ZUMTOBEL

# LEED®
# LIGHT GUIDE

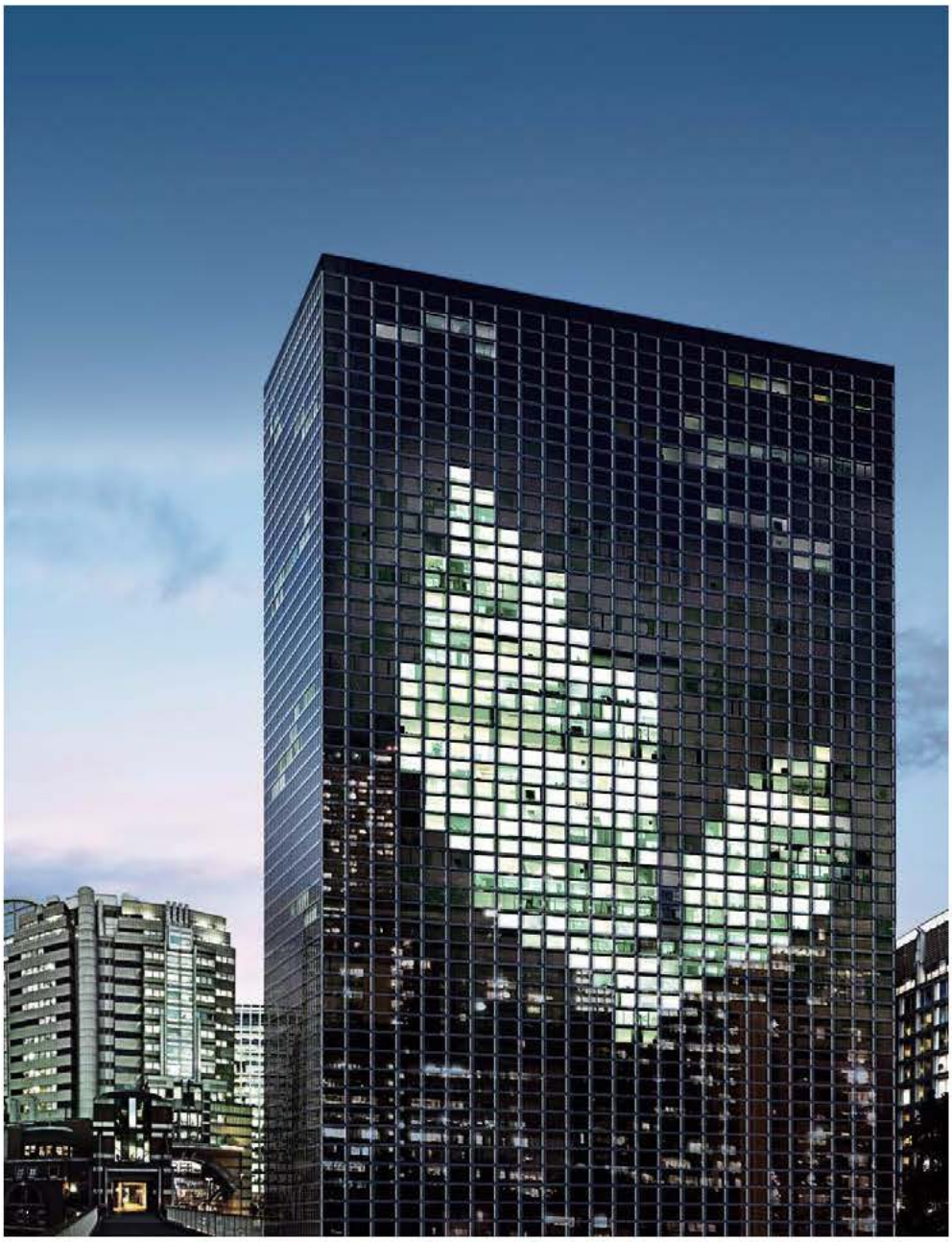
Lighting Solutions
by ZUMTOBEL
for LEED®

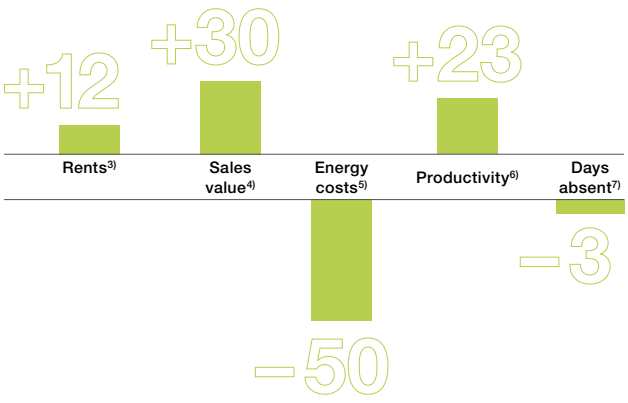
**March 2014**

**How to use the LEED® Light Guide**
Taking the LEED® (Leadership in Energy and Environmental Design) certification system as an example, we would like to show you in this guide how Zumtobel can help you achieve certification of your building.

In addition to a description of the relevant criteria in the sphere of lighting, you will find the summary of a LEED® simulation using a reference building, where the possibilities of optimising a model office building's energy efficiency on the basis of different LED lighting solutions were analysed.

The entire guide is based on the LEED® 2009 Rating System for New Construction and Major Renovations. A glossary of technical terms is provided as an annex to the LEED® LIGHT GUIDE.






Source
1) 2013 Dodge Construction Green Outlook, McGraw-Hill Construction, 2012
2) World Green Building Trends - Smart Market Report, McGraw-Hill Construction, 2013
3)–6) The Business Case for Green Building, World Green Building Council, 2013
7) Green Buildings and Productivity, CBRE Richard Ellis and USD Untiversity of San Diego, 2009

**Green Building Certification**

In a world of change, sustainable building is an active contribution to saving resources and ensuring a safe basis of existence for the generations to come. The significantly growing number of environmentally certified buildings shows that Green Building is a trend that will leave its mark on the international construction sector in the future.

In 1990 the first certification system for sustainable buildings BREEAM (Building Research Establishment Environmental Assessment Method) is developed. By a simple rating system of 8 categories a label of 4 different levels is awarded.

In the coming years other certification systems in different countries arise:
1996 in France HQE (Haute Qualité Environnementale), www.assohqe.org
1998 in Switzerland MINERGIE (Minergiestandard), www.minergie.ch
2000 in the USA LEED® (Leadership in Energy and Environmental Design), www.usgbc.org
2002 in Italy KlimaHaus (KlimaHaus Agentur), www.klimahaus.it
2005 in Singapoor BCA Green Mark (Building and Construction Authority), www.bca.gov.sg
2007 in Germany DGNB (Deutsche Gesellschaft für nachhaltiges Bauen), www.dgnb.de
2007 in India GRIHA (Green Rating for Integrated Habitat Assessment), www.grihaindia.org
2009 in Austria ÖGNI (Österreichische Gesellschaft für Nachhaltige Immobilienwirtschaft), www.ogni.at

All certification systems define different criteria and set different priorities in order to make the environmental, social and economic impact of buildings comparable.

**Green Outlook and Benefits of Green Buildings**

According to a study by McGraw-Hill Construction[1], as much as 44 % of all commercial and institutional buildings were built in a sustainable way already in 2012. By 2016, this share is expected to have increased to 55 %. An increase is also expected for the refurbishment of buildings. 50 % of the companies questioned in surveys[2] reported that they had sustainable refurbishment projects in the pipeline.

Green buildings provide the following benefits, among others:
- Increasing demand on the part of tenants and readiness to pay higher rents (up to 3 % per LEED® certification level)[3]
- The selling price that can be achieved is up to 30 % higher for LEED®-certified office buildings[4]
- Operating and energy costs of LEED®-certified buildings are reduced by up to 50 %[5]
- Improved $CO_2$ balance of the company
- Environmental certification is an instrument of corporate communication that opens up additional attractive marketing opportunities
- Improved well being
- Increase in performance by up to 23 % thanks to perfect lighting solution[6]
- Up to 3 fewer sick days per employee per year[7]

# Part I : Introduction
## LEED®

**General Information on LEED®**

What is LEED®?
Leadership in Energy and Environmental Design (LEED®) is a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes and neighbourhoods.
Developed by the U.S. Green Building Council (USGBC), LEED® is intended to help building owners and operators be environmentally responsible and use resources efficiently (Wikipedia).

LEED® Rating Systems
- New Construction and Major Renovations, 2009, v.3
- Existing Buildings Operations and Maintenance
- Commercial Interiors
- Core and Shell Development
- Retail
- Schools
- Homes
- Neighbourhood Development
- Healthcare

**LEED® Certification levels**

| | |
|---|---|
| Certified | 40 to 49 points |
| Silver | 50 to 59 points |
| Gold | 60 to 79 points |
| Platinum | 80 to 110 points |

**LEED® Prerequisites**
Each version of LEED® contains unique prerequisite requirements that must be satisfied in order to achieve certification. The phrase or term “prerequisite” refers to a mandatory project characteristic, measurement, quality, value, or function as identified within the LEED® rating system.

Prerequisites represent the key criteria that define green building and neighbourhood development performance. Each project must satisfy all specified prerequisites outlined in the LEED® Rating System under which it is registered. Failure to meet any prerequisite will render a project ineligible for certification (Source: www.gbci.org)

**Main Credit Categories**

SS = SUSTAINABLE SITES
Sustainable sites credits encourage strategies that minimize the impact on ecosystems and water resources.

WE = WATER EFFICIENCY
Water efficiency credits promote smarter use of water, inside and out, to reduce potable water consumption.

EA = ENERGY & ATMOSPHERE
Energy & atmosphere credits promote better building energy performance through innovative strategies.

MR = MATERIALS & RESOURCES
Materials & resources credits encourage the use of sustainable building materials and the reduction of waste.

IEQ = INDOOR ENVIRONMENTAL QUALITY
Indoor environmental quality credits promote better indoor air quality and access to daylight and views.

**Two Bonus Credit Categories**

ID = INNOVATION IN DESIGN
Innovation in design or innovation in operation credits address sustainable building expertise as well as design measures not covered by the five LEED® credit categories. Six bonus points are available in this category.

RP = REGIONAL PRIORITY CREDIT
Regional priority credits address regional environmental priorities for buildings in different geographic regions. Four bonus points are available in this category.

**LEED® Pilot Credit Library**

PC = PILOT CREDIT
As a flexible, interactive mechanism for testing proposed credits in the marketplace, the Pilot Credit Library gathers real-time feedback on credit usability and ability to meet a credit's intent.

# Part II : Criteria relevant to lighting
## Prerequisites | Main Credit Categories

**SS Credit 8: Light Pollution Reduction**
To minimize light trespass from the building and site, reduce sky-glow to increase night sky access, improve night-time visibility through glare reduction and reduce development impact from lighting on nocturnal environments.

**Possible points: 1 / 26 (Credit / Category)**

**Requirements**

**Interior Lighting**
(Option 1 or 2 requisite)

**Option 1:**
Light pollution reduction by use of automatic controls for lighting.

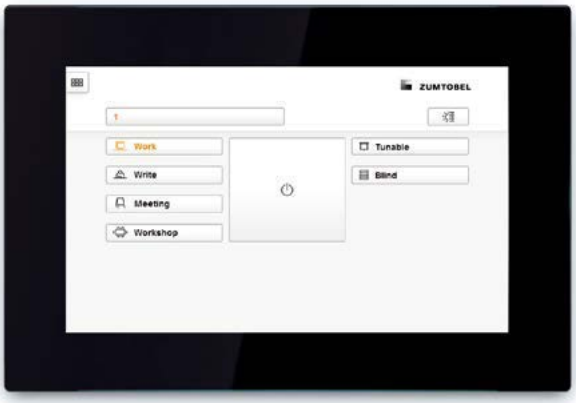
Note: Achieve power reduction of al least 50 % between 11.00 p.m. and 5.00 a.m. by automatic controls for luminaires in direct sight of any opening in the envelope.

**Option 2:**
Light pollution reduction by use of automatic shading devices.

Note: All openings in the envelope in direct sight of any non-emergency luminaires must have shielding controlled / closed by automatic devices. Transmittance of shielding must be less than 10 %.

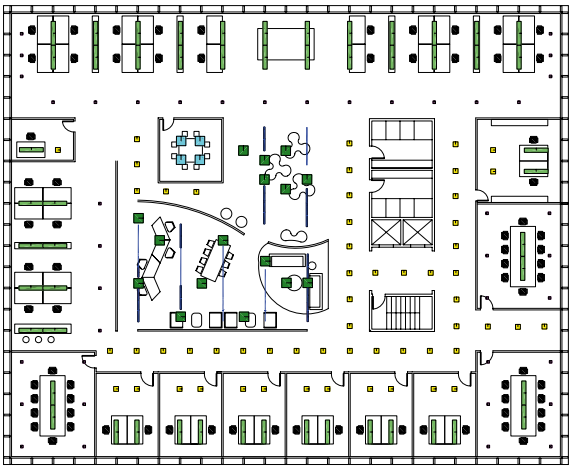
**Contribution by Zumtobel**

Specifications of Zumtobel control devices.




Zumtobel LITECOM

Drawings with locations and sequence of operation of Zumtobel controls.



Groundplan of Reference-building

## REQUIREMENTS

**Exterior Lighting**
(requisite)

Lighting Zone classification for project site
to be specified by the planner.
Note: LZ1 – LZ4 following IESNA RP 33

Calculation of exterior lighting power densities according to
ANSI / ASHRAE / IESNA 90.1- 2007 Section 9.
Note: Lighting power densities must not exceed this standard

Description of light trespass analyses containing manufacturer's luminaire data sheets with lamp lumen levels and photometric data.
Note: Prove that light trespass meets Lighting Zone requirements (e.g. LZ3: prove that less than 5 % of total sum of exterior lumens on site is above 90° from straight down).

Photometric site plan or illumination model.
Note: Prove that foot-candle level at the site boundary is not above Lighting Zone requirements.

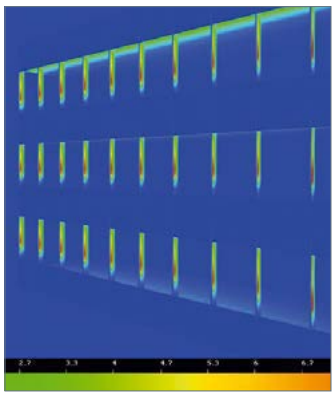
**Additional**
In order to achieve one point, meet the requirements
for interior lighting either Option 1 or Option 2 and the requirements for exterior lighting.

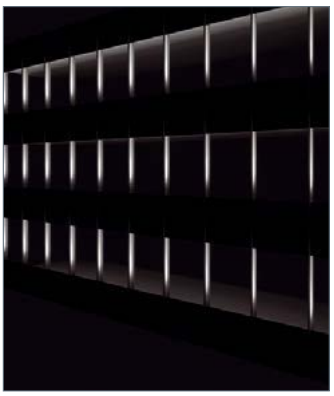
## Contribution by Zumtobel

Luminaire data sheet including lamp lumen levels and photometric data (Exterior Lighting).


Data sheet
Zumtobel PAN

Illumination model / photometric site plan as a special Zumtobel service in coordination with the lighting designer.





# Part II : Criteria relevant to lighting
## Prerequisites | Main Credit Categories

**EA Prerequisite 1: Fundamental Commissioning of Building Energy Systems**
To verify that the project's energy-related systems are installed, calibrated and perform according to the owner's project requirements, basis of design and construction documents. Benefits of commissioning include reduced energy use, lower operating costs, reduced contractor callbacks, better building documentation, improved occupant productivity and verification that the systems perform in accordance with the owner's project requirements.

**Possible points: 0 (Prerequisite)**

**Requirements**

A commissioning authority (CxA) for the overall project has to be named, which is responsible for overseeing the commissioning activities.

The owner's project requirements have to be documented and the CxA must review these documents.

A commissioning plan has to be developed and implemented.

The installation and performance of the systems must be verified.

A commissioning summary report has to be completed.
Note: Lighting and Daylighting controls are specifically mentioned among systems that need to be commissioned.

**Contribution by Zumtobel**

Documentation and verification of project requirements as well as installation and performance of the lighting systems are documented in collaboration with a Zumtobel Project Manager and verification can be provided via the Lighting Performance Platform.


Lighting Performance Platform

**EA Credit 3: Enhanced Commissioning**
To begin the commissioning process early in the design process and execute additional activities after systems performance verification has been completed.

**Possible points: 2/35 (Credit/Category)**

**Requirements**

**All Options:**
Building on EA Prerequisite 1, this credit requires more detailed and more independent commissioning and verification of the buildings systems.
Designate a CxA who is not an employee of a design company or contractor with construction contracts.

More detailed design reviews and commissioning required.
Conduct commissioning design review prior to construction phase.

Contractor submittals for the installation and commissioning of the building systems have to be reviewed by the CxA team.

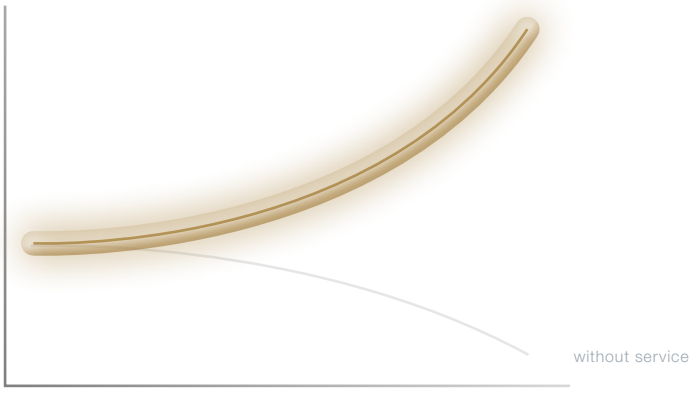
A systems manual for the commissioning of the systems has to be developed.

Training documents regarding the buildings systems have to be prepared for O&M personnel.

Building operation has to be reviewed within 10 month after substantial completion.

**Contribution by Zumtobel**

Zumtobel Services offers additional extended Project Documentation as well as on-site training for facility managers and users if required. In addition, maintenance agreements are offered to ensure the systems' correct functioning.




Zumtobel Services

# Part II : Criteria relevant to lighting
## Prerequisites | Main Credit Categories

**EA Prerequisite 2: Minimum Energy Performance**
To establish the minimum level of energy efficiency for the proposed building and systems to reduce environmental and economic impacts associated with excessive energy use.

**Possible points: 0 (Prerequisite)**

**Requirements**

**Option 1:**
Whole Building Energy Simulation. Demonstrate a 10 % improvement in the proposed building performance rating compared to a baseline building according to Appendix G ASHRAE 90.1. For existing buildings, 5 % are sufficient.

Note: This simulation is carried out by a consultant.

The simulation is carried out using simulation software approved by LEED®. Only the overall energy consumption of the building is relevant. Trade-offs between categories are possible, i.e. for the prerequisite there are no prescribed maximum values for the energy consumption of lighting as long as the overall building rating meets the requirements.

The amount of saving is expressed in the energy cost method, therefore it is not only relevant how much energy is consumed but also what the source of this energy is and how much it costs.

**Option 2 and 3:**
In Options 2 and 3, the building has to comply with prescriptive measures in specific design guides. These options are very rarely used in Europe.

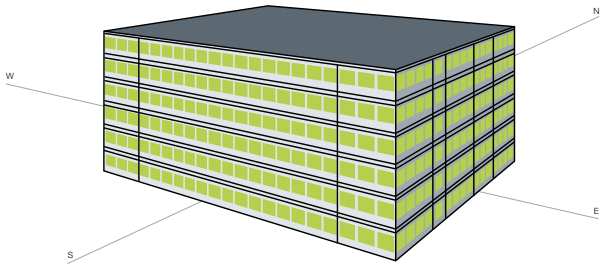
**Contribution by Zumtobel**

The engineer doing the simulation will require a schedule with the connected load per room or room type together with information regarding controls.

| Table 9.6.1 Space Type | ft² | Baseline Case | Proposed Case | | | |
|---|---|---|---|---|---|---|
| | | W/ft² | W/ft² | | | LPD |
| Office-Enclosed | 1.000 | 1,10 | 1,20 | occupancy sensor | 10% | 1,08 |
| Office-Open Plan | 1.500 | 1,10 | 1,10 | occupancy sensor | 10% | 0,99 |
| Conference/Meeting/Multipurpose | 500 | 1,30 | 1,40 | occupancy sensor | 15% | 1,19 |
| | | | | | | |
| | | | | | | |
| *Total* | *3.000* | *1,13* | *1,18* | | | *1,05* |

Simulations are carried out using simulation software approved by LEED®.

Daylight-based management and presence detection can be calculated by the simulation software directly. For all other saving potentials via controls a narrative will be required but it can not be guaranteed that arguments regarding additional saving potentials will be accepted.



**EA Credit 1: Optimize Energy Performance**
To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.

**Possible points: up to 19/35 (Credit/Category)**

**Requirements**

**All Options:**
The methods to prove compliance are identical to the EAP2 (Prerequisite). The percentage of energy cost saved in comparison to the baseline building must be demonstrated.

Note: Additional points are awarded for results exceeding the requirements of EAP2. While highly efficient lighting might not be necessary to meet the requirements of the Prerequisite (EAP2), it will have a big impact on the number of additional points that can be awarded in this credit. To obtain one point, a 12 % saving has to be achieved, for the full points a 48 % saving. The credit refers to the energy consumption of the complete building.

As the energy cost method is used to evaluate the savings, it is important which energy source is used. Lighting is using electricity, which is usually the most expensive form of energy. For this reason, energy-efficient lighting has a strong impact.

**Contribution by Zumtobel**

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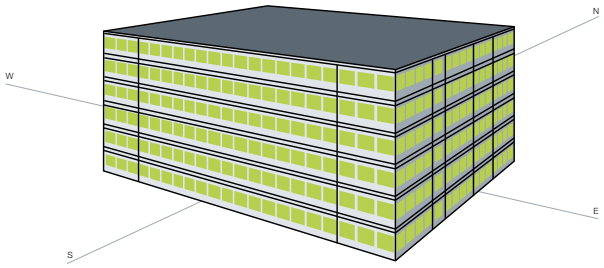


# Part II : Criteria relevant to lighting
## Prerequisites | Main Credit Categories

**IEQ Credit 6.1:**
**Controllability of Systems – Lighting**
To provide a high level of lighting system control by individual occupants or groups in multi-occupant spaces (e.g. classrooms and conference areas) and promote their productivity, comfort and well-being.

**Possible points: 1 / 15 (Credit / Category)**

**Requirements**

Provide individual lighting controls for 90 % (minimum) of the building occupants to enable adjustments to suit individual task needs and preferences.

Note: Percentage is calculated as percentage of individual workstations with controls divided by total number of workstations.

Provide lighting system controls for all shared multi-occupant spaces to enable adjustments that meet group needs and preferences.

Note: The documentation can be done in the form of a floor plan which shows the location of lighting controls as well as the zones and the types of controls that are used. Individual and shared work areas need to be indicated.

**Contribution by Zumtobel**

Zumtobel free-standing luminaires used at individual workspaces can help to raise the percentage of individual workstations with lighting controls.

LIGHT FIELDS evolution

Floor plans showing the zoning of the lighting along with the location and the type of the lighting controls can be used to document the availability of lighting controls.

**IEQ Credit 8.1:**
**Daylight and Views – Daylight**
To provide building occupants with a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

**Possible points: 1 / 15 (Credit / Category)**

**Requirements**

Demonstrate compliance through 1 of the 4 Options:

**Option 1: Simulation**
Demonstrate by computer daylight simulation and calculation that at least 75 % of the regularly occupied spaces achieve daylight illuminance between 25 fc and 500 fc. Criterion: clear sky conditions, September 21 at 9.00 a.m. and 3.00 p.m.

**Option 2: Calculations**
Determine the product of visible light transmittance and window to floor ratio. The value has to be between 0.15 and 0.18.

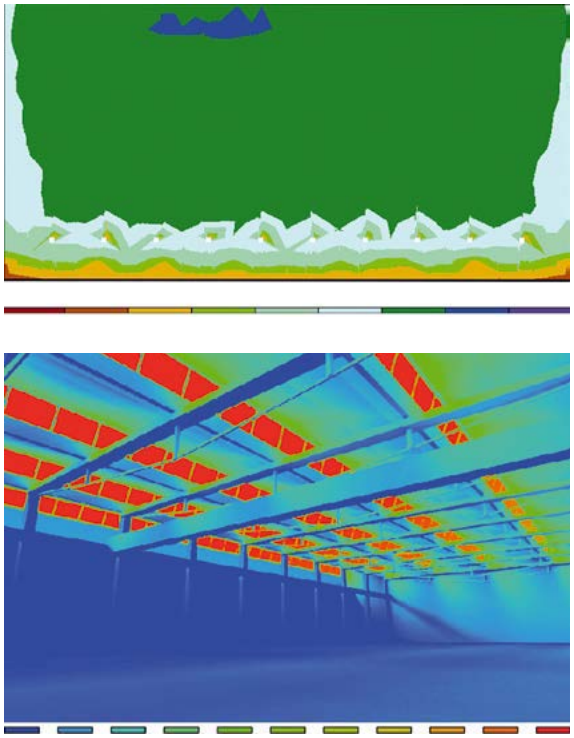
**Option 3: Floor plan with recorded measurement results**
Demonstrate by indoor light measurements that the minimum daylight illumination level of 25 fc has been achieved in at least 75 % of regularly occupied spaces.

**Option 4:**
Any of the above calculation methods may be combined to show the minimum daylight illumination in at least 75 % of regularly occupied spaces.

**Additional: New Construction and Core and Shell:**
Daylighting in at least 75 % of regularly occupied spaces to achieve 1 Point

**Contribution by Zumtobel**

A daylight simulation to demonstrate compliance to IEQ Credit 8.1 is a special Zumtobel service in coordination with planner.



# Part II : Criteria relevant to lighting
## Bonus Credit Categories

**ID Credit 1: Innovation and Design Process – Specific Title**
To provide design teams and projects with the opportunity to achieve exceptional performance above the requirements set by the LEED® Green Building Rating System and/or innovative performance in green building categories not specifically addressed by the LEED® Green Building Rating System.

**Possible points: 1/5 (Credit / Category)**

**Requirements**

**Path 1:**
Innovation credits provide the opportunity to achieve credit for exceptional performance above the requirements set by LEED® or innovative performance in Green Building categories not specifically addressed by the LEED® Green Building Rating System. Pilot credits are refined through LEED® project evaluations before they complete the balloting process for introduction into LEED®. One point is awarded for each innovation up to a maximum of 5.

Note: When submitting an ID credit, project teams must outline:
- proposed credit intent
- requirement(s) for compliance
- submittal(s) necessary to demonstrate compliance
- summary of potential design approaches that may be used to meet the requirements

**Contribution by Zumtobel**

Zumtobel products can contribute to meet the requirements for exemplary performance in EAc1 and EAc3.

SEQUENCE Suspended luminaire

**Path 2:**
Achieve exemplary performance in an existing prerequisite or credit that allows exemplary performance. One point awarded for each credit in which exemplary performance is demonstrated up to a maximum of 3.

Note: Exemplary performance is defined as doubling the credit requirements of reaching the next incremental percentage threshold. Credits relevant to lighting that allow exemplary performance are EAc1, EAc3 and EQc 8.1

Zumtobel Lighting Solutions may contribute to innovative design schemes under the innovation credit path.

Standardfloor of building model with lighting solution

**ID Credit 2: LEED® Accredited Professional**
To support and encourage the design integration required by LEED® to streamline the application and certification process.

**Possible points: 1/1 (Credit/Category)**

**Requirements**

At least 1 principal participant of the project team shall be a LEED® Accredited Professional (AP).

**Contribution by Zumtobel**

Zumtobel collaborates with LEED® Accredited Professionals

Jens Glöggler, Managing Director
ATP sustain GmbH,
LEED® Accredited Professional

# Part II : Criteria relevant to lighting
## Bonus Credit Categories

**RP Credit 1: Regional Priority – Specific Credit**
To provide an incentive for the achievement of credits that address geographically specific environmental priorities.

**Possible points: 4 / 4 (Credit / Category)**

**Requirements**

Adoptions were made to the following countries: United States, Argentina, Brazil, Chile, China, Colombia, Finland, Hong Kong, Macau, Mexico, Norway, Romania, Spain, Sweden, Turkey

For countries without predefined regional priority points there will automatically be awarded one of 4 points each, if you achieve the credits in the categories WEc1, WEc2, WEc3, EAc1, EAc3 or EAc5.

Note: Select a version, system, country and zip code to view the available regional priority credits: www.usgbc.org/rpc

**Contribution by Zumtobel**

Zumtobel Lighting has production sites among others in USA, China and Sweden.

# Part II : Criteria relevant to lighting
## Pilot Credit Categories

**SS Pilot Credit 7: Light Pollution Reduction**
To increase night sky access, improve night-time visibility, and reduce the consequences of development for wildlife and people.

**Possible points: 1 / 5 (Credit / Category)**

**Requirements**

Meet one of two Options for Requirement 1 (Uplight) and Requirement 2 (Trespass) for New Construction, Core Shell, Schools, Retail and Healthcare projects.

**Option 1: BUG Rating Method**
Don't exceed maximum luminaire uplight rating, backlight and glare ratings as defined in IESNA TM-15-11, Addendum A

**Option 2: Calculation Method**
Don't exceed maximum percentage of total lumens emitted above horizon and vertical illuminance levels at the Lighting Boundary.

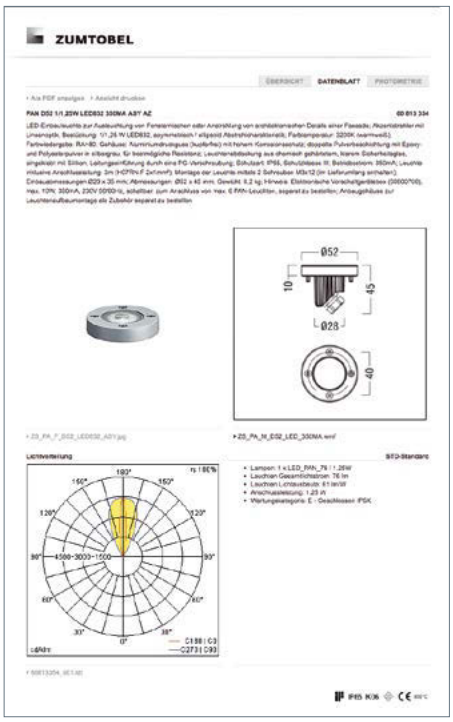
Note: Do not exceed the percentage of total lumens emitted above the horizon defined in LEED® Pilot Credit 7, Table 2 for Requirement 1. Do not exceed the maximum vertical illuminance levels at the Light Boundary defined in LEED® Pilot Credit 7, Table 4 for Requirement 2.

**Additional:**
For existing buildings (Operations and Maintenance) meet the Requirements 1 and 2 above and additionally Requirement 1 for interior lighting.

Note: In all spaces with luminaires in direct sight of the envelope, lighting has to be automatically reduced by at least 90 % when the space becomes unoccupied during night-time hours.

**Contribution by Zumtobel**

Zumtobel data sheet showing catalogue number, quality of this luminaire, 3D orientation of the luminaire, lumens emitted by the luminaire in that orientation, lumens emitted by the luminaire in that orientation above the horizon.




Data sheet Zumtobel PAN

# Part II : Criteria relevant to lighting
## Pilot Credit Categories

**IEQ Pilot Credit 22: Interior Lighting Quality**
Provide for occupant comfort by establishing quality criteria for interior lighting within a space.

**Possible points: 1 / 5 (Credit / Category)**

### Requirements

Meet the requirements of ASHRAE 90.1 Section 9.5 or Section 9.6. They define minimum requirements for energy efficiency either for the complete building or for specific spaces.

Note: Only installed lighting power is relevant, saving potentials through controls can not be included. Trade-offs between building or room types are permitted, but the total installed interior lighting power must not exceed the total interior lighting power allowance.

**Additional:**
Achieve at least 4 out of a list of lighting quality criteria defined in the pilot credit library for at least 90 % of the regularly occupied floor space.

Note: If your lighting design meets the requirements of EN 12464, these criteria should be easy to fulfil. They refer to glare, CRI, service life of lamps and luminaires, reflectance grades and the brightness of walls and ceilings in comparison to work surfaces.

### Contribution by Zumtobel

Spreadsheet comparing the connected load for each room type to the allowance in the standard. Alternatively, the full building can be compared. For details refer to ASHRAE standard 90.1 which can be downloaded at: www.ashrae.org

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| | | | | | | |
| | | | | | | |
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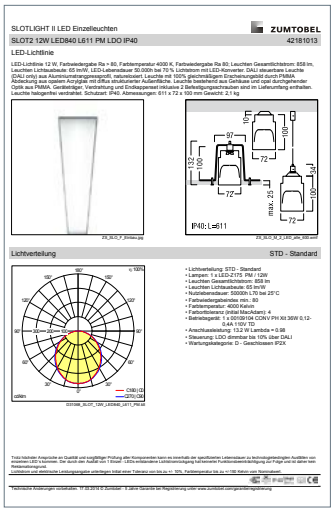
Narrative explaining which of the criteria are fulfilled.
There is no specific form to the report.


Lighting Calculations and / or luminaire Datasheets will be necessary for most criteria.


SLOTLIGHT II LED Einzelleuchten
ZUMTOBEL
SLOT2 12W LED840 L611 PM LDO IP40
42181013
LED-Lichtlinie
Lichtverteilung
STD - Standard

Some criteria only refer to reflectance grades of surfaces or technical specifications of luminaires, then data sheets are sufficient.

Dialux / Relux results are only required where levels of illumination are relevant. It is possible to pick four criteria where no lighting calculation is required.

**MR Pilot Credit 61:**
**Material Disclosure and Assessment**
To encourage the use of products and materials for which life-cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts. To reward project teams for selecting products from manufacturers who have verified improved

**Possible points: 1 / 5 (Credit / Category)**

**Requirements**

**Option 2: Multi-attribute optimization**
Use products that comply with one of the criteria below for 50 %, by cost, of the total value of permanently installed products in the project. Products will be valued as below:

- Third-party certified products that demonstrate impact reduction below industry average in at least 3 of the following categories are valued at 100 % of their cost for credit achievement calculations
- Global warming potential [CO2e]
- Depletion of stratospheric ozone layer [kg CFC-11]
- Acidification of land and water sources [moles H+] or [kg SO2]
- Eutrophication [kg nitrogen] or [kg phosphate]
- Formation of tropospheric ozone [kg NOx] or [kg ethene]
- Depletion of non-renewable energy resources [MJ]
- USGBC-approved program
- Products that comply with other USGBC-approved multi-attribute frameworks

For credit achievement calculation, products sourced (extracted, manufactured, purchased) within 100 miles (160 km) of the project site are valued at 200 % of their base contributing cost.

Note: For further details see
www.usgbc.org/node/2606895?return=/pilotcredits

**Contribution by Zumtobel**

The Environmental Product Declarations (EPD) according to ISO 14025 and EN 15804 are based on the ‘Luminaires, lamps and components or luminaires’ Product-Category Rules (PCR). Life Cycle Assessment Practitioner is PE INTERNATIONAL.


ZUMTOBEL

**Environmental Product Declaration**
**According to ISO 14025 and EN 15804**

| | |
|---|---|
| Declaration Holder: | Zumtobel Lighting GmbH |
| Program Holder: | Institute Construction and Environment (IBU) e.V. |
| Declaration number: | ECO-ZGR-60814647-Office-EU-2014-07-08 |
| Date of Issue: | 2014-07-08 |
| Validity Date: | 2019-07-08 |

60814647 **PANOS EVO E150LG 21W LED840 230V WH**

# Part II : Criteria relevant to lighting
## Pilot Credit Categories

**MR Pilot Credit 63:**
**Whole Building Life Cycle Assessment**
To increase the use of products and materials with life cycles and ingredients that improve overall environmental, economic and social performance.

**Possible points: 1 / 5 (Credit / Category)**

**Requirements**

**Option 4:**
Conduct a life-cycle assessment (LCA) of the project's structure and enclosure that demonstrates a minimum of 10 % reduction, compared with a reference building, in at least 3 of the 6 impact measures listed below, (1 must be global warming potential).

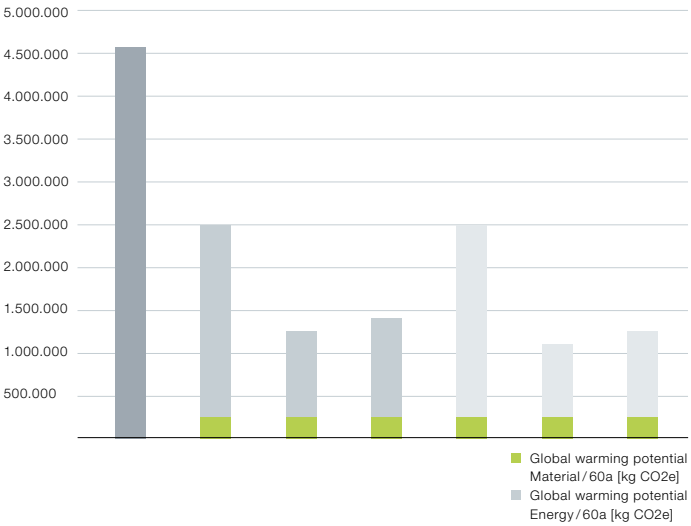
No impact category assessed as part of the LCA may increase by more than 5 % compared with the reference building.
The reference and design buildings must be of comparable size, function, orientation, and operating energy performance as defined in EA Prerequisite Minimum Energy Performance. The service life of the reference and design buildings must be the same and at least 60 years to fully account for maintenance and replacement.

Use the same LCA software tools and data sets to evaluate both the reference case and the design case, and report all listed impact categories. Data sets must be compliant with ISO 14044. Select at least 3 of the following impact measures for reduction:

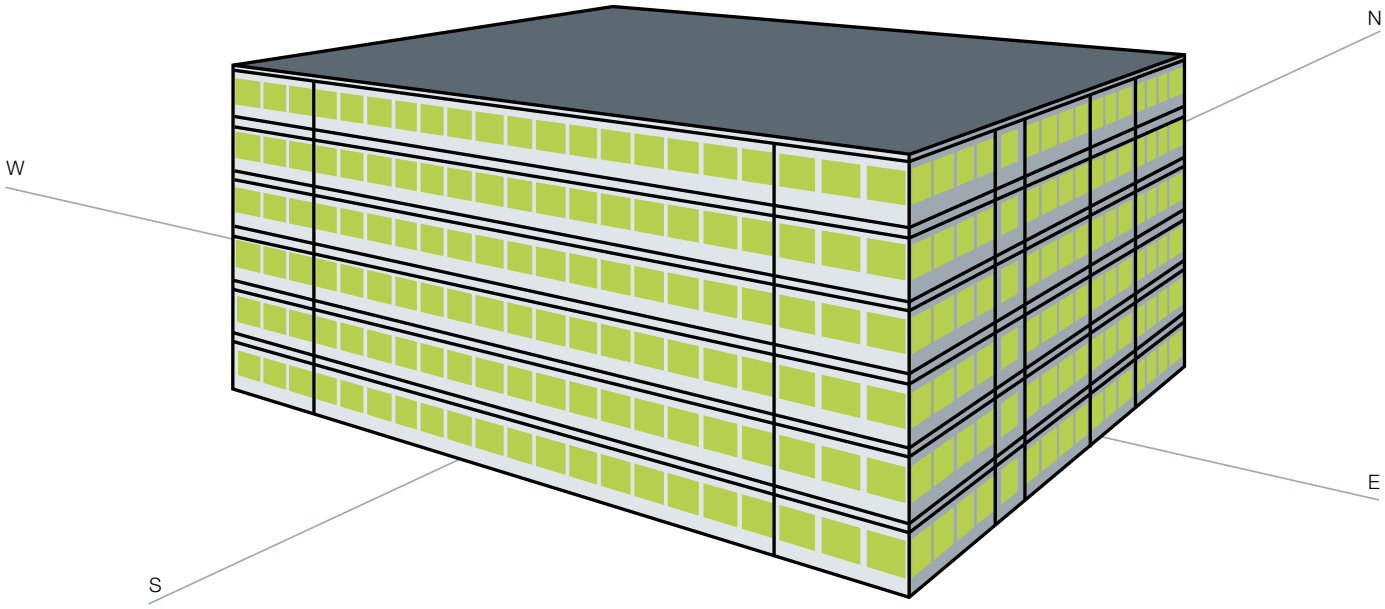
- Global warming potential [CO2e]
- Depletion of the stratospheric ozone layer [kg CFC-11]
- Acidification of land and water sources [moles H+] or [kg SO2]
- Eutrophication [kg nitrogen] or [kg phosphate]
- Formation of tropospheric ozone [kg NOx] or [kg ethene]
- Depletion of non-renewable energy resources [MJ]

**Contribution by Zumtobel**

Zumtobel can adjust the standard service life of an Environmental Product Declination (EPD) from 15 years up to a service life of 60 years to fulfill the requirements. Refer to lighting solution 1 (page 38) or lighting solution 2 (page 46).



# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Foreword




**Foreword**

The aim of this study was to optimise the energy efficiency of a model office building through various LED lighting solutions within the internationally acknowledged LEED® (Leadership in Energy and Environmental Design) certification system.

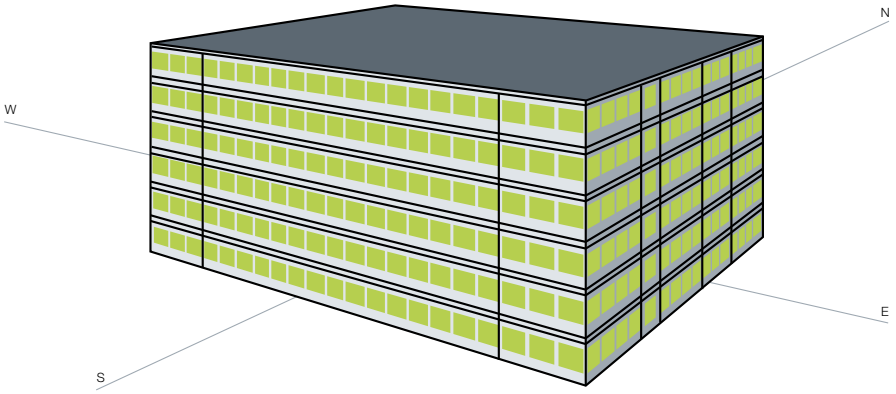
In the LEED® rating system (LEED®, 2009 v.3) for New Construction and Major Renovations, a 6-level reference building with room-specific installed loads was modelled according to ASHRAE 90.1-2007 [2] and compared with 2 different LED lighting solutions under the European standard according to DIN 12464. Both LED lighting solutions were assessed both with and without daylight-based control and blinds in each case.

The following results were documented: energy and lighting costs in EUR/$m^2$, cost savings in %, the score with respect to LEED® EA criterion 1: optimisation of energy efficiency; monthly and annual energy consumption in kWh/$m^2$, the breakdown of energy consumption in %, and the breakdown of energy costs in % of the entire office building.

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Design of the study

### Building model

A model building with 6 standard floors was prepared based on this standard floor. The height between floors was set at 3.40 m, the clear ceiling height was assumed to be 3.00 m.




### Room types

The room types were assumed in line with the layout of the groundfloor. Room occupancy corresponds to the number of seats indicated. The required supply of ambient air was assumed according to the room floor space and the number of persons, in line with the minimum requirements of ASHRAE 62.1-2007 [3]. The toilets are provided with a decentralised exhaust-air system according to the minimum requirements of the standard.

All lounges are heated to 20 °C and cooled down to 26 °C. The toilets are not cooled. The stairwell and escalators are heated to 15 °C.

In the office areas and in the conference rooms, the maximum equipment load according to the Core&Shell Guide [6] was assumed. In the toilets, the equipment loads were assumed in line with the California Model Guide for energy savings [8]. The cost component of equipment loads is around 25 %.

### Utilisation of rooms

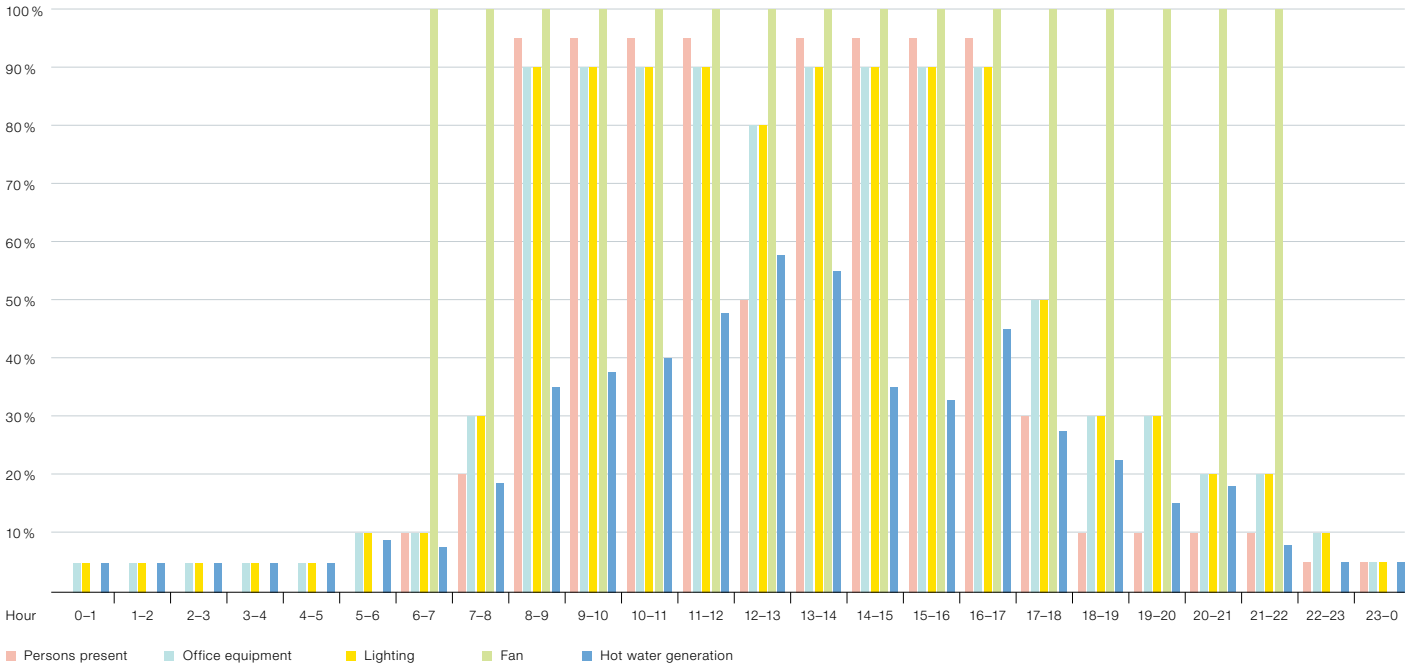
The type of utilisation of the rooms was determined according to the specifications of the ASHRAE 90.1-2007-User Manual [7]. Only workdays from Monday to Friday were taken into account.

The hourly utilisation profiles for supply with external air, room occupancy, office equipment loads, use of artificial lighting, and hot water consumption were determined. With respect to the type of utilisation of the rooms, a distinction was made between offices with side rooms and conference rooms.

| Utilisation of rooms | Gross area [m²] | Heating temp. [°C] | Cooling temp. [°C] | Equipment load [W/m²] | Persons present | Persons [m² p.P.] | Ambiant air in/out [m³/hm²] | decentr. exhaust air [m³/hm²] |
|---|---|---|---|---|---|---|---|---|
| Office cubicles | 171 | 20 | 26 | 16.1 | 15 | 11 | 1.8 | – |
| Team offices | 319 | 20 | 26 | 16.1 | 28 | 11 | 1.8 | – |
| Conferences | 126 | 20 | 26 | 10.8 | 30 | 4 | 3.1 | – |
| Lounge | 93 | 20 | 26 | – | 21 | 4 | 6.2 | – |
| Lobby | 52 | 20 | 26 | – | 9 | 6 | 2.6 | – |
| Toilets | 26 | 20 | – | 5.4 | – | – | – | 18.3 |
| Corridors | 192 | 20 | 26 | 2.2 | – | – | 1.1 | – |
| Stairs | 10 | 15 | – | – | – | – | 1.1 | – |
| Escalators | 7 | 15 | – | – | – | – | 1.1 | – |
| | **995** | | | | **103** | | | |

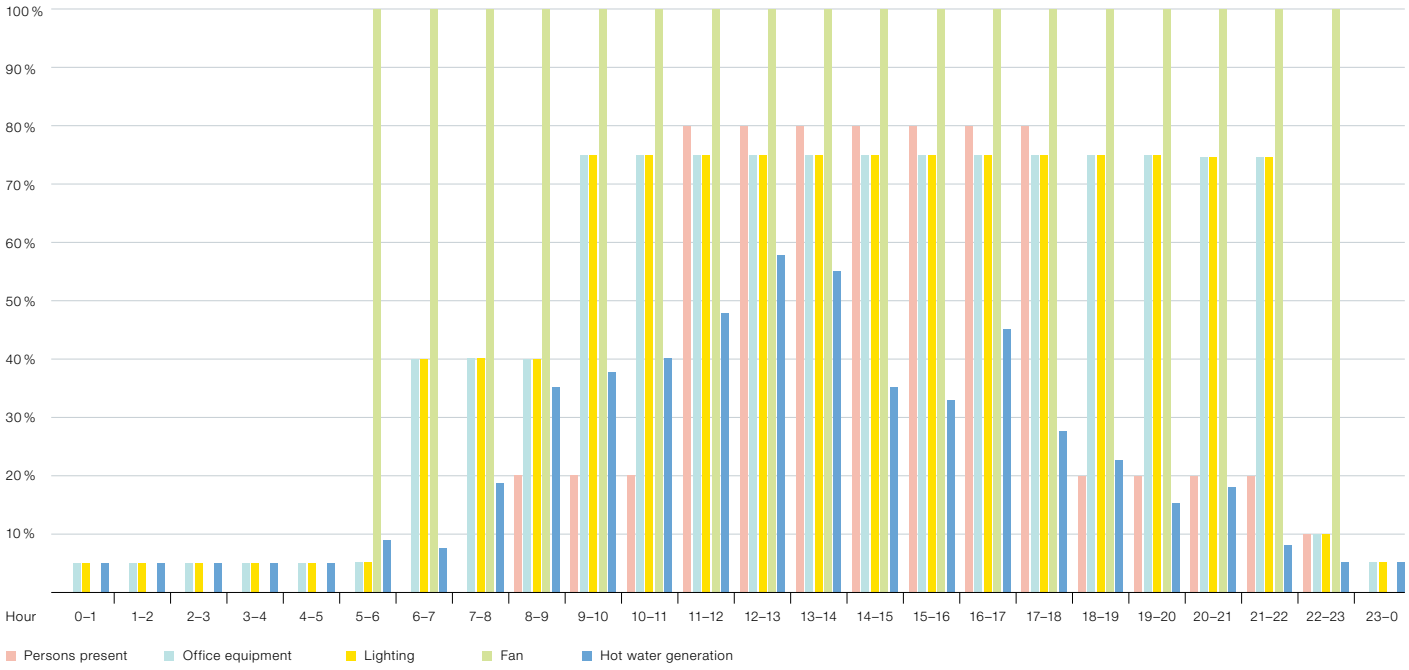
## Utilisation profile: Offices and side rooms (Mon – Fri)

**Utilisation profile**




## Utilisation profile: Meeting rooms (Mon – Fri)

**Utilisation profile**

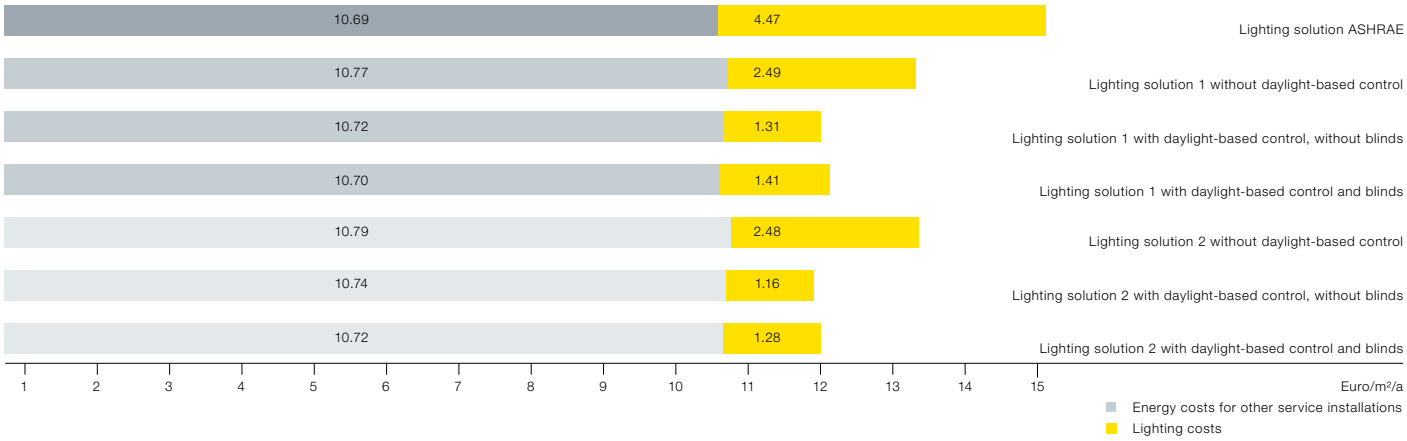


# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Summary

### Results

For a 6-level model building, based on a zone layout by Zumtobel [1], building and installation simulations were carried out to determine the energy performance under the LEED® NC standard. First of all, the reference model according to modelling instruction ASHRAE 90.1-2007 Annex G [2] was reproduced and calculated for the London location. Subsequently, alternative versions of the artificial lighting design were implemented into this reference model. In this way, it was possible to examine the influence of modern artificial LED lighting design and the impact of daylight-based control on energy costs and the so-called LEED® EAc1 Energy Performance.

### Energy costs and lighting costs




**–74 %**

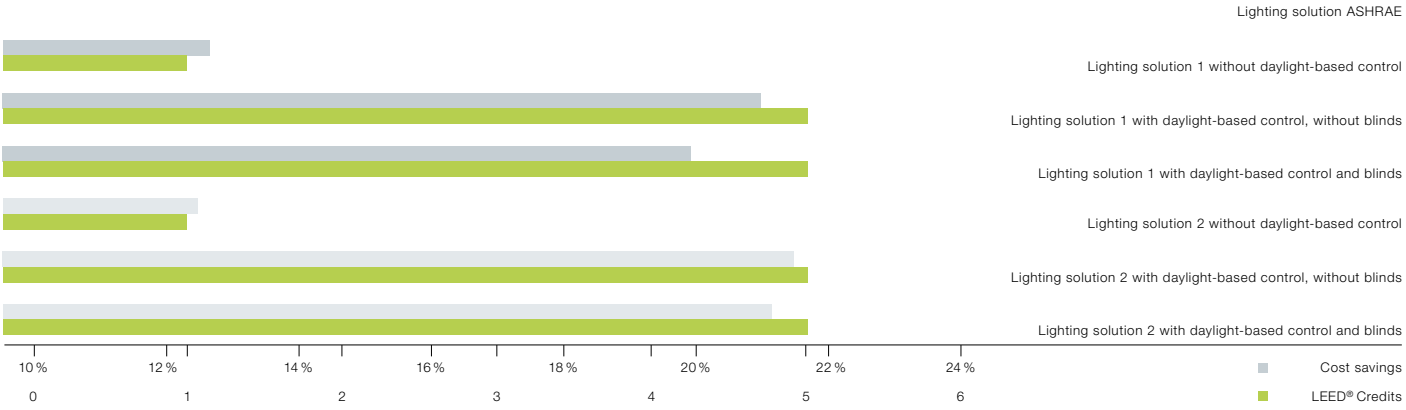
**Lighting costs**

The calculation shows specific energy costs of approx. 15 EUR/m²/a for the reference model, with a high lighting cost component of 4.47 EUR/m²/a. By installing the LED luminaires, the lighting cost component can be reduced to some 56 %. In combination with daylight-based control, the lighting costs are reduced to approx. 26-32 %. In this case, the influence of effective glare protection amounts to some 3 %. The influence of the lighting installation on the remaining operating costs for cooling and heating is only minor, since cost savings in the sphere of cooling are offset by an increase in heating costs.

### Saving and Credits

Installing the lighting solutions analysed results in energy cost savings between approx. 12 and 22 %. As a minimum standard, cost savings of 10 % must be demonstrated within the scope of LEED® certification. Any cost savings above 10 % will be rewarded with one LEED® Credit per 2 % of savings. Accordingly, 1–5 Credits derive from the variants examined.

### Cost savings and energy performance of the variants




**–22 %**

**Energycost savings of the entire building**

In conventional artificial lighting design in Western Europe, due to legally prescribed higher lighting standards, the installed luminous output will frequently even be higher than the light output required under the LEED® ASHRAE standard. In this case, conventional artificial lighting design reduces optimisation in other service installations, causing an unsatisfactory energy performance. This may be evaded by using LED luminaires and/or daylight-based control concepts.

„Accordingly, the design of the artificial lighting is an important lever to optimise LEED® Energy Performance.“

Dr. Ing. Heinrich Post,
Consulting engineers
for building climate
and energy schemes

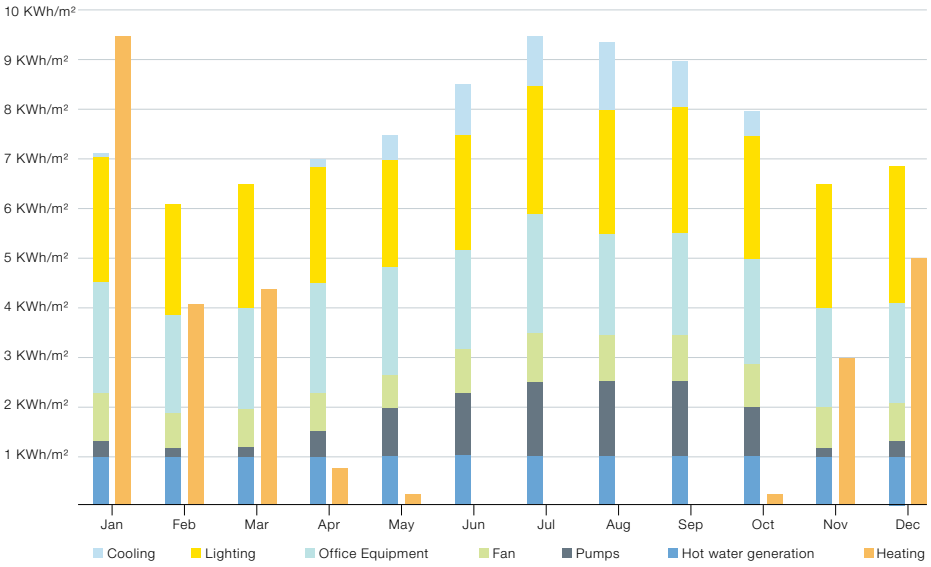
b+e

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Basic variant according to ASHRAE

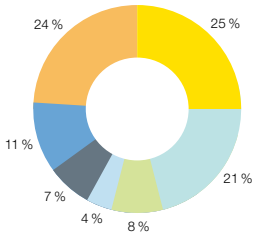
**Basic variant according to ASHRAE**

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and heating are calculated. The consumption of electrical energy roughly amounts to 91.6 kWh/m²/a, the consumption of natural gas to around 28.5 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating, lighting and office equipment represent the largest part of the energy consumed. Lighting and office equipment constitute the largest part of the energy costs.

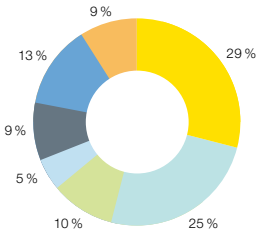
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



**Lighting installation according to ASHRAE**

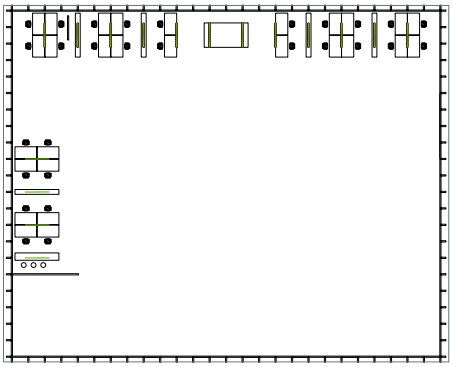
The artificial lighting installation according to room utilisation under table 9.6.1 ASHRAE 90.1-2007 [2] was reproduced as the basic variant.

| Utilisation of rooms | Gross area | Installed lighting | | Presence detector | Daylight sensor |
|---|---|---|---|---|---|
| | [m²] | [W/m²] | [W] | [ ] | [ ] |
| Office cubicles | 171 | 11.8 | 2 027 | – | – |
| Team offices | 319 | 11.8 | 3 777 | – | – |
| Conferences | 126 | 14.0 | 1 762 | – | – |
| Lounge | 93 | 11.8 | 1 101 | – | – |
| Lobby | 52 | 14.0 | 727 | – | – |
| Toilets | 26 | 9.7 | 251 | – | – |
| Corridors | 192 | 5.4 | 1 032 | – | – |
| Stairs | 10 | 6.5 | 62 | – | – |
| Escalators | 7 | – | – | – | – |
| | **995** | | **10,738** | | |

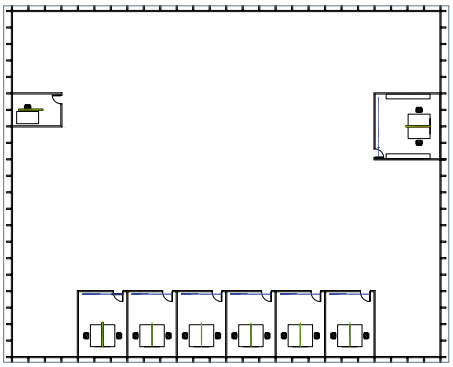
# Part III : LEED® energy efficiency study (EAp2/EAc1)

## Variants for Lighting solution 1

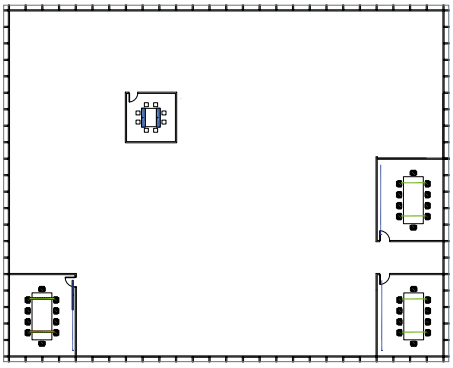
### Team offices



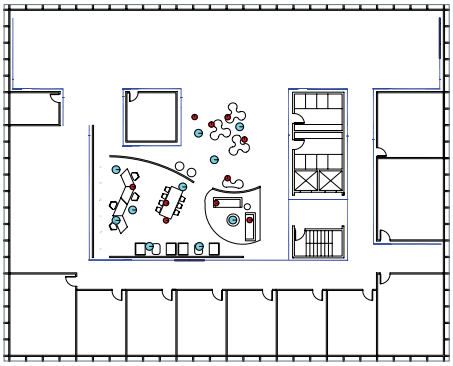
### Office cubicles



### Conferences



### Corridors



### Products used

**SEQUENCE suspended luminaire, symmetrical**
90 W; L, 9000 lm; CRI > 80

**SLOTLIGHT II recessed luminaire**
24 W; 2200 lm; CRI > 80

**LIGHT FIELDS evolution recessed luminaire**
44 W; 4524 lm; CRI > 80

**SUPERSYSTEM Downlight unit**
4 W; 264 lm; CRI > 80

**ONDARIA surface-mounted luminaire**
58 W; 5240 lm; CRI > 80

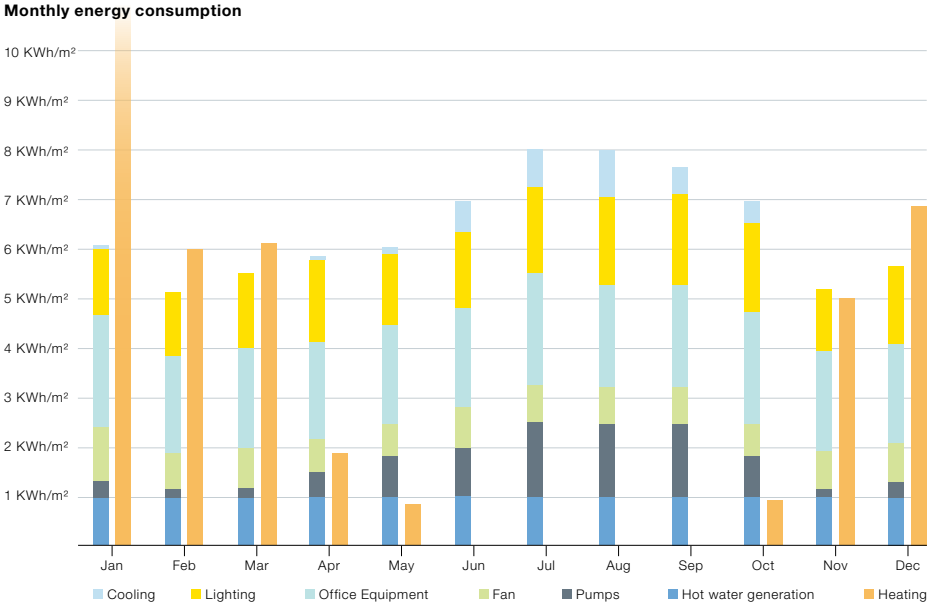
**ONDARIA surface-mounted luminaire**
31 W; 223 lm; CRI > 80

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Lighting solution 1 without daylight-based control

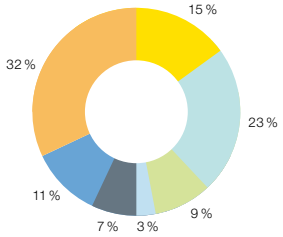
### General

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and gas heating are calculated. The consumption of electrical energy roughly amounts to 76.7 kWh/m²/a, the consumption of natural gas to around 35.0 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating and office equipment represent the largest part of the energy consumed. Office equipment constitutes the largest part of the energy costs.

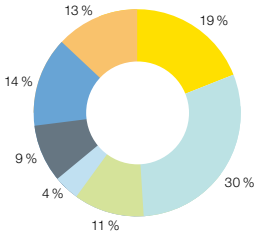
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



## Lighting solution

The lighting solution 1 is an LED-lighting solution. In the stairwell and in the toilets, the installations according to ASHRAE are kept, but motion sensors are installed. The installed artificial light output is around 43 % less than in the basic variant.

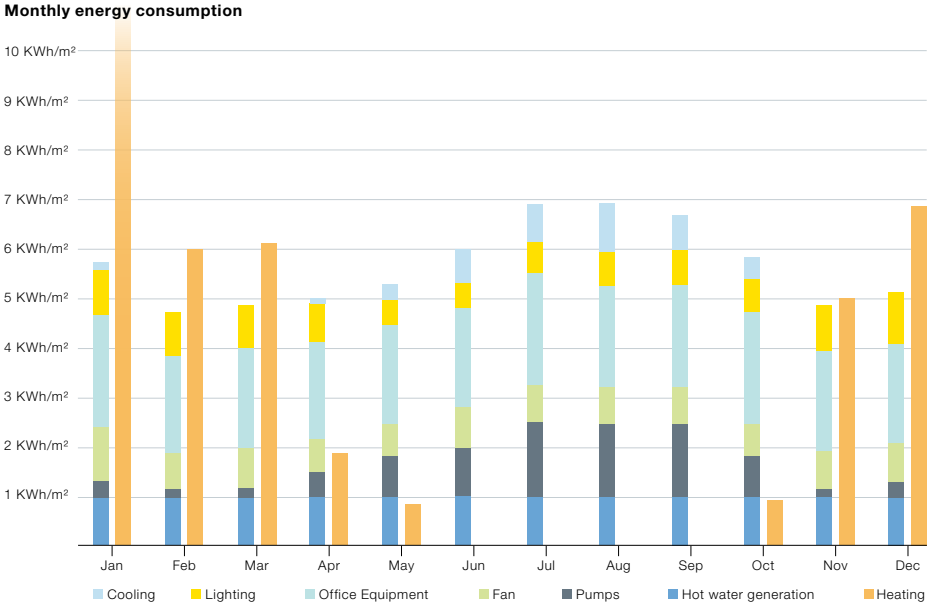
| Utilisation of rooms | Gross area | Installed lighting | | Presence detector | Daylight sensor |
|---|---|---|---|---|---|
| | [m²] | [W/m²] | [W] | [ ] | [ ] |
| Office cubicles | 171 | 6.2 | 1 054 | – | – |
| Team offices | 319 | 6.0 | 1 915 | – | – |
| Conferences | 126 | 6.8 | 856 | – | – |
| Lounge | 93 | 6.3 | 585 | – | – |
| Lobby | 52 | 6.3 | 329 | – | – |
| Toilets | 26 | 8.7 | 226 | x | – |
| Corridors | 192 | 5.8 | 1 113 | – | – |
| Stairs | 10 | 5.8 | 55 | x | – |
| Escalators | 7 | – | | – | – |
| | **995** | | **6,133** | | |

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Lighting solution 1 with daylight-based control, without blinds

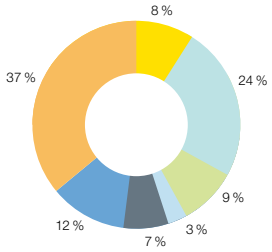
### General

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and gas heating are calculated. The consumption of electrical energy roughly amounts to 67.3 kWh/m²/a. the consumption of natural gas to around 38.7 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating and office equipment represent the largest part of the energy consumed. Office equipment constitutes the largest part of the energy costs.

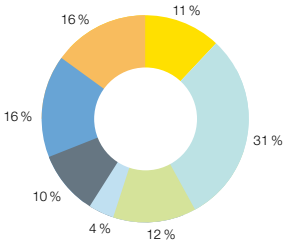
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



## Lighting solution

This lighting solution includes additional daylight-based control through photosensors on the facade for offices and conference rooms. The sensors are located at desk level, at a distance of some 1.7–1.9 m from the facade, measuring the daylight entering through the windows. In case of incident daylight, the sensors reduce the artificial lighting continuously from 500 lux to 0 lux. In case of full daylight illumination, residuary energy consumption due to the stand-by mode of the sensors is between approx. 0.5–1.5 %. In the team offices and in the 3- and 4-axes offices, an additional sensor is installed at a distance of around 1.1–1.2 m from the rear wall. It serves to reduce the output of luminaires situated outside the immediate task area when the incident daylight provides an illuminancelevel of 100 lux. All sensors are also equipped with presence detectors. According to ASHRAE 90.1-2007 [2], a reduction of the installed load by 10 % is taken into account.

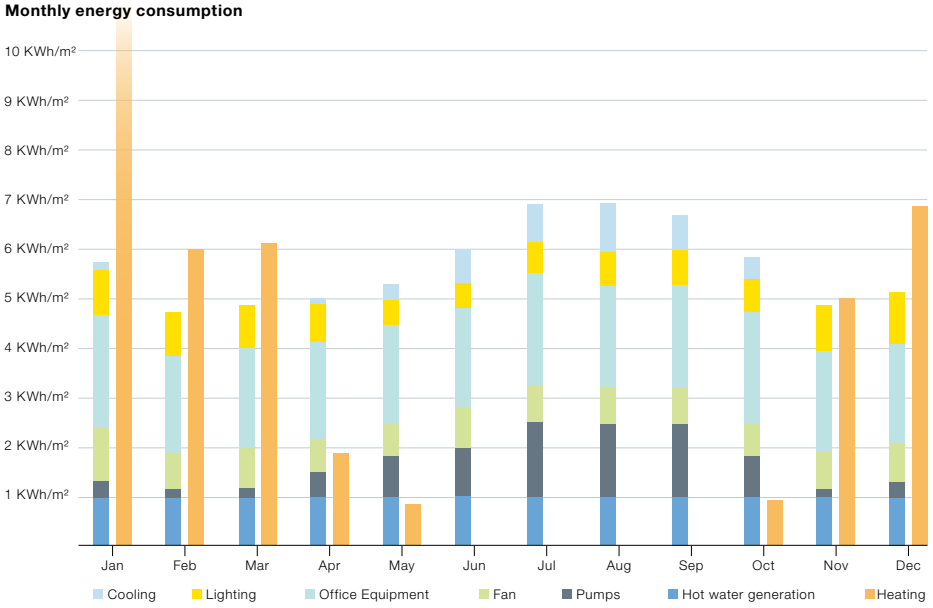
| Utilisation of rooms | Gross area | Installed lighting | | Presence detector | Daylight sensor |
|---|---|---|---|---|---|
| | [m²] | [W/m²] | [W] | [ ] | [ ] |
| Office cubicles | 171 | 6.2 | 1 054 | – | x |
| Team offices | 319 | 6.0 | 1 915 | – | x |
| Conferences | 126 | 6.8 | 856 | – | x |
| Lounge | 93 | 6.3 | 585 | – | – |
| Lobby | 52 | 6.3 | 329 | – | – |
| Toilets | 26 | 8.7 | 226 | x | – |
| Corridors | 192 | 5.8 | 1 113 | – | – |
| Stairs | 10 | 5.8 | 55 | x | – |
| Escalators | 7 | – | | – | – |
| | **995** | | **6,133** | | |

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Lighting solution 1 with daylight-based control and blinds

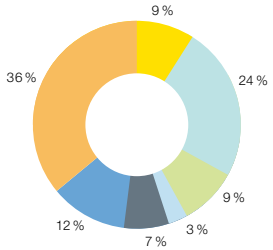
### General

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and gas heating are calculated. The consumption of electrical energy roughly amounts to 68.0 kWh/m²/a. the consumption of natural gas to around 38.3 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating and office equipment represent the largest part of the energy consumed. Office equipment constitutes the largest part of the energy costs.

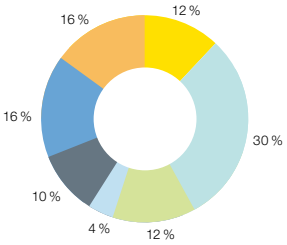
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



## Lighting solution

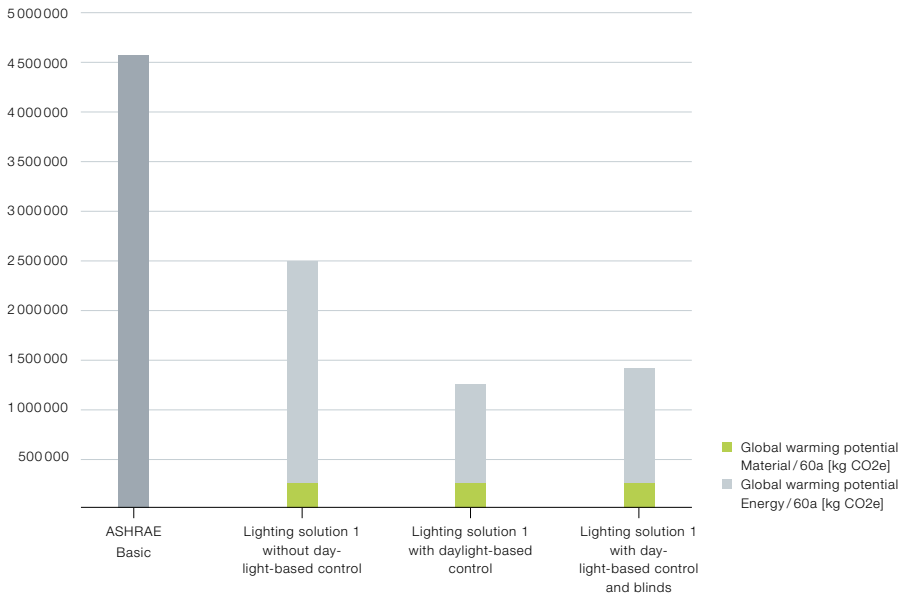
Daylight-based control takes account of glare produced by incident daylight. A maximum glare factor of 22 is assumed to assess glare according to [10]. Glare is calculated separately for each sensor.

| Utilisation of rooms | Gross area | Installed lighting | | Presence detector | Daylight sensor |
|---|---|---|---|---|---|
| | [m²] | [W/m²] | [W] | [ ] | [ ] |
| Office cubicles | 171 | 6.2 | 1054 | – | x |
| Team offices | 319 | 6.0 | 1915 | – | x |
| Conferences | 126 | 6.8 | 856 | – | x |
| Lounge | 93 | 6.3 | 585 | – | – |
| Lobby | 52 | 6.3 | 329 | – | – |
| Toilets | 26 | 8.7 | 226 | – | – |
| Corridors | 192 | 5.8 | 1113 | – | – |
| Stairs | 10 | 5.8 | 55 | – | – |
| Escalators | 7 | – | | – | – |
| | **995** | | **6,133** | | |

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Life cycle assessment for Lighting solution 1

**Life cycle assessment**

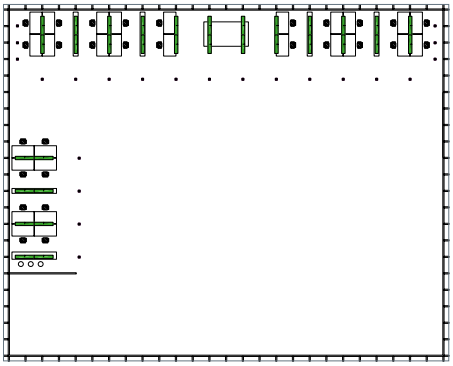
**MR Pilot Credit 63**
To achieve MR Pilot Credit 63, the life cycle analysis of the lighting solution can be modelled over a period of 60 years. For the LCA of the lighting solution, the energy consumption of the „LEED® Energy Performance (EAp2/EAc1) for a model building with different artificial lighting design options“ study is combined with the LCA data from the EPDs of the luminaires. In accordance with DIN 15804 (A1-A3 | A4, A5 | B6 | C2-C4 | D), the production, transport, utilisation, disposal and recycling stages are taken into account. The service life of the lighting solution is assumed to be 15 years, and the results are subsequently adjusted to a building service life of 60 years.



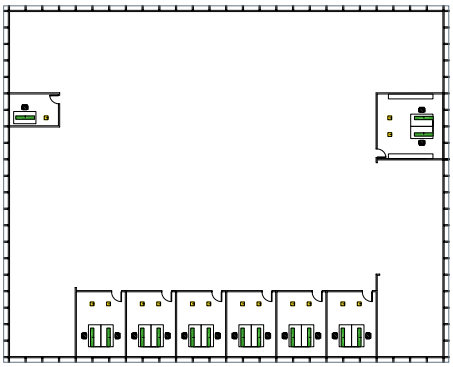

**MR Pilot Credit 61**
Zumtobel EPDs can help to achieve MR Pilot Credit 61.

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Variants for Lighting solution 2

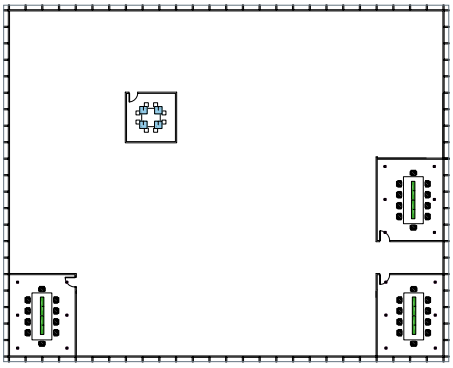
### Team offices



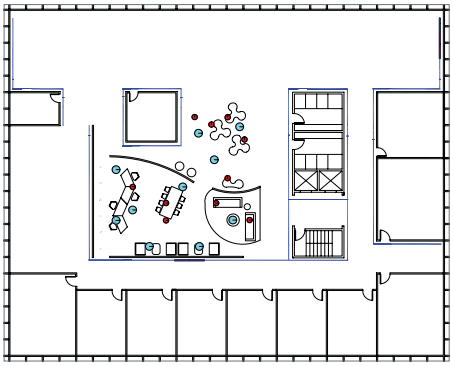
### Office cubicles



### Conferences



### Corridors



### Products used

**LIGHT FIELDS evolution suspended luminaire**
60 W; L, 5400 lm; CRI > 80

**SLOTLIGHT II recessed luminaire**
24 W; 2200 lm; CRI > 80

**PANOS INFINITY recessed luminaire**
16 W; 1073 lm; CRI > 90

**LIGHT FIELDS evolution MINI recessed luminaire**
15 W; 1281 lm; CRI > 80

**MELLOW LIGHT V recessed luminaire**
28 W; 3000 lm; CRI > 80

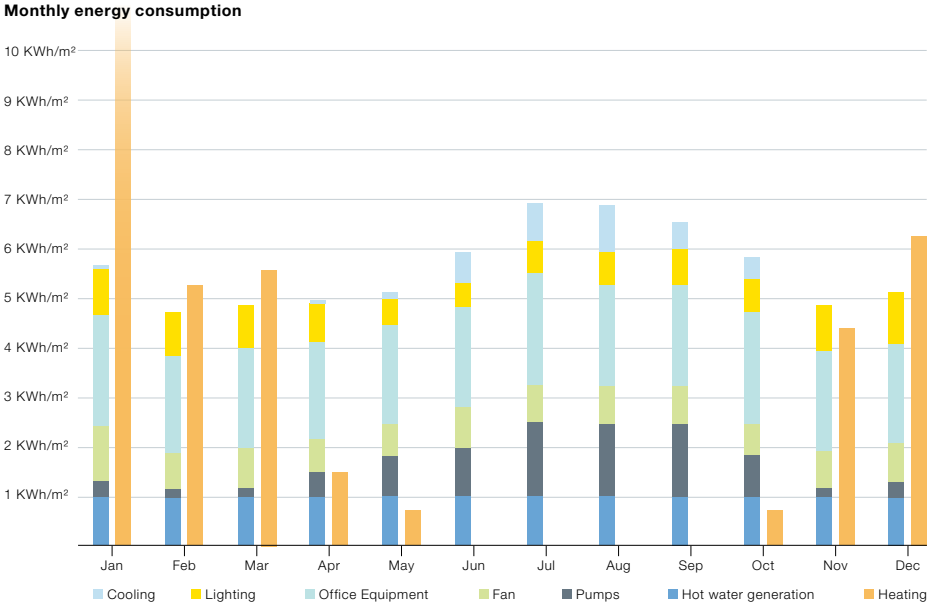
**CIELOS surface-mounted luminaire**
28 W; 3000 lm; CRI > 80

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Lighting solution without daylight-based control

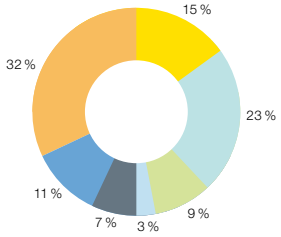
### General

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and gas heating are calculated. The consumption of electrical energy roughly amounts to 76.7 kWh/m²/a. the consumption of natural gas to around 35.2 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating and office equipment represent the largest part of the energy consumed. Office equipment constitutes the largest part of the energy costs.

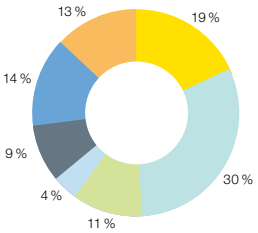
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



## Ligting solution

Lighting solution 2 includes an artificial LED lighting installation. In the stairwell and in the toilets, the installations according to ASHRAE are kept, but motion sensors are installed. The installed artificial light output is around 44 % lower.

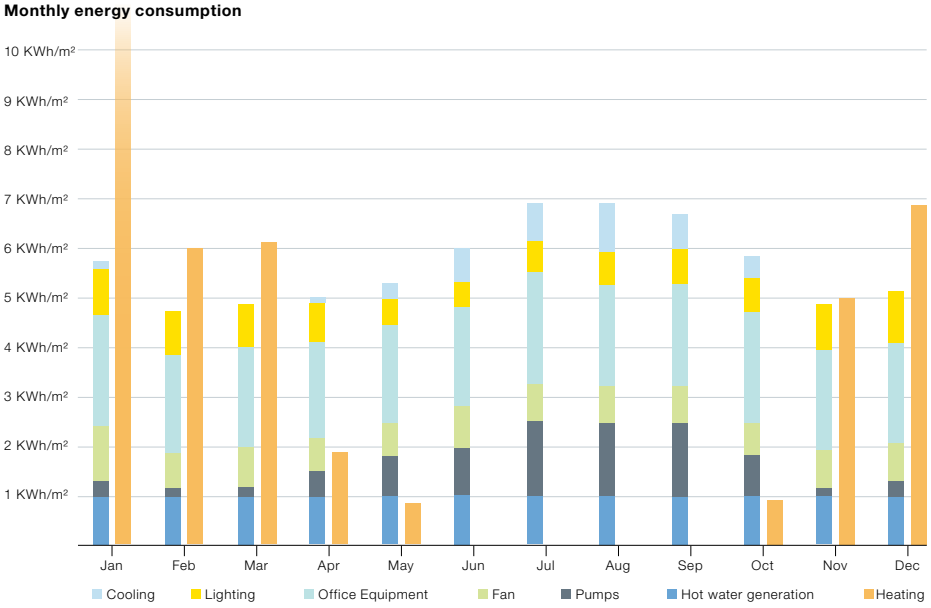
| Utilisation of rooms | Gross area | Installed lighting | | Presence detector | Daylight sensor |
|---|---|---|---|---|---|
| | [m²] | [W/m²] | [W] | [ ] | [ ] |
| Office cubicles | 171 | 6.6 | 1 125 | – | – |
| Team offices | 319 | 7.0 | 2 246 | – | – |
| Conferences | 126 | 6.0 | 760 | – | – |
| Lounge | 93 | 8.0 | 744 | – | – |
| Lobby | 52 | 5.7 | 297 | – | – |
| Toilets | 26 | 8.7 | 226 | x | – |
| Corridors | 192 | 3.0 | 571 | – | – |
| Stairs | 10 | 5.8 | 55 | x | – |
| Escalators | 7 | – | – | – | – |
| | **995** | | **6,025** | | |

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Lighting solution 2 with daylight-based control, without blinds

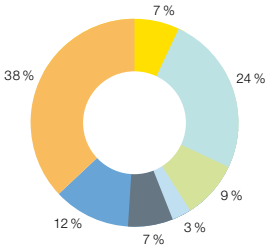
### General

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and gas heating are calculated. The consumption of electrical energy roughly amounts to 66.2 kWh/m²/a, the consumption of natural gas to around 39.4 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating and office equipment represent the largest part of the energy consumed. Office equipment constitutes the largest part of the energy costs.

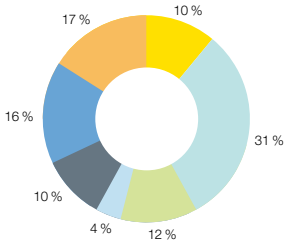
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



## Lighting solution

This lighting solution includes additional daylight-based control through photosensors on the facade for offices and meeting rooms. The sensors are located at desk level, at a distance of some 1.7–1.9 m from the facade, measuring the daylight entering through the windows. In case of incident daylight, the sensors reduce the artificial lighting continuously from 500 lux to 0 lux. In case of full daylight illumination, residuary energy consumption due to the stand-by mode of the sensors is between approx. 0.5 and 1.5 %. In the team offices and in the 3- and 4-axes offices, an additional sensor is installed at a distance of around 1.1–1.2 m from the rear wall. It serves to reduce the output of luminaires situated outside the immediate task area when the incident daylight provides an illuminancelevel of 100 lux. All sensors are also equipped with presence detectors. According to ASHRAE 90.1-2007 [2], a reduction of the installed load by 10 % is taken into account.

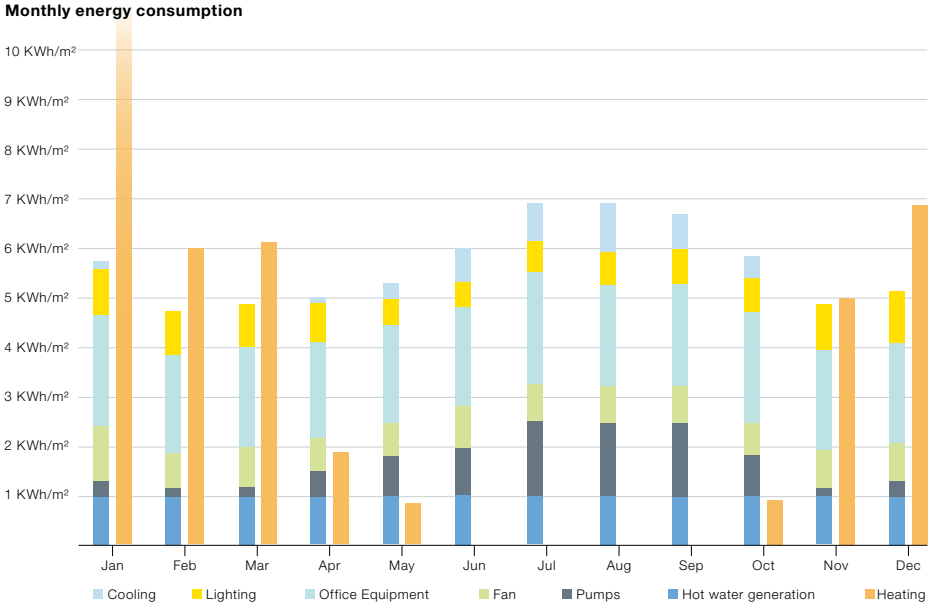
| Utilisation of rooms | Gross area [m²] | Installed lighting [W/m²] | [W] | Presence detector [ ] | Daylight sensor [ ] |
|---|---|---|---|---|---|
| Office cubicles | 171 | 6.6 | 1 125 | – | x |
| Team offices | 319 | 7.0 | 2 246 | – | x |
| Conferences | 126 | 6.0 | 760 | – | x |
| Lounge | 93 | 8.0 | 744 | – | – |
| Lobby | 52 | 5.7 | 297 | – | – |
| Toilets | 26 | 8.7 | 226 | x | – |
| Corridors | 192 | 3.0 | 571 | – | – |
| Stairs | 10 | 5.8 | 55 | x | – |
| Escalators | 7 | – | – | – | – |
| | **995** | | **6,025** | | |

# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Lighting solution 2 with daylight-based control and blinds

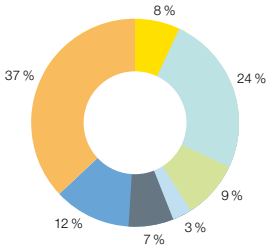
### General

To assess energy performance, the respective energy consumption of refrigerator units, cooling towers, lighting, office equipment, fan assemblies, pumps, electrical hot water generation, and gas heating are calculated. The consumption of electrical energy roughly amounts to 67.1 kWh/m²/a, the consumption of natural gas to around 38.8 kWh/m²/a. In summer, the consumption of electrical energy is highest. In winter, the consumption of natural gas is predominant. Heating and office equipment represent the largest part of the energy consumed. Office equipment constitutes the largest part of the energy costs.

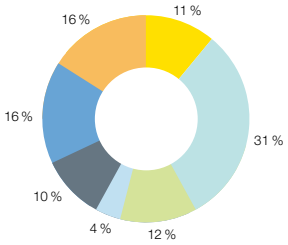
**Monthly energy consumption**




**Breakdown of energy consumption**




**Breakdown of energy costs**



### Lighting solution

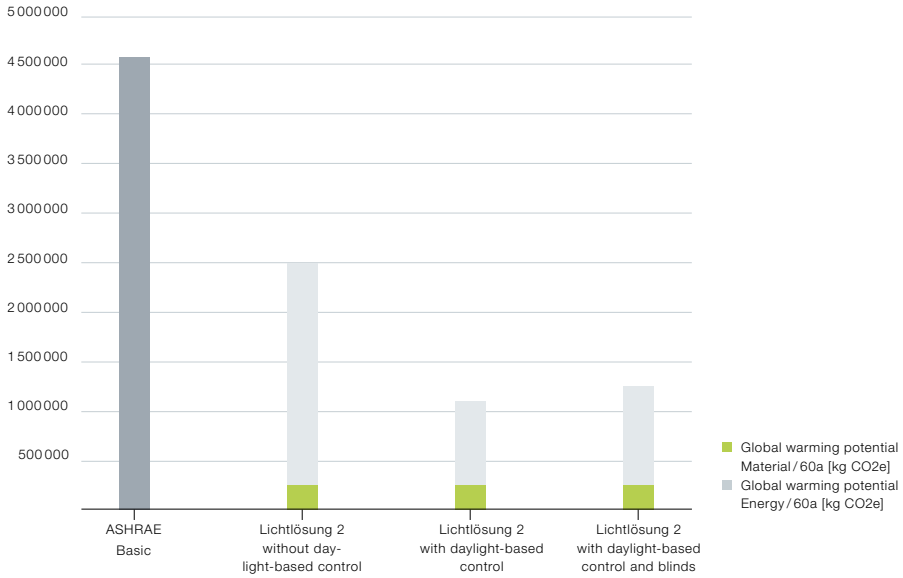
Daylight-based control takes account of glare produced by incident daylight. A maximum glare factor of 22 is assumed to assess glare according to [10]. Glare is calculated separately for each sensor.

| Utilisation of rooms | Gross area [m²] | Installed lighting [W/m²] | [W] | Presence detector [ ] | Daylight sensor [ ] |
|---|---|---|---|---|---|
| Office cubicles | 171 | 6.6 | 1 125 | – | x |
| Team offices | 319 | 7.0 | 2 246 | – | x |
| Conferences | 126 | 6.0 | 760 | – | x |
| Lounge | 93 | 8.0 | 744 | – | – |
| Lobby | 52 | 5.7 | 297 | – | – |
| Toilets | 26 | 8.7 | 226 | x | – |
| Corridors | 192 | 3.0 | 571 | – | – |
| Stairs | 10 | 5.8 | 55 | x | – |
| Escalators | 7 | – | – | – | – |
| | **995** | | **6,025** | | |

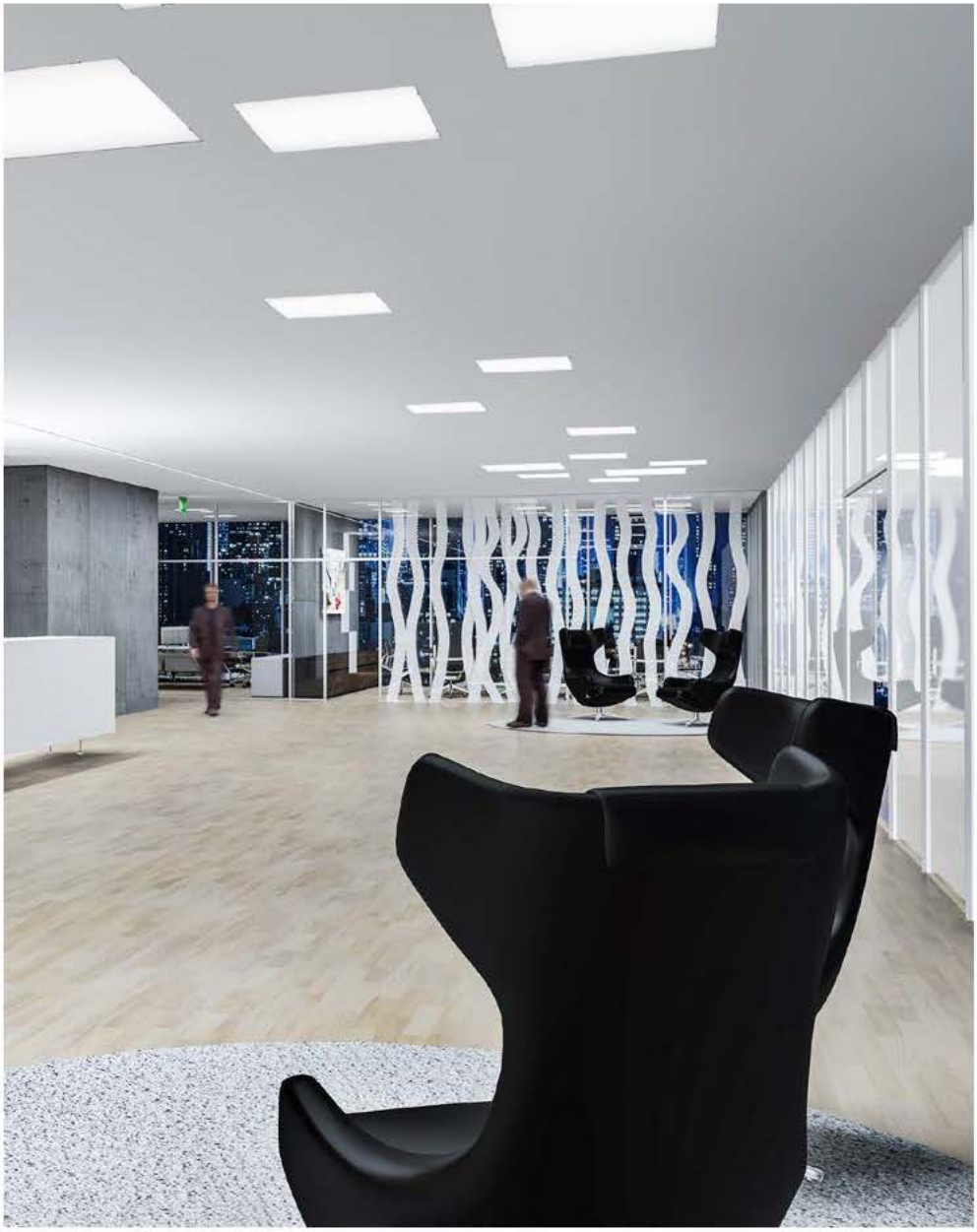
# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Life cycle assessment for Lighting solution 2

**Life cycle assessment**

**MR Pilot Credit 63**
To achieve MR Pilot Credit 63, the life cycle analysis of the lighting solution can be modelled over a period of 60 years. For the LCA of the lighting solution, the energy consumption of the „LEED® Energy Performance (EAp2/EAc1) for a model building with different artificial lighting design options“ study is combined with the LCA data from the EPDs of the luminaires. In accordance with DIN 15804 (A1-A3 | A4, A5 | B6 | C2-C4 | D), the production, transport, utilisation, disposal and recycling stages are taken into account. The service life of the lighting solution is assumed to be 15 years, and the results are subsequently adjusted to a building service life of 60 years.




**MR Pilot Credit 61**
Zumtobel EPDs can help to achieve MR Pilot Credit 61.



# Part III : LEED® energy efficiency study (EAp2/EAc1)
## Basic conditions / Documents

### List of basic conditions

Subsequently, the model assumptions and the methods used in the analysis are described.

### Methods

To analyse the lighting design, the client provided a standard floor with installed lighting, accommodating offices, conference rooms and access areas [1]. A model building with 6 standard floors was prepared based on this standard floor.

The missing parameters for the building and installation model were taken from the specifications for the reference model procedure of the ASHRAE/IESNA standard 90.1-2007 [2] that are described in Annex G of the standard. The reference model method allows to compare the energy costs of a building assessed within the scope of LEED® EAp2/EAc1. The parameters depend on the size of the building, its location and on the type of energy supply. The most important model parameters were fixed by indicating the building size: „more than 5 floors“, location: „London“ and energy supply: „electricity and gas“.

The simulation program eQUEST [4] was used as the calculation program. This software is based on the calculation core DOE2.2 [5] that also takes account of available daylight [9]. The calculation of available daylight at the reference points is effected by calculating the daylight coefficient (proportion of luminous intensity inside/outside) for an overcast sky and for a clear sky with 20 positions of the sun. The calculation of interior reflections takes place in a simplified manner by means of the split flux method, with a distinction being made between room reflections below and above window level. Glare is calculated using a glare index according to Hopkins [10] that describes the logarithmic proportion of the luminance levels at window level and on the window wall.

### Energy rates

The building is supplied with electricity and gas. A mixed energy price was agreed with the client as the energy rate in each case.

| Energy rates | Price per kWh |
|---|---|
| Electricity | 0.15 Euro/kWh |
| Gas | 0.05 Euro/kWh |

### Weather data

| London Heathrow | |
|---|---|
| Latitude: | N51,48° |
| Longitude: | W0,50° |
| Height: | 24 m |
| Time zone: | UTC=0 |
| Temperate zone: | 4A |

### Room types

The eQUEST energy model includes 120 thermal zones with 9 room types each. The zones comprise an area of 5970 m².

| Utilisation of rooms | Area [m²] | Percent [%] |
|---|---|---|
| Office cubicles | 1027 | 17,2 |
| Team offices | 1914 | 32,1 |
| Conferences | 756 | 12,7 |
| Lounge | 558 | 9,3 |
| Lobby | 312 | 5,2 |
| Toilets | 155 | 2,6 |
| Corridors | 1150 | 19,3 |
| Stairs | 57 | 1,0 |
| Escalators | 41 | 0,7 |
| | **5970** | **100** |

### Gebäudekonstruktionen

The thermal quality of the external building structures was assumed according to climate zone 4A from table 5-5-4 of the ASHRAE 90.1-2007 standard. The proportion of window surfaces of the exterior facade was set at 40 % in line with the specification. Plasterboard walls were chosen as partitions, and an elevated concrete floor as separating ceilings. To take account of daylight-based control, the reflection parameters for interior wall surfaces and transmission parameters for glazed surfaces and blinds were assumed according to the client‘s specification.

| Exterior wall structure | U-value Conductance [W/m²K] | SGHC [ ] | rho-light [ ] | tau-light [ ] |
|---|---|---|---|---|
| **Exterior walls** | | | | |
| Roof, insulated | 0.27 | | 0.85 | |
| Exterior wall, metal structure | 0.36 | | 0.60 | |
| Bottom floor to soil | L = 1.26 | | 0.30 | |
| **Interior surfaces** | | | | |
| Ceiling | | | 0.85 | |
| Interior wall | | | 0.60 | |
| Floor | | | 0.30 | |
| **Außenfenster** | | | | |
| Exterior window (metal frame) | 3.12 | 0.40 | | 0.60 |
| Blinds | | | | 0.15 |

## Technical installations

Energy supply is effected according to table G3.1.1A ASHRAE 90.1-2007 [2] by means of an atmospheric gas boiler and a compression refrigeration machine with wet heat exchange. The gas boiler is over-dimensioned at a rate of 25 %, the refrigeration machine at a rate of 15 %.

Hot water supply is effected at 82 °C / 54 °C by means of a non-regulated pump. Cold water supply takes place at 6.7 °C / 13 °C through a primary circuit and a secondary circuit, by means of a non-regulated pump in each case. Re-cooling (heat exchange) is effected using a non-regulated pump via a wet heat exchange tower. The temperatures of the hot and cold water circuits are regulated through the respective outdoor temperature.

In the toilets, decentralised, electrical hot water boilers are installed. A maximum water requirement of 1.5 litres/h per person is assumed.

**Efficiency of building services equipment**

| | |
|---|---|
| Compression refrigeration machine | COP = 4.45 |
| Pumps: cold water supply | 350 W/l/s, ungeregelt |
| Re-cooling plant | COP = 75.0 |
| Pump: re-cooling (heat exchange | 310 W/l/s, ungeregelt |
| Boiler | $\eta$ = 80 % |
| Pump: hot water supply | 350 W/l/s, ungeregelt |
| Electrical hot water generation | $\eta$ = 93 % |

## Ventilation and air-conditioning

Supply with ambient air, cooling and gas heating is effected according to table G3.1.1A ASHRAE 90.1-2007 [2], for one floor in each case, through a ventilation system with variable flow rate regulation. Supply with ambient air is determined according to the respective utilisation of the room under ASHRAE 62.1-2007 [3]. Heating and cooling are effected at an excess or under temperature of around 11 K. The pressure drop at the piping, air filters and sound traps is taken into account according to table G3.1.2.9 ASHRAE 90.1-2007 [2].

| **Efficiency of ventilation and air-conditioning** | **Supply air [W/m³/h]** | **Exhaust air [W/m³/h]** |
|---|---|---|
| Fan performance ground floor - level 5 | 0.45 | 0.41 |
| Fan performance toilets | – | 0.18 |

## Documents


[1] Floorplan and variants of lighting solution, for standard floor
Zumtobel, Dornbirn, 06.02.14

[2] ANSI/ASHRAE/IESNA Standard 90.1-2007
Energy Standard for Buildings Except Low-Rise Residential Buildings
ASHRAE Atlanta 2007

[3] ANSI/ASHRAE/IESNA Standard 62.1-2007
Ventilation for Acceptable Indoor Air Quality
ASHRAE Atlanta 2007

[4] eQUEST 3.63b, Release : 7/03/2009
James J. Hirsch & Associates, Camarillo, California, 2009

[5] DOE2.2,
Simulation Research Group
Lawrence Berkeley National Laboratory
University of California, 1998

[6] LEED® 2009 for Core & Shell Development Rating System
USGBC, 2008

[7] 90.1 User's Manual ANSI/ASHRAE/IESNA Standard 90.1-2007
ASHRAE Atlanta 2008

[8] Energy Savings Modeling and Inspection Guidelines for
Commercial Building Federal Tax Deductions
U.S. Department of Energy, 2007

[9] Daylighting Simulation in DOE-2
Winkelmann, Selkowitz
Berkely, California, 1985

[10] An empirical Formula for the computation
of the indirect component of daylight factors
Hopkins, Longmore, Petherbridge
Trans. Illum. Eng. Soc., London, 1954


## Partners and project team

b+e

Consulting engineers for building climate and energy schemes, Munich
Dr. Ing. Heinrich Post

ZUMTOBEL

Zumtobel Lighting GmbH, Dornbirn

# Part IV : Glossary

**ANSI**
The American National Standards Institute ANSI is the U.S. office for standardization of industrial practices helping to assure the safety and health of consumers and the protection of the environment. (WIKI)

**ANSI/ASHRAE/IESNA Standard 90.1-2007**
ASHRAE 90.1 (energy standard for buildings except low-rise residential buildings) is a US standard that provides minimum requirements for energy efficient designs. The updated version in 2007 (Standard 90.1-2007) covers many sections of a building which include building envelope, HVAC, hot water, and lighting. (WIKIPEDIA)

**ASHRAE**
American Society of Heating, Refrigerating and Air Conditioning Engineers) is a building technology society focusing on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry. (wiki)

**Ballast**
A ballast is the device necessary to control the current for gas discharge lamps and fluorescent lamps. To improve the visual comfort the use of flicker-free ballasts is required. To increase the efficiency of a luminaire the ballasts' losses have to be optimized.

**Commissioning**
Commissioning is the process to verify that the project's energy-related systems are installed, calibrated and perform according to the owner's project requirements, basis of design and construction documents. (www.usgbc.org)

**Converter**
LEDs are powered via appropriate direct current (DC) converters which fulfill the same role as the ballasts in fluorescent luminaires.

**CRI**
The spectral components of the light determine how well various object's colours can be reproduced. The higher the colour rendering index (Ra or CRI) the better the colour rendering in comparison with the optimum reference light. The maximum colour rendering index value of 100 is defined by an incandescent lightsource. Values in excess of 80 are considered to be very good.

**CxA**
The commissioning authority of a building project in the LEED® nomenclature.

**DALI**
The term DALI stands for Digital Addressable Lighting Interface. DALI is a protocol for digital addressing of technical lighting control gear. It is a standard defined by several manufacturers of luminaires and electronic ballasts. DALI enables bidirectional communication to report information such as faulty lamps, dimming levels etc.

**Daylight measuring head**
A daylight measuring head measures the amount of available daylight. It is installed outside the building and records the position of the sun as well as direct and indirect light components. Together with the geographical location of the installation and its range of sun positions stored in every installation, the natural lighting conditions in a particular room can be determined.

**EPD**
An environmental product declaration (EPD) is a standardized way of quantifying the environmental impact of a product or system in a life cycle assessment. (WIKIPEDIA)

**IBU**
The Institut Bauen und Umwelt e. V. (IBU) is an association, that introduces an uniform label for construction products which hold an EPD.

**IESNA**
The Illuminating Engineering Society of North America (IES) publishes standards for the lighting industry. (www.iesna.org)

**Illuminance**
Illuminance describes the quantity of luminous flux falling on a surface. It decreases by the square of the distance (inverse square law). Relevant standards (e.g. EN 12464 Lighting of indoor workplaces) specify the required illuminance.
Illuminance: E(lx) = luminous flux (lm) / area ($m^2$)
Abbreviation: E
Unit: lx Lux
Unit: fc Foot-candle
Conversion: 1 fc = 10,76391 lx

**Illuminance levels on ceilings and walls**
Unlit ceilings and walls create an unpleasant room impression. Bright surfaces, however, pleasantly enhance the room climate. The EN 12464 standard therefore requires an illuminance level of at least 30 lx or 50 lx* on ceilings and at least 50 lx or 75 lx* on walls. In fact, these levels ought to be significantly exceeded and should be at least 175 lx on walls. * in offices, class rooms, hospitals

**Illuminance maintenance value Ēm**
The illuminance maintenance value Ēm is the value below which the illuminance level must not fall in the visual task area.

**Installed load**
The total installed load (Pn) in kW of a lighting solution before consideration of lighting management.
Abbreviation: Pn
Unit: kW

**ISO 14025**
The ISO 14025 is a norm, which regulates how product declarations of the type III have to be created.

**LCA**
Life-cycle assessment (LCA) is an analysis of the environmental aspects and potential impacts associated with a product, process, or service. (LEED® user)

**LED**
A light-emitting diode (LED) is an semiconductor component that emits light when a current flows through it. LEDs typically have a long service life (e.g. 50 000 hours at 70 % luminous flux), a compact size, a high luminous efficiency (lm/W) and a good to excellent colour rendering index (CRI).

**LEED®**
Leadership in Energy & Environmental Design (LEED®) is a program that provides third-party verification of green buildings. Building projects satisfy prerequisites and earn points to achieve different levels of certification. Prerequisites and credits differ for each rating system, and teams choose the best fit for the project. (www.usgbc.org)

**LEED® 2009**
Launched in April 2009, LEED® 2009, sometimes referred to as LEED® v3, is the current version of the LEED® Green Building Certification System. LEED® 2009 is built on the fundamental structure of the previous rating systems but makes sure new technology and urgent priorities are addressed. (www.usgbc.org)

**LEED® AP**
A LEED® Accredited Professional (AP) has advanced knowledge in green building as well as expertise in a particular LEED® rating system. A LEED® AP has an understanding of the LEED® rating system and the ability to facilitate the certification process. Therefore the USGBC recommends that at least 1 principal participant of the project team should be a LEED® AP.

**LEED® GA**
A LEED® Green Associate (GA) credential demonstrates a solid, current understanding of green building principles and practices.

**LEED® Main categories**
In 5 main categories points for adopting specified building practices, materials or products are offered:
SS = SUSTAINABLE SITES
WE = WATER EFFICIENCY
EA = ENERGY & ATMOSPHERE
MR = MATERIALS & RESOURCES
IEQ = INDOOR ENVIRONMENTAL QUALITY

In addition there are two bonus credit categories and one pilot credit library:
ID = INNOVATION IN DESIGN
RP = REGIONAL PRIORITY CREDIT
PC = PILOT CREDIT
(www.usgbc.org)

**LEED® Pilot Credit Library**
The LEED® Pilot Credit Library is a rating system development tool designed to test new and revised LEED® credit language, alternative compliance paths, and new or innovative green building technologies and concepts. (www.usgbc.org)

**LEED® Points**
Within each of the LEED® credit categories, projects must satisfy prerequisites and earn points. The number of points the project earns determines its level of LEED® certification:
Certified 40 to 49 points
Silver 50 to 59 points
Gold 60 to 79 points
Platinum 80 to 110 points
(www.usgbc.org)

**LEED® Prerequisites**
LEED® prerequisites are the baseline requirements that must be in place for a building to be considered for LEED® certification.

**LEED® Rating systems**
Rating systems are groups of requirements for projects that want to achieve LEED® certification. Each group is geared towards the unique needs of a project or building type.
(www.usgbc.org)

**Lighting control**
By lighting controls individuals can enhance their comfort, productivity, satisfaction, and overall well being over the lighting levels in their workspaces. Lighting controls can also increase the energy efficiency of a lighting system by encouraging occupants to use task lighting focused on their activities and work area rather than increasing the general ambient lighting level. (LEED® user)

**Lighting Management**
Lighting management provides added value by saving energy, by using daylight, by having the possibility of changing colour temperatures and by integrating emergency lighting.

**Light pollution**
Light pollution, also known as photopollution or luminous pollution, is excessive, misdirected, or obtrusive artificial light. Light pollution is becoming an increasingly serious problem that affects the aesthetic appearance of nocturnal landscapes as well as creatures that are active at night, such as insects and migrating birds. (WIKIPEDIA and Dr. Thomas Posch, International Dark Sky Association)

**Lighting Power Density**
Lighting Power Density (LPD) represents the load of a lighting equipment in a defined area, or the watts per square foot of the lighting equipment. LPD is a lighting power requirement defined in North America by the American National Standards Institute (ANSI) in the ANSI / ASHRAE / IESNA 90.1- 2007 Section 9
Abbreviation: LPD
Unit: W/m²
Unit: W/ft²
Conversion: (W/ft²) / 0.093 = W/m²

**Lighting environmental zones**
Environmental zones promise to reduce overall light pollution by helping to limit, or in some cases eliminate, light wastage.
The Illuminating Engineering Society of North America (IESNA) has adopted the concept of environmental zones from the The Commission Internationale de l'Eclairage (CIE) and recommends their use in developing new outdoor lighting (IESNA 1999):

E1: Areas with intrinsically dark landscapes
National parks or residential areas with strict limits on light trespass
Roads usually unlitE2: Areas of low ambient brightness
Outer urban or rural residential areas
E3: Areas of medium ambient brightness
Urban residential areas
E4: Areas of high ambient brightness
Urban areas, residential and commercial with high levels of night time activity
(Source: IESNA 1999)

# Part IV : Glossary

**Light trespass**
Light trespass occurs when unwanted light enters one's property, for instance, by shining over a neighbour's fence. A common light trespass problem occurs when a strong light enters the window of one's home from the outside, causing problems such as sleep deprivation or the blocking of an evening view. (WIKIPEDIA)

**Look down sensor**
A look down sensor is an indoor sensor measuring the amount of light on a horizontal level. Direct incident light from free-standing luminaires, or reflections on reflective surfaces such as window sills made of metal also interfere with the sensor. Therefore the use of a look down sensor is only recommended in the case of movable luminaires and low detection heights such as free-standing luminaires, for instance.

**Look out sensor**
A look out sensor is an indoor sensor measuring incident light through the window. The system is therefore unaffected by reflections and reflected glare.

**Luminous intensity**
The luminous intensity describes the quantity of light that is radiated in a particular direction. This is a useful measurement for directive lighting elements such as reflectors. It is represented by the luminous intensity distribution curve (LDC).
Abbreviation: I
Unit: cd Candela

**Luminous flux**
The luminous flux describes the quantity of light emitted by a light source. The luminous efficiency is the ratio of the luminous flux to the electrical power consumed (lm/W). It is a measure of a light source' s economic efficiency.
Abbreviation: $\Phi$ Phi
Unit: lm Lumen

**Luminous efficiency**
The ratio of luminous flux to the required electric power gives the luminous efficiency [lm/W]. The system luminous efficiency also takes the ballasts' losses into account. Luminous efficiency describes the efficiency of a light source or a luminaire and is now one of the most important performance characteristics of all.

**Luminaire**
A luminaire is an electrical device used to create artificial light.

**Luminance**
Luminance is the only basic lighting parameter that is perceived by the eye. It specifies the brightness of a surface and is essentially dependent on its reflectance (finish and colour).
Abbreviation: L
Unit: cd/m²

**Maintenance Factor**
The maintenance factor (MF) multiplied by the initial illuminance value gives the illuminance maintenance value. The maintenance factor can be determined individually, and takes the installation's reduction in luminous flux caused by soiling and ageing of lamps, luminaires and room surfaces into account. EN 12464 specifies that the lighting designer must document the maintenance factor and maintenance schedule.

**Multi-Occupant Space**
Conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc. Individuals using these spaces share the lighting and temperature controls and they should have, at a minimum, a separate zone with accessible thermostat and an air-flow control. Group multi-occupant spaces do not include open office plans that contain individual workstations. (LEED® user)

**Presence Detectors**
Presence detectors make sure that light is only switched on when it is actually needed. Presence detectors reduce the operating hours of luminaires adjusted precisely to the times of use.

**Regularly occupied Space**
Regularly occupied spaces (ROS) are areas where one or more individuals normally spend time (more than one hour per person per day on average) seated or standing as they work, study, or perform other focused activities inside a building. (LEED® user)

**Room-related lighting concepts**
Room-related lighting concepts take neither individual task areas nor different visual tasks into account. They are based on the most demanding task performed in the room. The position of the workstation is not defined, the entire room disposes of a uniform lighting quality.

**Service life (Average rated life)**
The number of hours at which half of a large group of light source samples fail under standard test conditions. For LED is determined taking the drop in luminous flux into account (e.g. 50 000 hours at 70 % luminous flux). As there is no standardised procedure in this respect, every manufacturer specifies the service life of its LEDs individually. Usually, a luminous flux level of 70 % is assumed.

**Simulation (LEED®)**
A computer based building model running with software approved by LEED® to calculate the overall energy consumption of the building. A Simulation is normally used for the whole building area method.

**Space By Space Method**
The space by space method is one of the two primary calculation methods allowed under LEED®. It uses a defined list of many possible space types within a building the associated watts per square foot allowance. For example, ANSI/ASHRAE/IESNA Standard 90.1-2007 allows the Emergency Space of a hospital to be designed for 2.7 watts per square foot, but the Recovery areas of a hospital would be allowed 0.8 watts per square foot. (WIKIPEDIA)

**Spatial illumination**
In order to enhance people' s and objects' recognisability in a room, basic requirements are placed on cylindrical illuminance $\bar{E}Z$ and modelling. Hence, $\bar{E}Z$ should be as high as 150 lx in rooms used for communication. Modelling is the ratio between cylindrical and horizontal illuminance at a specific point and should be between 0.3 and 0.6.

**Task area related lighting concepts**
Task area related lighting concepts are a customised tool to fully exploit the additional options provided. The quantity and quality of light can now be specified exactly. At the same time they offer financial scope that can be used to improve lighting comfort and enhance the effect of a room.

**UGRL**
Unified Glare Rating Limit (UGRL) is the upper limit for direct glare. The UGRL value calculated in the design process must lie below this.
≤ 16 Technical drawing
≤ 19 Reading, writing, training, meetings, computer-based work
≤ 22 Craft and light industries
≤ 25 Heavy industry
≤ 28 Railway platforms, foyers

**UO**
Uniformity (UO) is the ratio between the lowest (Emin) and the mean illuminance level (Ē) in the area to be evaluated. The result is a minimum level as defined e.g. in the EN 12464-1.

**USGBC**
The U.S. Green Building Council (USGBC) is a non-profit organization committed to a prosperous and sustainable future through cost-efficient and energy-saving green buildings. (www.usgbc.org)

**Visual task area**
Illuminance levels are specified for specific visual tasks and are designed for the area in which these may take place. If the exact location is unknown, the room as a whole or a defined area of the workstation is used for specification. The visual task area may be a horizontal, vertical or inclined plane.

**Whole Building Area Method**
The whole building method is one of the two primary calculation methods allowed under LEED®. It uses a defined list of many possible whole building types and the associated watts per square foot allowance. For example, ANSI/ASHRAE/IESNA Standard 90.1-2007 allows manufacturing facilities 1.3 watts per square foot, while parking garages are only allowed 0.3 watts per square foot. Normally this method is used in combination with a building energy simulation. (WIKIPEDIA)

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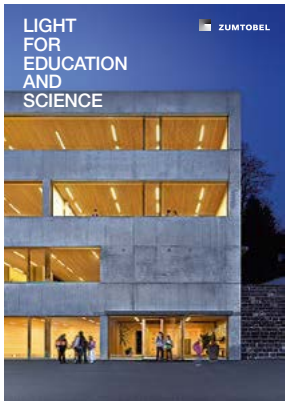

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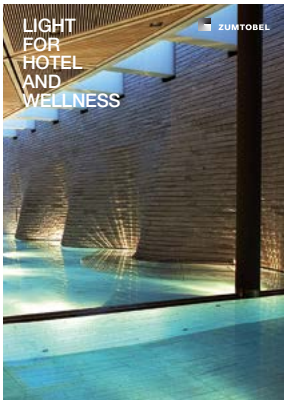

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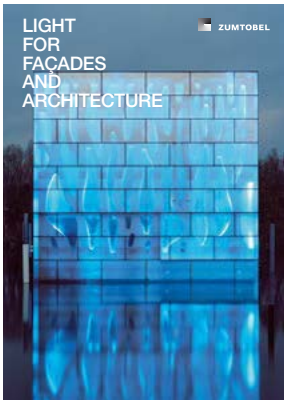

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- Offices and Communication
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We provide unique customer benefits by integrating technology, design, emotion and energy efficiency. Under the Humanergy Balance concept, we combine the best possible ergonomic lighting quality for an individual's well-being with the responsible use of energy resources. The company's own sales organisations in twenty countries, as well as commercial agencies in fifty other countries, form an international network of experts and design partners providing professional lighting consulting, design assistance and comprehensive services.

### Lighting and sustainability

In line with our corporate philosophy *"We want to use light to create worlds of experience, make work easier and improve communications and safety while remaining fully aware of our responsibility to the environment"*, Zumtobel offers energy-efficient high-quality products, while at the same time making sure that our production processes based on the considerate use of resources are environmentally compatible.

**zumtobel.com/sustainability**

5
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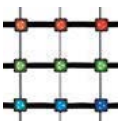

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