F Room B + Bath	AC Room B	Iron	L&F Room C	L&F Drawing	Store + guest room + Bath 4 & 5	Loung &kitchen	Microwave & freezer	Spare
Load Rating (Watts)		1250	857.5	900	800		743.3	1500	1000	443	361	352	1568	2000	
Length Of conductor (m)		24.4	28.04	25	4.6		13	23	7.5	7	9.2	7.8	7.2	8	
Derated Ampacity		11.06	11.06	11.06	11.06		11.06	8.769	11.06	11.06	11.06	11.06	11.692	13.25	
Load Cuurent (Amps)		5.7	3.9	4.09	3.7		3.4	6.818	4.545	2.015	1.64	1.6	7.12	9.1	

Distribution Board Design

Distribution Board Layout

The distribution board in the apartment reroutes three phase supply from the metering panel to each phase and subsequently each load. To protect against short circuits, each distribution line from the board is fitted with a short circuit fuse of a rating suitable for the current it is expected to carry, as derived in the cable sizing proposal. The proposed design of the distribution board is shown in Figure 3.

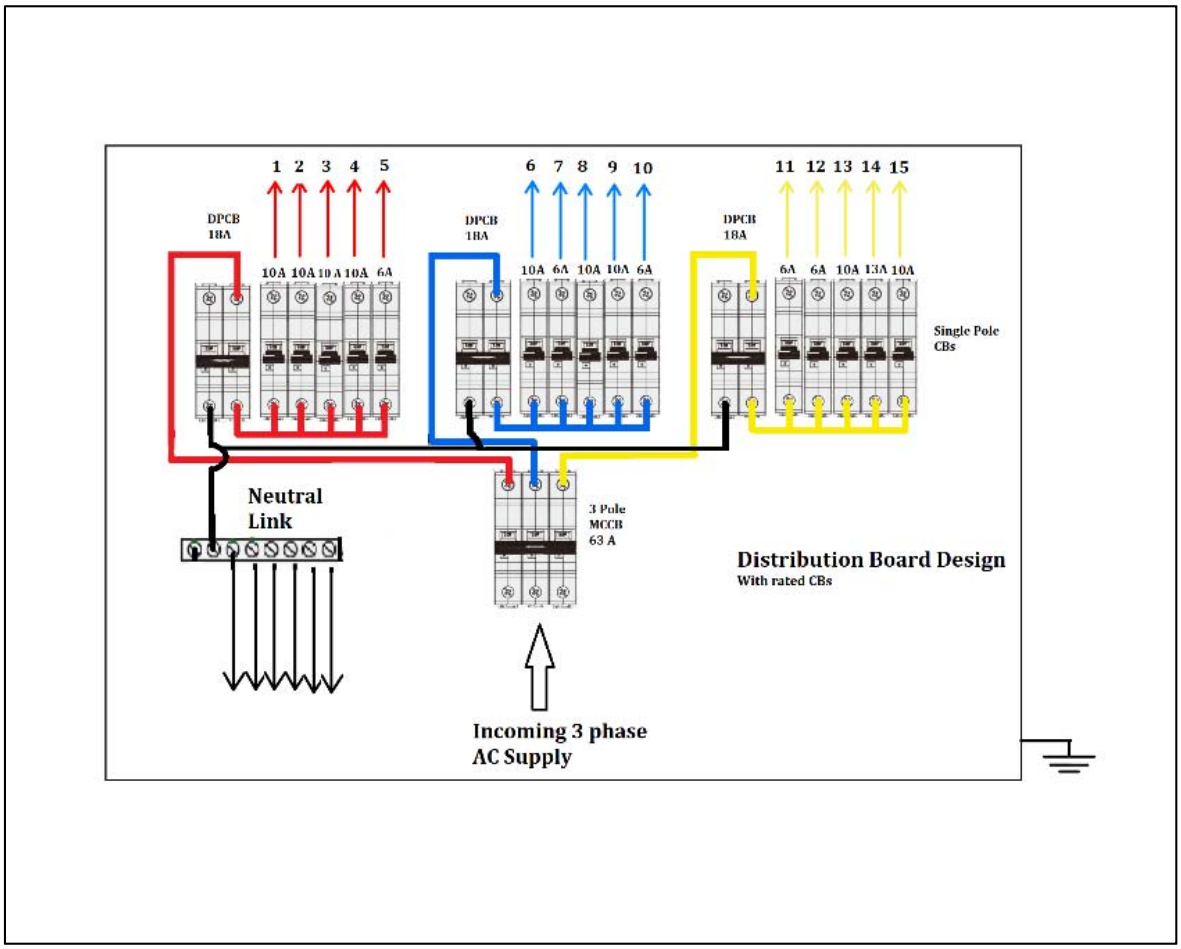


Figure 3: Distribution Board Design

Breaker Sizing

However, as the breakers in the distribution board are Overcurrent Protective Devices (OCPDs), their ratings are slightly higher than the actual rated current of the cable they are connected to. Specifically, NEC sizing rules. Secs. 210-22(c), 220-3(a), 220-10(b), and

384-16(c) all relate to the sizing rules for OCPDs. The first three all specify ther same requirement:

$$\textbf{\textit{OCPD size} = 100\% of discontinuous load + 125\% of continuous load}$$

This implies that for any rated value of current the beaker size necessary to keep the system safe is 1.25 times the rated current. Thus, the rerated current of the distribution cable connected to each breaker is the cable's rated current scaled by the Safety Factor.

$$\textbf{\textit{Safety factor} = 1.25}$$

Based on the safety factor modification, the values for the proposed breaker sizes are tabulated in Table 8.

Breaker Number	Load Description	Connected Load (Watts)	Rated Current (Amps)	Rerated Current (Amps)	Proposed Breaker size (Amps)
1	Spare	-	-	-	10
2	AC - Room A	1250	5.7	7.125	10
3	L & F – Room A +bath	857.5	3.9	4.875	10
4	Balcony	900	4.09	5.1125	10
5	Fridge	800	3.7	4.625	6
6	Spare	-	-	-	10
7	L & F – Room B +Bath	743.3	3.4	4.25	6

8	AC – Room B	1500	6.818	8.5225	10
9	Iron	1000	4.545	5.681	10
10	L & F – Room C	443	2.015	2.5187	6
11	L & F – Drawing	361	1.64	2.05	6
12	Store + guest + bath	352	1.6	2	6
13	Lounge & kitchen	1568	7.12	8.9	10
14	Microwave + freezer	2000	9.1	11.375	13
15	Spare	-	-	-	10

Table 8: Proposed Breaker Sizes

Analysis of Distribution Board Design

- Commercially available circuit breakers are designed with fixed ratings: 3A, 5A, 6A, 10A, and 13 A, to name a few. Thus, the breaker with the smallest current rating greater than the rerated current is chosen for each load.
- Three pole MCB therefore has a rating of 63 A to withstand load current of 54 A.
- 10 A circuit breakers have been provided for each of the three spare outgoing connections to ensure the apartment can still run its most current-heavy appliances (Air Conditioners) through these breakers in case of faults.
- The highest current rating of the circuit breakers used in this scheme is 13 A for powering two highly inductive loads: microwave and freezer. This is to be expected, as the inductive nature and consequent lower power factor of inductive loads mean these loads draw more current.

Conclusions

Over the course of this Complex Engineering Problem, the authors gained insights into many aspects of designing lighting schemes and cable installations based on standard operating procedures. Some of these insights are summarized as conclusions below.

Luminaires and Lighting Schemes

- Luminaire selection requires a multifaceted approach that involves accounting for lamp efficiency, load loss factors (LLF, based on UF and MF), isolux contours, and polar curves.
- Isolux contours show regions of a working plane that receive the same level of illumination. Polar curves show the direction, spread, and intensity of illumination from a specific luminaire.
- DIALux Evo is a useful tool for prototyping lighting schemes for a given installation. However, its proposed schemes are rarely, if ever, cost effective. The scheme must be optimized by the design engineer to strike a balance between achieving desired luminous flux distribution and economic feasibility.
- Luminaire manufacturers such as Philips publish digital catalogs of their lighting products, which can be imported as third-party plugins/extensions for popular modeling software packages like DIALux Evo and 3DS Max.
- Reflective surfaces can greatly alter the resultant average luminous flux in a given area, and must be accounted for when placing luminaires in order to achieve target luminous flux.

Cable Sizing

- Pakistan Cables, a leading Pakistani power cable manufacturer, uses IEC standards for cable sizing.
- Other electric cable standards include the National Electric Code (NEC). Unlike the IEC, NEC is not a universal standard, and is adapted to create regional/local variants.
- Cable sizing does not need to be performed for UGCs which deliver power from PMTs to metering panels/individual buildings, as the design (dimensions, insulation, conductor arrangement, etc.) of such cables is standardized.

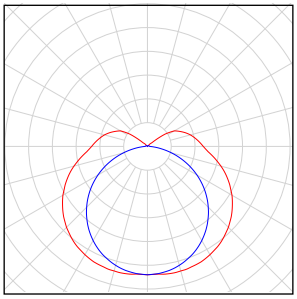
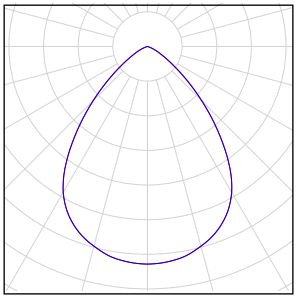
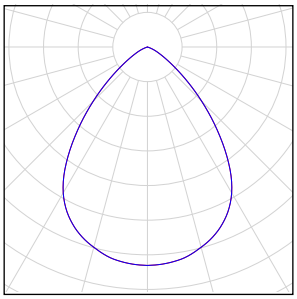
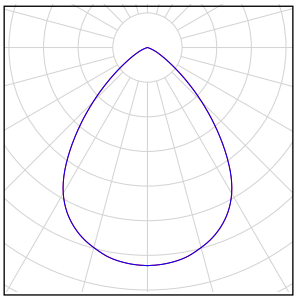
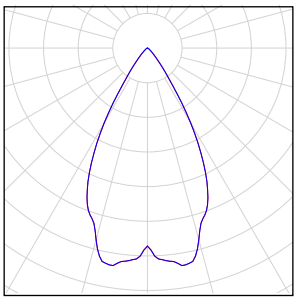
Circuit Breaker Selection

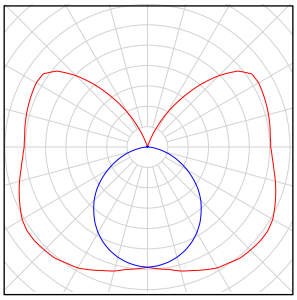
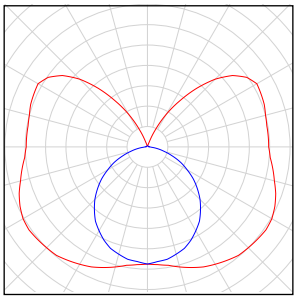
- Circuit breaker selection involves rerating the peak current in the relevant cables by a safety factor, which is 1.25 according to NEC standards.
- Including spare distribution lines in a wiring scheme improves system robustness and maintainability: if one line is defective, its load can be switched to a spare line. However, this increases the maximum power demand, total length of cables required, and quantity of circuit breakers, all of which incur greater cost.

Appendix A
DIALux Evo
Lighting Scheme Report

Table of contents

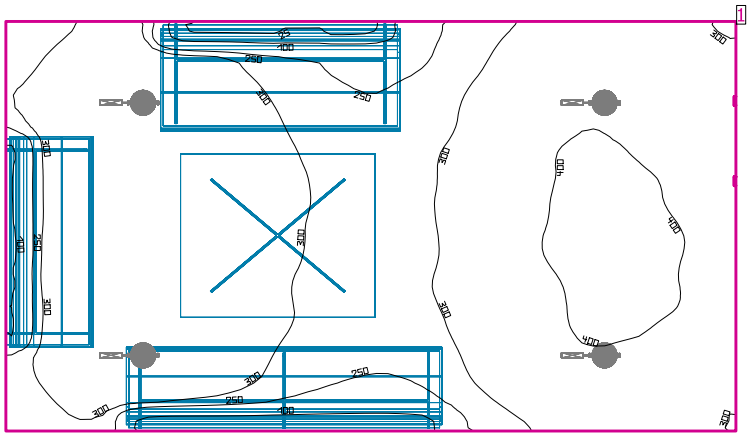
Project 0

Quantity	Luminaire (Luminous emittance)		
1	Philips Lighting - BN132C PSU L300 1 xLED3S/840 Luminous emittance 1 Fitting: 1xLED3S/840/- Light output ratio: 100% Lamp luminous flux: 350 lm Luminaire luminous flux: 350 lm Power: 4.0 W Luminous efficacy: 87.5 lm/W Colorimetric data 1xLED3S/840/-: CCT 3000 K, CRI 100		
17	Philips Lighting - DN570B PSE-E 1xLED24S/840 C Luminous emittance 1 Fitting: 1xLED24S/840/- Light output ratio: 100% Lamp luminous flux: 2600 lm Luminaire luminous flux: 2600 lm Power: 21.5 W Luminous efficacy: 120.9 lm/W Colorimetric data 1xLED24S/840/-: CCT 3000 K, CRI 100		
3	Philips Lighting - DN570C PSED-E 1xLED12S/827 C Luminous emittance 1 Fitting: 1xLED12S/827/- Light output ratio: 100% Lamp luminous flux: 1200 lm Luminaire luminous flux: 1200 lm Power: 11.6 W Luminous efficacy: 103.4 lm/W Colorimetric data 1xLED12S/827/-: CCT 3000 K, CRI 100		
9	Philips Lighting - DN570C PSED-E 1xLED20S/827 C Luminous emittance 1 Fitting: 1xLED20S/827/- Light output ratio: 100% Lamp luminous flux: 1950 lm Luminaire luminous flux: 1950 lm Power: 18.8 W Luminous efficacy: 103.7 lm/W Colorimetric data 1xLED20S/827/-: CCT 3000 K, CRI 100		
2	Philips Lighting - PT570P 1xLED25S/827 WB Luminous emittance 1 Fitting: 1xLED25S/827/- Light output ratio: 100% Lamp luminous flux: 2559 lm Luminaire luminous flux: 2559 lm Power: 36.0 W Luminous efficacy: 71.1 lm/W Colorimetric data 1xLED25S/827/-: CCT 3000 K, CRI 100		

Quantity	Luminaire (Luminous emittance)		
2	Philips Lighting - TMS022 1xTL-D30W_33-640 Luminous emittance 1 Fitting: 1xTL-D30W/33-640 Light output ratio: 96.59% Lamp luminous flux: 2100 lm Luminaire luminous flux: 2028 lm Power: 37.5 W Luminous efficacy: 54.1 lm/W Colorimetric data 1xTL-D30W/33-640: CCT 3000 K, CRI 100		
9	Philips Lighting - TMS022 1xTL-D58W HFS_451 Luminous emittance 1 Fitting: 1xTL-D58W/451 Light output ratio: 95.18% Lamp luminous flux: 5000 lm Luminaire luminous flux: 4759 lm Power: 55.0 W Luminous efficacy: 86.5 lm/W Colorimetric data 1xTL-D58W/451: CCT 3000 K, CRI 100		

Total lamp luminous flux: 120018 lm, Total luminaire luminous flux: 117705 lm, Total Load: 1215.5 W, Luminous efficacy: 96.8 lm/W

Drawing Room



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 69.3%, Floor 56.4%, Light loss factor: 0.80

Workplane

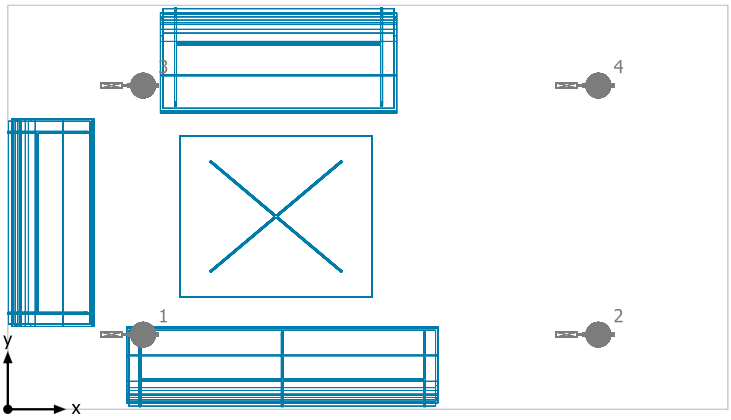
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Drawing Room	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	319 (≥ 300)	11.9	433	0.04	0.03

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Philips Lighting - DN570B PSE-E 1xLED24S/840 C	2600	21.5	120.9
	Total via all luminaires	10400	86.0	120.9

Lighting power density: 3.93 W/m² = 1.23 W/m²/100 lx (Floor area of room 21.90 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 150 - 240 kWh/a of maximum 800 kWh/a

Drawing Room



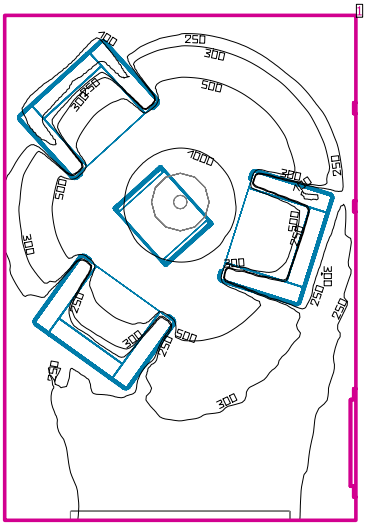
Philips Lighting DN570B PSE-E 1xLED24S/840 C

No.	X [m]	Y [m]	Mounting height [m]
1	1.174	0.648	3.048
2	5.124	0.648	3.048
3	1.174	2.809	3.048
4	5.124	2.809	3.048

Drawing Room

Drawing Room

Guest Room



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 65.2%, Floor 69.8%, Light loss factor: 0.80

Workplane

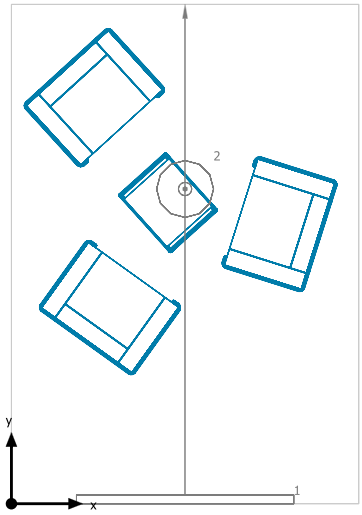
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Guest Room	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	397 (≥ 300)	75.9	1083	0.19	0.07

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Philips Lighting - PT570P 1xLED25S/827 WB	2559	36.0	71.1
1	Philips Lighting - TMS022 1xTL-D58W HFS_451	4759	55.0	86.5
	Total via all luminaires	7318	91.0	80.4

Lighting power density: 10.65 W/m² = 2.68 W/m²/100 lx (Floor area of room 8.55 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 250 kWh/a of maximum 350 kWh/a

Guest Room



Philips Lighting TMS022 1xTL-D58W HFS_451

No.	X [m]	Y [m]	Mounting height [m]
1	1.219	0.000	2.438

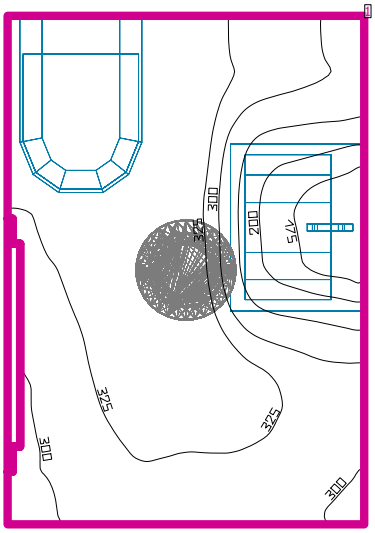
Philips Lighting PT570P 1xLED25S/827 WB

No.	X [m]	Y [m]	Mounting height [m]
2	1.219	2.209	2.448

Guest Room

Guest Room

Bath 4



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 90.0%, Floor 70.5%, Light loss factor: 0.80

Workplane

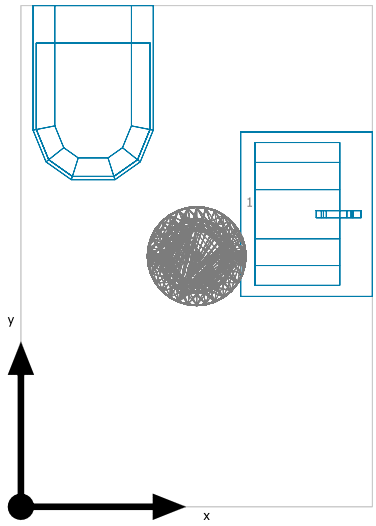
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Bath 4	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	306 (≥ 300)	157	348	0.51	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Philips Lighting - DN570C PSED-E 1xLED12S/827 C	1200	11.6	103.4
	Total via all luminaires	1200	11.6	103.4

Lighting power density: 7.15 W/m² = 2.34 W/m²/100 lx (Floor area of room 1.62 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 20 - 32 kWh/a of maximum 100 kWh/a

Bath 4



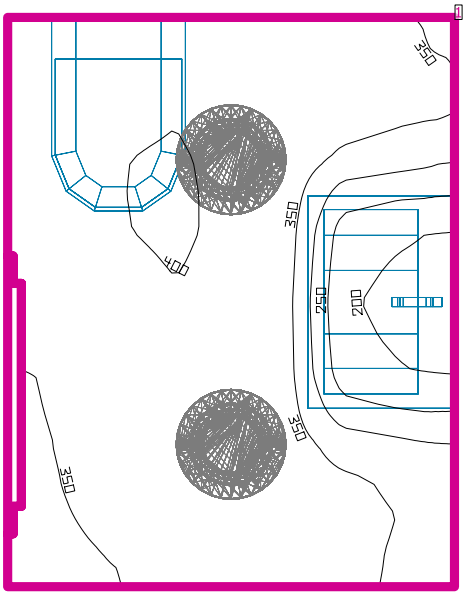
Philips Lighting DN570C PSED-E 1xLED12S/827 C

No.	X [m]	Y [m]	Mounting height [m]
1	0.533	0.760	3.048

Bath 4

Bath 4

Bath 5



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 90.0%, Floor 70.5%, Light loss factor: 0.50

Workplane

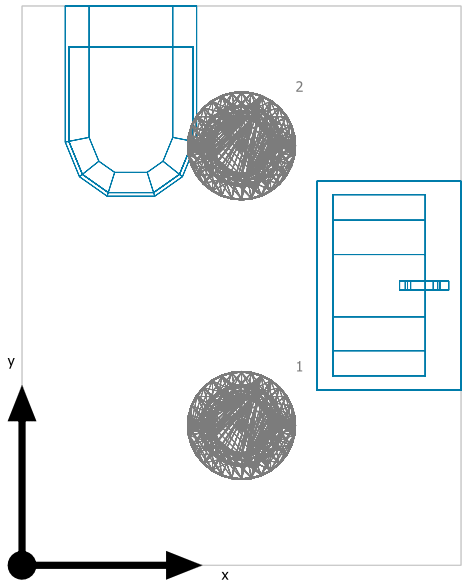
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Bath 5	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	350 (≥ 300)	181	403	0.52	0.45

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Philips Lighting - DN570C PSED-E 1xLED12S/827 C	1200	11.6	103.4
	Total via all luminaires	2400	23.2	103.4

Lighting power density: 12.25 W/m² = 3.50 W/m²/100 lx (Floor area of room 1.89 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 40 - 64 kWh/a of maximum 100 kWh/a

Bath 5



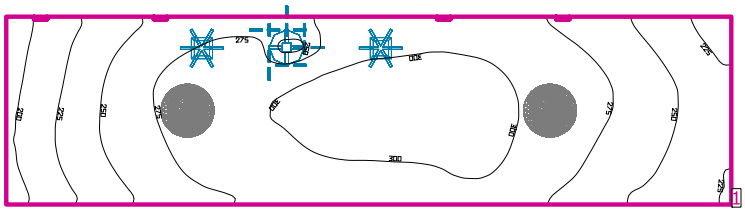
Philips Lighting DN570C PSED-E 1xLED12S/827 C

No.	X [m]	Y [m]	Mounting height [m]
1	0.610	0.388	3.048
2	0.610	1.165	3.048

Bath 5

Bath 5

Balcony



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 54.9%, Floor 70.5%, Light loss factor: 0.80

Workplane

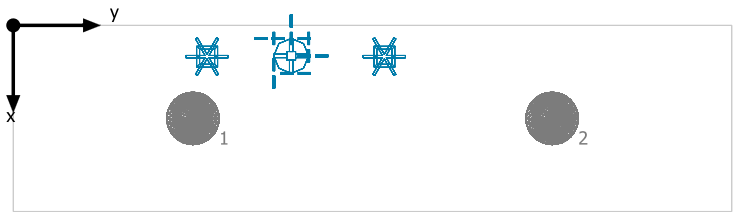
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Balcony	Perpendicular illuminance (adaptive) [lx] Height: 0.600 m, Wall zone: 0.000 m	271 (≥ 250)	185	309	0.68	0.60

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Philips Lighting - DN570C PSED-E 1xLED20S/827 C	1950	18.8	103.7
	Total via all luminaires	3900	37.6	103.7

Lighting power density: 8.56 W/m² = 3.16 W/m²/100 lx (Floor area of room 4.39 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 65 - 100 kWh/a of maximum 200 kWh/a

Balcony

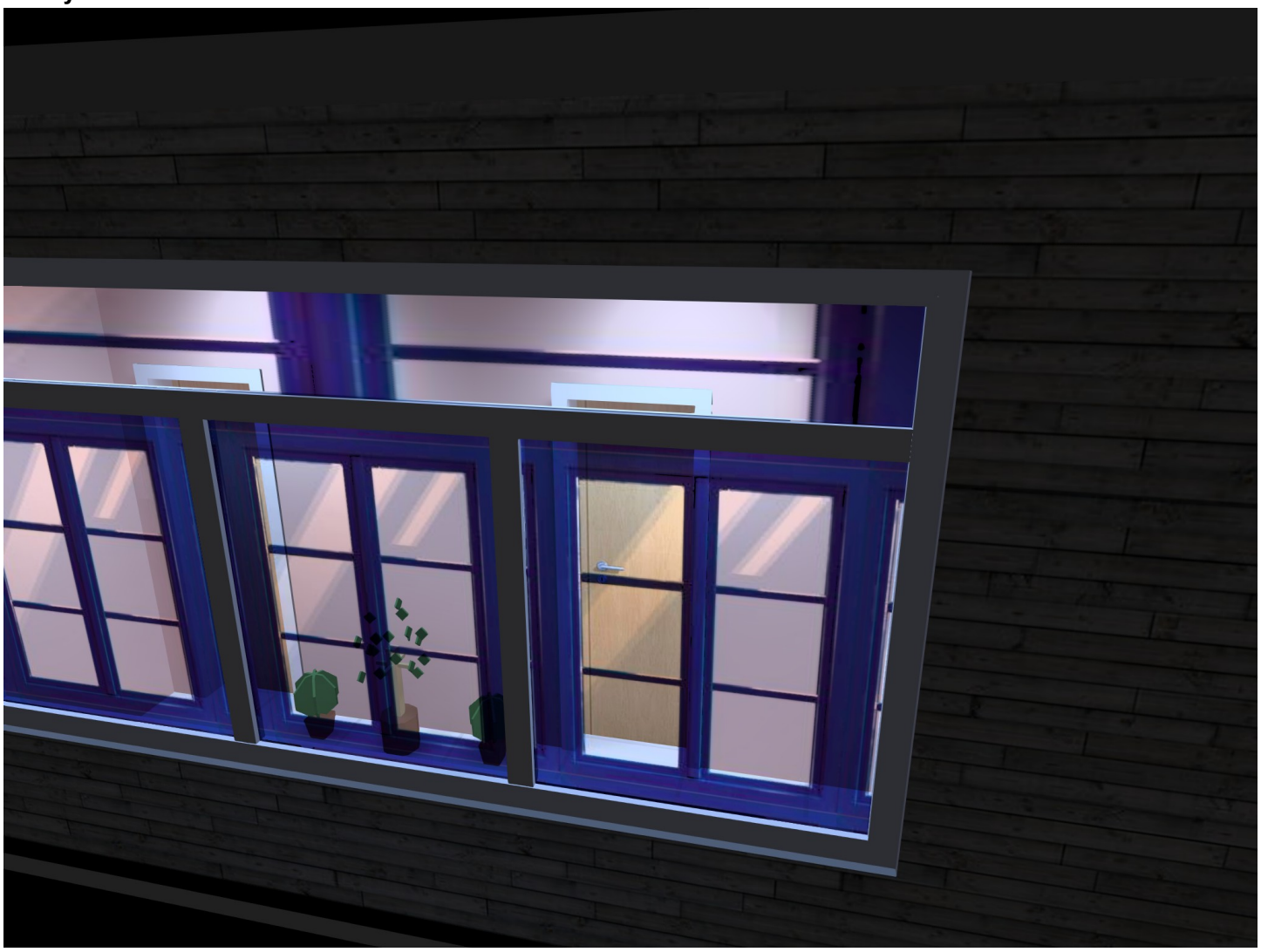


Philips Lighting DN570C PSED-E 1xLED20S/827 C

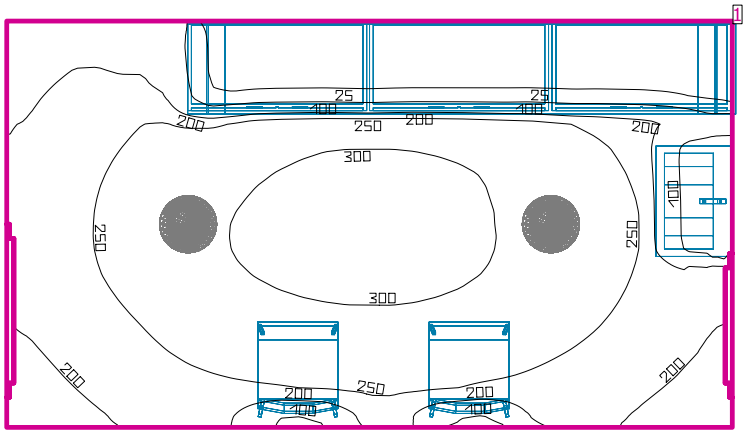
No.	X [m]	Y [m]	Mounting height [m]
1	0.533	1.030	3.048
2	0.533	3.089	3.048

Balcony

Storey 1



Kitchen



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 47.5%, Floor 70.5%, Light loss factor: 0.80

Workplane

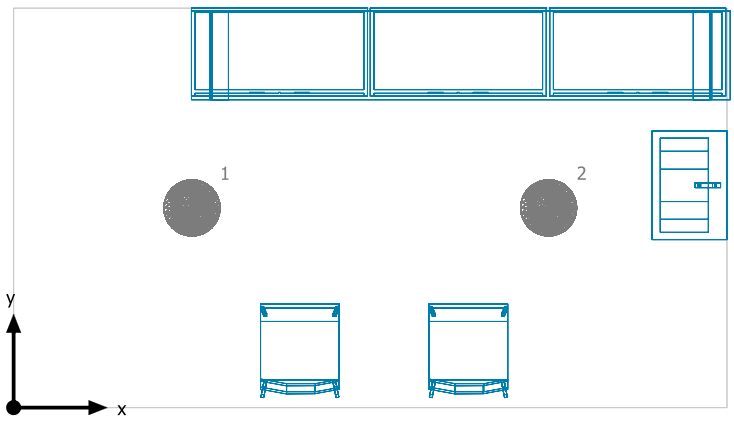
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Kitchen	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	207 (≥ 200)	0.00	313	0.00	0.00

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Philips Lighting - DN570C PSED-E 1xLED20S/827 C	1950	18.8	103.7
	Total via all luminaires	3900	37.6	103.7

Lighting power density: 4.63 W/m² = 2.23 W/m²/100 lx (Floor area of room 8.13 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 100 kWh/a of maximum 300 kWh/a

Kitchen



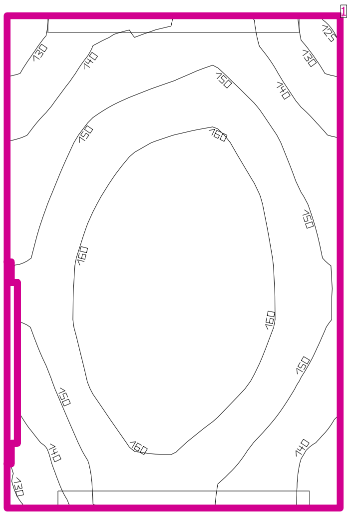
Philips Lighting DN570C PSED-E 1xLED20S/827 C

No.	X [m]	Y [m]	Mounting height [m]
1	0.952	1.067	3.048
2	2.857	1.067	3.048

Kitchen

Kitchen

Store



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 56.9%, Floor 20.0%, Light loss factor: 0.50

Workplane

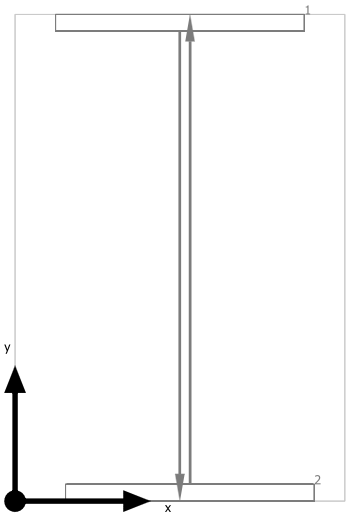
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Store	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	153 (≥ 150)	124	169	0.81	0.73

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Philips Lighting - TMS022 1xTL-D30W_33-640	2028	37.5	54.1
	Total via all luminaires	4056	75.0	54.1

Lighting power density: 34.19 W/m² = 22.38 W/m²/100 lx (Floor area of room 2.19 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 210 kWh/a of maximum 100 kWh/a

Store



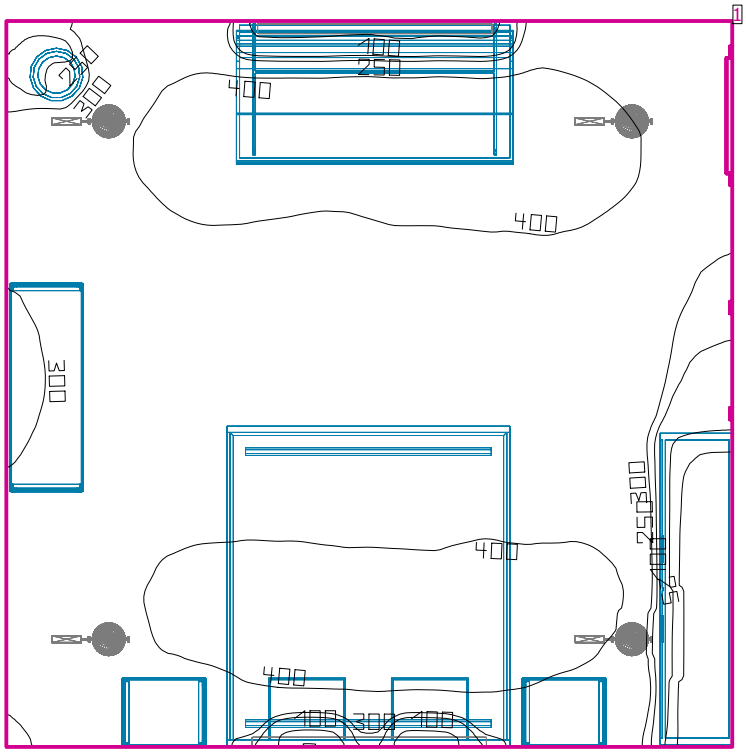
Philips Lighting TMS022 1xTL-D30W_33-640

No.	X [m]	Y [m]	Mounting height [m]
1	0.610	1.799	2.438
2	0.647	0.000	2.438

Store

Store

Room A



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 35.9%, Floor 69.8%, Light loss factor: 0.80

Workplane

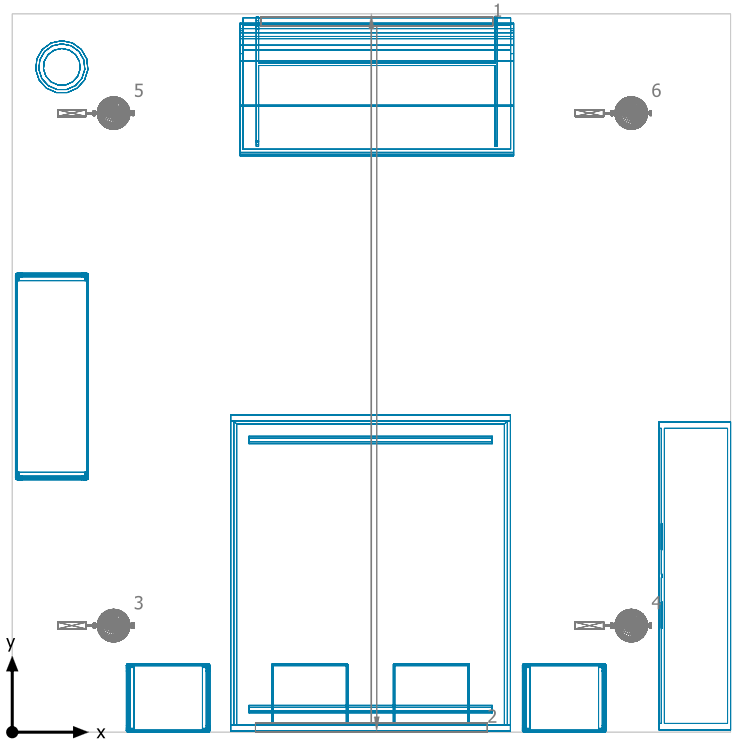
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Room A	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	348 (≥ 300)	0.46	437	0.00	0.00

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
4	Philips Lighting - DN570B PSE-E 1xLED24S/840 C	2600	21.5	120.9
2	Philips Lighting - TMS022 1xTL-D58W HFS_451	4759	55.0	86.5
	Total via all luminaires	19918	196.0	101.6

Lighting power density: 8.78 W/m² = 2.52 W/m²/100 lx (Floor area of room 22.32 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 430 - 540 kWh/a of maximum 800 kWh/a

Room A



Philips Lighting TMS022 1xTL-D58W HFS_451

No.	X [m]	Y [m]	Mounting height [m]
1	2.398	4.705	2.438
2	2.362	0.000	2.438

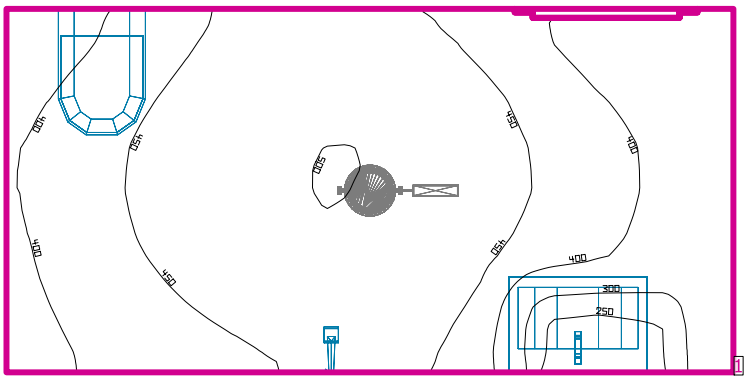
Philips Lighting DN570B PSE-E 1xLED24S/840 C

No.	X [m]	Y [m]	Mounting height [m]
3	0.667	0.701	3.048
4	4.071	0.701	3.048
5	0.667	4.071	3.048
6	4.071	4.071	3.048

Room A

Room A

Bath 1



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 90.0%, Floor 70.5%, Light loss factor: 0.80

Workplane

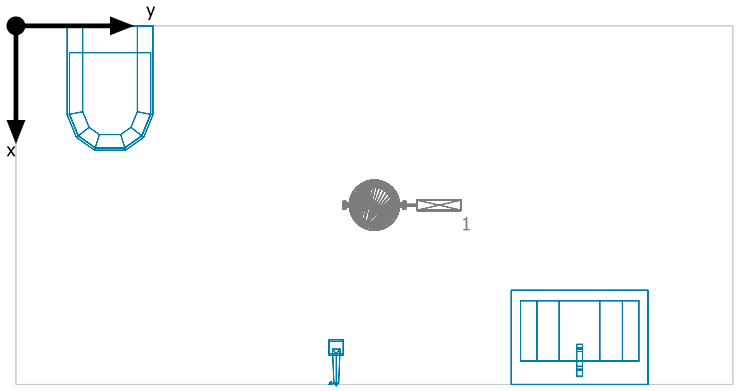
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Bath 1	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	428 (≥ 300)	229	501	0.54	0.46

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Philips Lighting - DN570B PSE-E 1xLED24S/840 C	2600	21.5	120.9
	Total via all luminaires	2600	21.5	120.9

Lighting power density: 4.63 W/m² = 1.08 W/m²/100 lx (Floor area of room 4.65 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 37 - 59 kWh/a of maximum 200 kWh/a

Bath 1



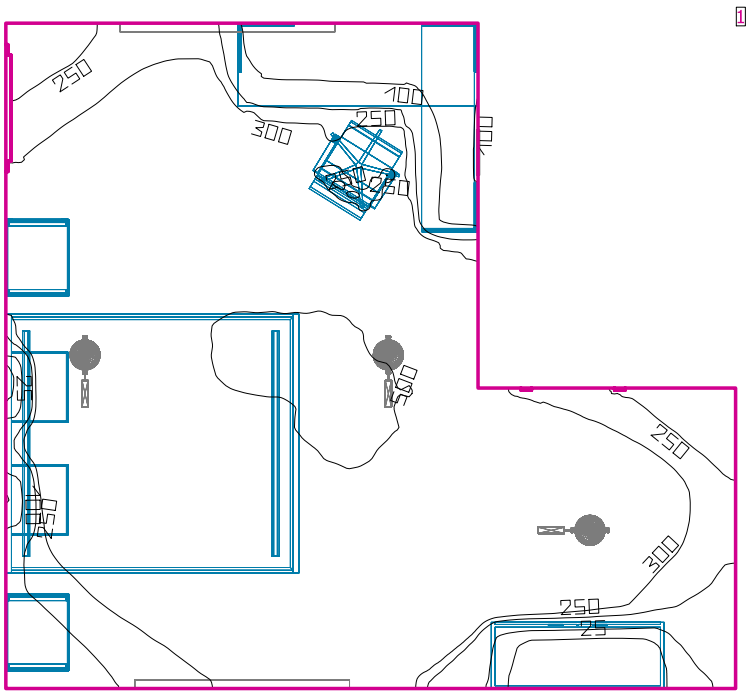
Philips Lighting DN570B PSE-E 1xLED24S/840 C

No.	X [m]	Y [m]	Mounting height [m]
1	0.762	1.524	3.048

Bath 1

Bath 1 (100)

Room B



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 35.9%, Floor 69.8%, Light loss factor: 0.80

Workplane

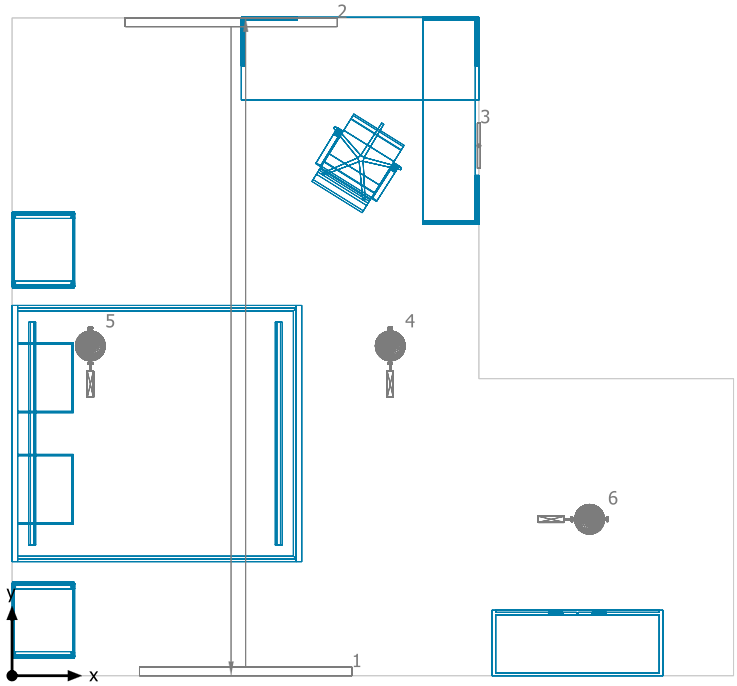
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Room B	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	346 (≥ 300)	1.42	511	0.00	0.00

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Philips Lighting - BN132C PSU L300 1 xLED3S/840	350	4.0	87.5
3	Philips Lighting - DN570B PSE-E 1xLED24S/840 C	2600	21.5	120.9
2	Philips Lighting - TMS022 1xTL-D58W HFS_451	4759	55.0	86.5
	Total via all luminaires	17668	178.5	99.0

Lighting power density: 9.04 W/m² = 2.62 W/m²/100 lx (Floor area of room 19.74 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 310 - 490 kWh/a of maximum 700 kWh/a

Room B



Philips Lighting TMS022 1xTL-D58W HFS_451

No.	X [m]	Y [m]	Mounting height [m]
1	1.678	0.000	2.438
2	1.574	4.724	2.438

Philips Lighting BN132C PSU L300 1 xLED3S/840

No.	X [m]	Y [m]	Mounting height [m]
3	3.353	3.806	1.300

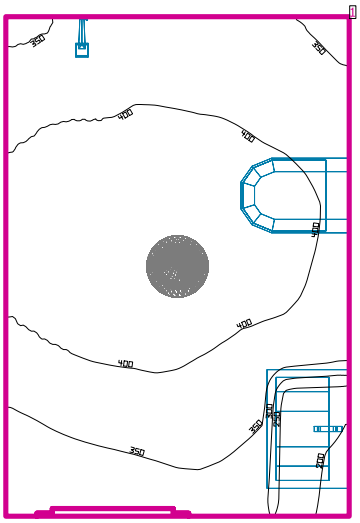
Philips Lighting DN570B PSE-E 1xLED24S/840 C

No.	X [m]	Y [m]	Mounting height [m]
4	2.716	2.369	3.048
5	0.562	2.369	3.048
6	4.148	1.123	3.048

Room B

Room B

Bath 2



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 90.0%, Floor 70.5%, Light loss factor: 0.80

Workplane

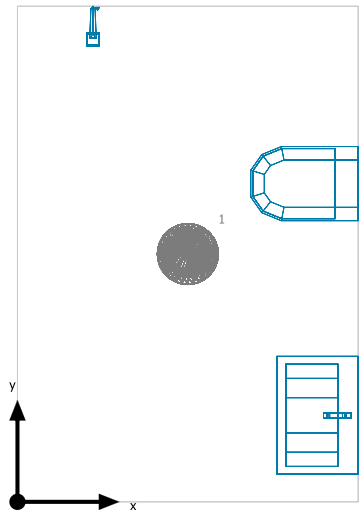
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Bath 2	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	378 (≥ 300)	189	437	0.50	0.43

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Philips Lighting - DN570C PSED-E 1xLED20S/827 C	1950	18.8	103.7
	Total via all luminaires	1950	18.8	103.7

Lighting power density: 4.60 W/m² = 1.22 W/m²/100 lx (Floor area of room 4.09 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 33 - 52 kWh/a of maximum 150 kWh/a

Bath 2



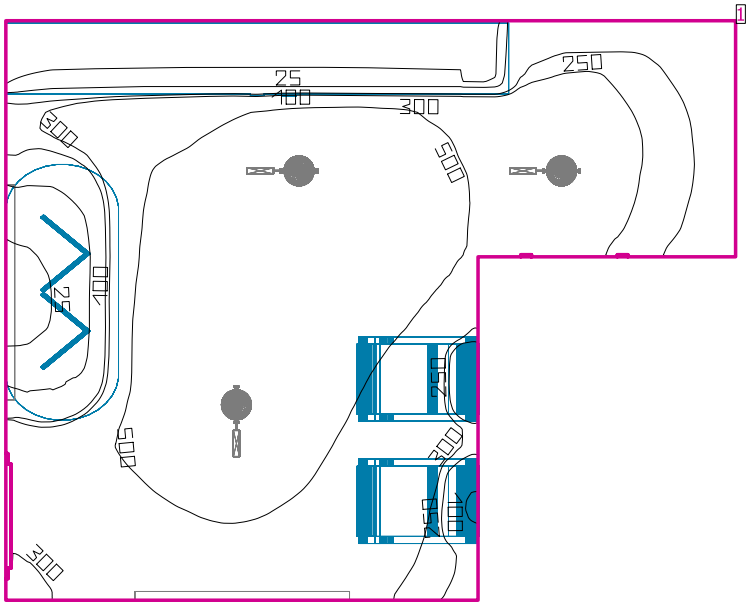
Philips Lighting DN570C PSED-E 1xLED20S/827 C

No.	X [m]	Y [m]	Mounting height [m]
1	0.838	1.219	3.048

Bath 2

Bath 2 (101)

Room C



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 35.7%, Floor 69.8%, Light loss factor: 0.80

Workplane

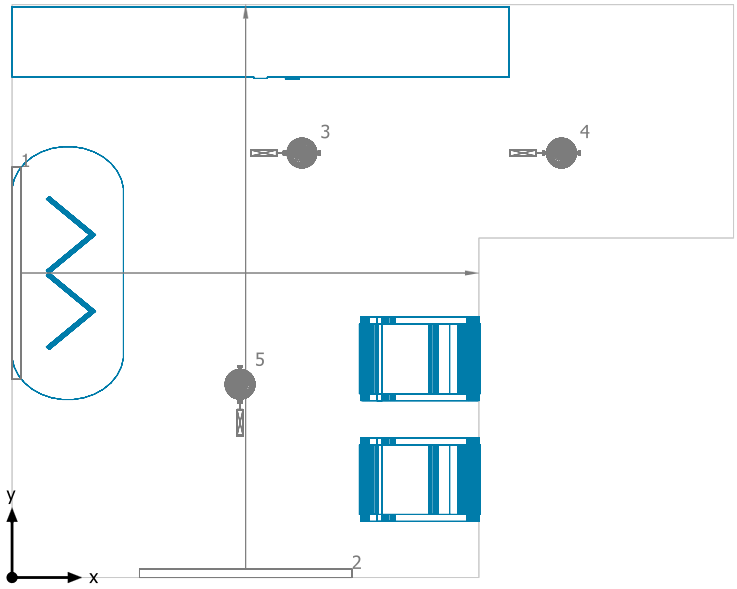
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Room C	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	366 (≥ 300)	0.75	623	0.00	0.00

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
3	Philips Lighting - DN570B PSE-E 1xLED24S/840 C	2600	21.5	120.9
2	Philips Lighting - TMS022 1xTL-D58W HFS_451	4759	55.0	86.5
	Total via all luminaires	17318	174.5	99.2

Lighting power density: 10.35 W/m² = 2.83 W/m²/100 lx (Floor area of room 16.86 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 380 - 480 kWh/a of maximum 600 kWh/a

Room C



Philips Lighting TMS022 1xTL-D58W HFS_451

No.	X [m]	Y [m]	Mounting height [m]
1	0.000	2.186	2.438
2	1.678	0.000	2.438

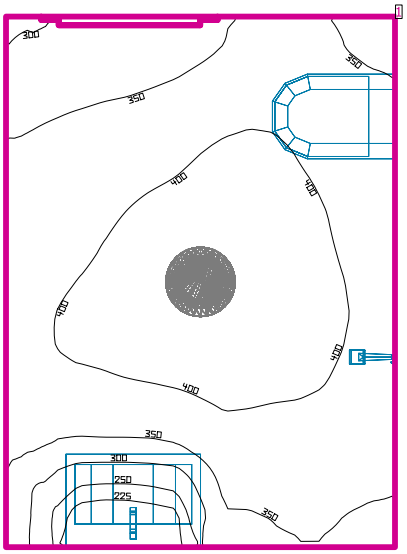
Philips Lighting DN570B PSE-E 1xLED24S/840 C

No.	X [m]	Y [m]	Mounting height [m]
3	2.082	3.049	3.048
4	3.946	3.049	3.048
5	1.637	1.388	3.048

Room C

Room C

Bath 3



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 90.0%, Floor 70.5%, Light loss factor: 0.80

Workplane

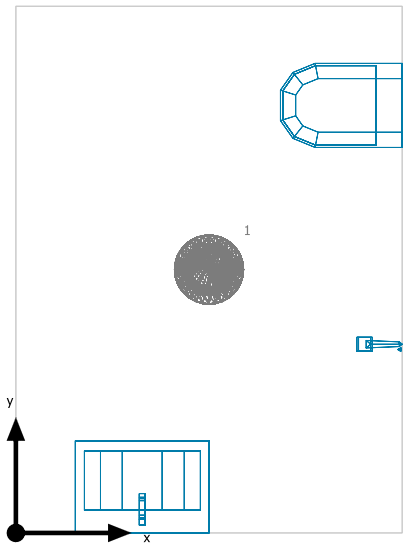
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Bath 3	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	371 (≥ 300)	202	427	0.54	0.47

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
1	Philips Lighting - DN570C PSED-E 1xLED20S/827 C	1950	18.8	103.7
	Total via all luminaires	1950	18.8	103.7

Lighting power density: 4.91 W/m² = 1.32 W/m²/100 lx (Floor area of room 3.83 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 33 - 52 kWh/a of maximum 150 kWh/a

Bath 3



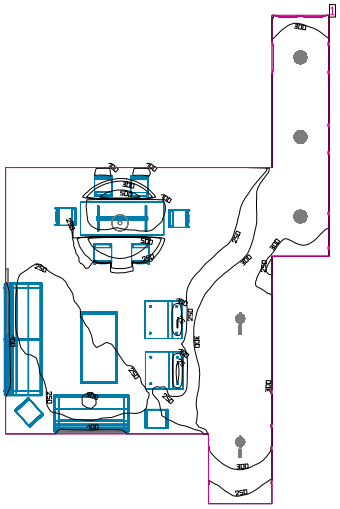
Philips Lighting DN570C PSED-E 1xLED20S/827 C

No.	X [m]	Y [m]	Mounting height [m]
1	0.838	1.143	3.048

Bath 3

Bath 3 (102)

Dining and Lounge



Clearance height: 3.048 m, Reflection factors: Ceiling 70.0%, Walls 64.8%, Floor 56.4%, Light loss factor: 0.80

Workplane

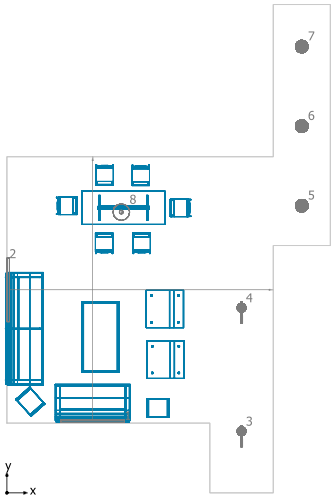
	Surface	Result	Average (Target)	Min	Max	Min/average	Min/max
1	Dining and Lounge	Perpendicular illuminance (adaptive) [lx] Height: 0.500 m, Wall zone: 0.000 m	264 (≥ 200)	13.1	951	0.05	0.01

#	Luminaire	Φ(Luminaire) [lm]	Power [W]	Luminous efficacy [lm/W]
2	Philips Lighting - DN570B PSE-E 1xLED24S/840 C	2600	21.5	120.9
3	Philips Lighting - DN570C PSED-E 1xLED20S/827 C	1950	18.8	103.7
1	Philips Lighting - PT570P 1xLED25S/827 WB	2559	36.0	71.1
2	Philips Lighting - TMS022 1xTL-D58W HFS_451	4759	55.0	86.5
	Total via all luminaires	23127	245.4	94.2

Lighting power density: 4.77 W/m² = 1.81 W/m²/100 lx (Floor area of room 51.47 m²)

The energy consumption quantities refer to the lights planned for the room without taking into account light scenes and their dimming levels.
Consumption: 490 - 670 kWh/a of maximum 1850 kWh/a

Dining and Lounge



Philips Lighting TMS022 1xTL-D58W HFS_451

No.	X [m]	Y [m]	Mounting height [m]
1	2.063	1.694	2.438
2	0.000	4.877	2.438

Philips Lighting DN570B PSE-E 1xLED24S/840 C

No.	X [m]	Y [m]	Mounting height [m]
3	5.639	1.482	3.048
4	5.639	4.446	3.048

Philips Lighting DN570C PSED-E 1xLED20S/827 C

No.	X [m]	Y [m]	Mounting height [m]
5	7.087	6.900	3.048
6	7.087	8.812	3.048
7	7.087	10.724	3.048

Philips Lighting PT570P 1xLED25S/827 WB

No.	X [m]	Y [m]	Mounting height [m]
8	2.749	6.747	2.448

Dining and Lounge

Storey 1

Appendix B
IEC Standards with Relevant References

Reference for "Safety Factor"

NEC sizing rules. Secs. 210-22(c), 220-3(a), 220-10(b), and 384-16(c) all relate to the sizing rules for overcurrent protective devices (OCPDs). The first three all specify the same requirement:

OCPD size = 100% of discontinuous load + 125% of continuous load.

This implies that for any rated value of current the beaker size necessary to keep the system safe is 1.25 times the rated current.

$$\boldsymbol{Safety\ factor = 1.25}$$

Table B.52.14 – Correction factor for ambient air temperatures other than 30 °C to be applied to the current-carrying capacities for cables in the air

Ambient temperature[a] °C	Insulation			
			Mineral[a]	
	PVC	XLPE and EPR	PVC covered or bare and exposed to touch 70 °C	Bare not exposed to touch 105 °C
10	1,22	1,15	1,26	1,14
15	1,17	1,12	1,20	1,11
20	1,12	1,08	1,14	1,07
25	1,06	1,04	1,07	1,04
30	1,00	1,00	1,00	1,00
35	0,94	0,96	0,93	0,96
40	0,87	0,91	0,85	0,92
45	0,79	0,87	0,78	0,88
50	0,71	0,82	0,67	0,84
55	0,61	0,76	0,57	0,80
60	0,50	0,71	0,45	0,75
65	–	0,65	–	0,70
70	–	0,58	–	0,65
75	–	0,50	–	0,60
80	–	0,41	–	0,54
85	–	–	–	0,47
90	–	–	–	0,40
95	–	–	–	0,32

[a] For higher ambient temperatures, consult the manufacturer.

APPENDIX MATERIAL

Table B.52.17 – Reduction factors for one circuit or one multi-core cable or for a group of more than one circuit, or more than one multi-core cable, to be used with current-carrying capacities of Tables B.52.2 to B.52.13

Item	Arrangement (cables touching)	Number of circuits or multi-core cables												To be used with current-carrying capacities, reference
		1	2	3	4	5	6	7	8	9	12	16	20	
1	Bunched in air, on a surface, embedded or enclosed	1,00	0,80	0,70	0,65	0,60	0,57	0,54	0,52	0,50	0,45	0,41	0,38	B.52.2 to B.52.13 Methods A to F
2	Single layer on wall, floor or unperforated cable tray systems	1,00	0,85	0,79	0,75	0,73	0,72	0,72	0,71	0,70	No further reduction factor for more than nine circuits or multicore cables			B.52.2 to B.52.7 Method C
3	Single layer fixed directly under a wooden ceiling	0,95	0,81	0,72	0,68	0,66	0,64	0,63	0,62	0,61				
4	Single layer on a perforated horizontal or vertical cable tray systems	1,00	0,88	0,82	0,77	0,75	0,73	0,73	0,72	0,72				B.52.8 to B.52.13 Methods E and F
5	Single layer on cable ladder systems or cleats etc.,	1,00	0,87	0,82	0,80	0,80	0,79	0,79	0,78	0,78				

NOTE 1 These factors are applicable to uniform groups of cables, equally loaded.

NOTE 2 Where horizontal clearances between adjacent cables exceeds twice their overall diameter, no reduction factor need be applied.

NOTE 3 The same factors are applied to:
- groups of two or three single-core cables;
- multi-core cables.

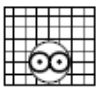
NOTE 4 If a system consists of both two- and three-core cables, the total number of cables is taken as the number of circuits, and the corresponding factor is applied to the tables for two loaded conductors for the two-core cables, and to the tables for three loaded conductors for the three-core cables.

NOTE 5 If a group consists of *n* single-core cables it may either be considered as *n*/2 circuits of two loaded conductors or *n*/3 circuits of three loaded conductors.

NOTE 6 The values given have been averaged over the range of conductor sizes and types of installation included in Tables B.52.2 to B.52.13 the overall accuracy of tabulated values is within 5 %.

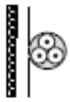
NOTE 7 For some installations and for other methods not provided for in the above table, it may be appropriate to use factors calculated for specific cases, see for example Tables B.52.20 and B.52.21.

Table B.52.2 – Current-carrying capacities in amperes for methods of installation in Table B.52.1 – PVC insulation/two loaded conductors, copper or aluminium – Conductor temperature: 70 °C, ambient temperature: 30 °C in air, 20 °C in ground

Nominal cross-sectional area of conductor mm²	Installation methods of Table B.52.1						
	A1	A2	B1	B2	C	D1	D2
							
1	2	3	4	5	6	7	8
Copper							
1,5	14,5	14	17,5	16,5	19,5	22	22
2,5	19,5	18,5	24	23	27	29	28
4	26	25	32	30	36	37	38
6	34	32	41	38	46	46	48
10	46	43	57	52	63	60	64
16	61	57	76	69	85	78	83
25	80	75	101	90	112	99	110
35	99	92	125	111	138	119	132
50	119	110	151	133	168	140	156
70	151	139	192	168	213	173	192
95	182	167	232	201	258	204	230
120	210	192	269	232	299	231	261
150	240	219	300	258	344	261	293
185	273	248	341	294	392	292	331
240	321	291	400	344	461	336	382
300	367	334	458	394	530	379	427
Aluminium							
2,5	15	14,5	18,5	17,5	21	22	
4	20	19,5	25	24	28	29	
6	26	25	32	30	36	36	
10	36	33	44	41	49	47	
16	48	44	60	54	66	61	63
25	63	58	79	71	83	77	82
35	77	71	97	86	103	93	98
50	93	86	118	104	125	109	117
70	118	108	150	131	160	135	145
95	142	130	181	157	195	159	173
120	164	150	210	181	226	180	200
150	189	172	234	201	261	204	224
185	215	195	266	230	298	228	255
240	252	229	312	269	352	262	298
300	289	263	358	308	406	296	336

NOTE In columns 3, 5, 6, 7 and 8, circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

Table B.52.10 – Current-carrying capacities in amperes for installation methods E, F and G of Table B.52.1 – PVC insulation, copper conductors – Conductor temperature: 70 °C, reference ambient temperature: 30 °C

Nominal cross-sectional area of conductor mm²	Installation methods of Table B.52.1						
	Multi-core cables		Single-core cables				
	Two loaded conductors	Three loaded conductors	Two loaded conductors touching	Three loaded conductors trefoil	Three loaded conductors, flat		
					Touching	Spaced	
						Horizontal	Vertical
							
	Method E	Method E	Method F	Method F	Method F	Method G	Method G
1	2	3	4	5	6	7	8
1,5	22	18,5	–	–	–	–	–
2,5	30	25	–	–	–	–	–
4	40	34	–	–	–	–	–
6	51	43	–	–	–	–	–
10	70	60	–	–	–	–	–
16	94	80	–	–	–	–	–
25	119	101	131	110	114	146	130
35	148	126	162	137	143	181	162
50	180	153	196	167	174	219	197
70	232	196	251	216	225	281	254
95	282	238	304	264	275	341	311
120	328	276	352	308	321	396	362
150	379	319	406	356	372	456	419
185	434	364	463	409	427	521	480
240	514	430	546	485	507	615	569
300	593	497	629	561	587	709	659
400	–	–	754	656	689	852	795
500	–	–	868	749	789	982	920
630	–	–	1 005	855	905	1 138	1 070

NOTE 1 Circular conductors are assumed for sizes up to and including 16 mm². Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

NOTE 2 D_e is the external diameter of the cable.