# THE EUROPEAN
# GREEN BUILDING PROGRAMME

## Technical Module on Lighting

**Contents**


1. Introduction ........................................................................................................ 1
2. Inventory of systems ........................................................................................ 2
3. Assessment of energy saving technical measures ............................................. 3
4. Action Plan ........................................................................................................ 7
5. Reporting ........................................................................................................... 7

Annex ..................................................................................................................... 8

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# 1. Introduction

By becoming a GreenBuilding Partner, your company can demonstrate its commitment to significantly reduce the energy consumption in its non-residential buildings which are participating in this effort.

In the following, you may find assistance for your process of assessing and realising the energy efficiency potentials in the area of Lighting.[1]

**Energy Saving Potential**

Lighting has a substantial impact on the energy consumption in non-residential buildings, accounting for up to 1/3 of the electricity used in some office buildings for example. With the help of modern technology, major energy savings can be achieved. Depending on the existing inventory and set-up of the lighting systems in your non-residential buildings, energy savings between 30% and 50% may be achieved by improving the existing lighting systems.

**Cost Effectiveness**

A GreenBuilding partner must achieve an Internal Rate of Return (IRR) of at least 20% for his energy efficiency investments, calculated over a 15-year period.[2] The IRR of investments in energy efficient lighting systems may significantly exceed 20%. Furthermore, investments in your lighting systems are not only very profitable but may also improve your lighting quality. Additionally, by reconsidering your lighting concept, you can make sure to meet both national and European lighting regulations[3] and standards[4] in one go.

An upgrade or re-design of your lighting systems should be performed if the cost of these measures is repaid well by the associated savings (IRR > 20%) and the lighting quality will be maintained or improved.

This document is subsidiary to the GreenBuilding "Partner Guidelines". It defines what a GreenBuilding Partner Action Plan should cover, if the Partner company's commitment includes the area of lighting. In particular, it explains what a Partner does for each of the following steps:

- **Inventory** of lighting components and system functioning
- **Assessment** of the applicability of possible energy savings measures

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1 For more detailed information please visit the EU-GreenLight website: <http://www.eu-greenlight.org/What-to-do/what.htm>

2 For the calculation of the IRR, see the GreenBuilding financing module.

3 Please note that implementation of the European directives 89/654/EEC (Council Directive concerning the minimum safety and health requirements for the workplace) and 90/270/EEC (Council Directive on the minimum safety and health requirements for work with display screen equipment) has lead to several national regulations concerning lighting. Please do consider these national regulations.

4 Such as: CEN/TC 169 (light and lighting), prEN 12464 (Lighting of work places), EN 1838 (lighting applications; emergency lighting).

- **Action Plan**, which defines what the Partner has decided to do to reduce operating costs by improving energy efficiency
- **Report** on the results of implementing the Action Plan.

Note that documents relating to the Inventory and the Assessment are in house, confidential documents, while the Action Plan and the Report are reported to GreenBuilding.

## 2. Inventory of systems

As a first step towards identifying applicable energy savings measures, a GB Partner should establish an inventory of the lighting equipment and major operating parameters. The Inventory is established in 3 phases.

**System Description**

As the luminaires used in a building can be large in number with varying specifications, documenting and assembling the data should be focused on the three to four largest groups of lighting systems with the largest power consumption. A preliminary investigation is recommended to identify these systems first. Reducing the diversity of lighting systems may well be a result of an evaluation of economic efficiency.

**Measurement of parameters**

The description is performed by consulting company records and / or a survey in order to assemble the following data:

a) Brief data about the examined building,
b) General data about the lighting systems,
c) Specific information about lamps (type, quantity, lifetime, specific energy use etc.)
d) Specific information about connecting devices and ballasts (classes, losses, etc.)
e) Information concerning optical issues (distribution of light, reflectors, etc.)
f) Specific information about control systems and devices
g) Information on average hours of operation

The lighting electricity consumption usually is not measured separately. Considering the amount of luminaires, a detailed measure of every single appliance is not applicable. The data for energy use for lamps and ballasts should be retrieved from manufacturers' catalogues or nameplates of the components. If so, measurement can be limited to an investigation of

- lighting quantity (in lux)
- operation hours and -modes

The collected data should enable you to calculate the total lighting power installed [in **kW**] and the lighting electricity use per year [in **kWh/year**] for your building. You may use the documents in the annex for an approximation of the lighting full load hours and power consumption for lighting in your premises.

The Collection of these data could be carried out by qualified in house engineering staff or by a third party, e.g. a qualified consultant or a GreenBuilding Endorser.

**Indicators of system performance**

On the basis of the estimated energy consumption for lighting, the energy efficiency of the lighting systems can be assessed with the following general indicators.

| |
|---|
| 1. Installed lighting power per area [**W/m²**] in relation to required lighting quantity [in **lux**][5] |
| 2. Electricity consumption for lighting per area [in **kWh/m²a**][6] |
| 3. Full load hours of lighting [in **h/a**][7] |

Considering the total lighting power installed or the lighting electricity use per year provides information only through comparison of the baseline setting and the post-installation setting, the use of the indicators 1-3 allows a direct benchmarking of the lighting system. Please note that the performance indicators have different focuses, depending on the occupancy of the building.[8]

## 3. Assessment of energy saving technical measures

The following situations indicate potential for energy savings in the field of lighting: rooms or areas with long operating hours, absence of control systems, intermittent occupancy pattern (good conditions for occupancy sensors), low-efficiency lighting technologies which can easily be replaced by more efficient products, no maintenance plan, etc.

- The energy efficiency of your lighting systems can be improved in the following steps: Selection of energy efficient lamps
- Selection of energy efficient connecting devices (ballasts)
- Improvement of luminaires
- Energy saving lighting control systems
- Introduction / improvement of maintenance procedures
- Design aspects

Energy savings result from finding an optimum combination[9] of different types of lamps with their specific supporting hardware (such as luminaires and ballasts) and the way the lighting system is applied in everyday use:[10]

5 See Annex 3 for details; even if the data given in the Annex would not be available for other countries these data may serve as a good starting point for benchmarking the lighting system.
6 See Annex 4 for details.
7 See Annex 5 for details.
8 A tool for the realisation of a lighting survey in your premises is the Green Light Lighting Survey Form which can be downloaded at http://www.eu-greenlight.org/What-to-do/what1.htm
9 Finding an optimum combination has to be done by an expert.

## Lamps

**Incandescent Lamps** have been the most common lamps in everyday life for more than 100 years. A filament is heated by an electric current to produce light. These lamps are the most inefficient type of lamps as up to 95% of the electricity is converted into heat. Incandescent lamps have a relatively short life-span (average value approximately 1000 h) while offering low initial cost and optimal colour rendering. *Halogen lamps* (as a special class of incandescent lamps) are more efficient (+20 - +50% compared to ordinary lamps).

**Fluorescent Lamps** consist of a sealed glass tube, white-coated on the inside and filled with an inert gas and a small quantity of mercury. The most common types are fluorescent tubes and compact fluorescent lamps. All fluorescent lamps require ballasts for starting and controlling the lighting process. The efficiency of fluorescent lamps exceeds that of incandescent lamps by factor five to factor eight, depending on the lighting system. Fluorescent lamps require higher investment (up to factor 15) but the total number of operating hours (life span) is also 10-15 times longer. Fluorescent lamps offer a slightly inferior colour rendering. **Fluorescent lamps are well suited for use in office and commercial areas**. Note that there are great differences in efficiency within this group of lamps (e.g. as a result of differences in tube diameter modern T5 lamps are much more efficient than older T8/T16 models). As a result, replacement of old fluorescent lamps by more efficient modern state-of-the-art technology is cost-effective in most cases.

**Other Discharge Lamps** are the most efficient option of lighting. There are many different types of lamps in this group, varying strongly in matters of cost, life-span, colour and quality of light. Therefore it is recommended to involve a lighting expert into the planning. Other discharge lamps are normally limited to special purposes such as lighting of production halls (e.g. with mercury vapour lamps), street lighting (e.g. with sodium vapour lamps) etc.[11]. The efficiency of these lamps normally outperforms the efficiency of ordinary lamps by more than factor 10. All discharge lamps require ballasts.

## Connecting Devices

The ballast is a connecting device between the power supply and one or more fluorescent or other discharge lamps. It serves mainly to limit the current to the required value, transforming the supply voltage and providing the necessary conditions for starting the lamp(s). As long as the lamps are operating ballasts

[10] A more detailed description can be found on the EU Green Light website <http://www.eu-greenlight.org/ >.

[11] More details can be found on the GreenLight website: http://www.eu-greenlight.org/What-to-do/what1.htm

consume electricity, too. One can distinguish mainly between magnetic and electronic ballasts. Electronic ballasts are much more efficient than magnetic ones. With EU-Directive 2000/55/EC on energy efficiency requirements for ballasts for fluorescent lighting, some classes of magnetic ballasts have been or have to be phased out of the market.[12] An overview over the benefits of electronic ballasts is given below:

- Electronic ballasts have relatively low losses. Replacing inefficient magnetic ballasts by their electronic counterparts, the saving potential is up to 25%.
- fluorescent lamps have a higher efficiency when operated with electronic ballasts, producing around 10-20% more light.
- Electronic ballasts impose softer starting conditions on the lamps. This leads to longer lamp life and hence reduced maintenance costs.
- Electronic ballasts can operate up to four lamps, their magnetic counterparts can operate only one to two lamps.
- Fluorescent lamps on magnetic ballasts flicker 100 times a second whereas on electronic ballasts they turn on and off more than 40.000 times a second, invisible to the human eye.

Ballasts may but must not be integrated into luminaires. Integral (or self-ballasted) lamps are compact fluorescent lamps with built-in ballast to fit a standard incandescent lamp holder.

### Luminaires

Modern luminaire design has resulted in improvements in efficiency compared with older luminaires. Whereas most basic white painted reflectors have a reflectance of about 70%, aluminium reflector reflectance can be up to 95%. Refurbishment of older installations using modern equipment can often result in substantial energy savings in addition to improved visual conditions (e.g. elimination of bright reflections from computer screen). Many modern luminaires contain carefully designed reflector systems to direct the light from the lamps in the required direction. These allow for fewer lamps or luminaires to be used to produce a given luminance. It may be possible to improve older, less efficient luminaires by replacing diffusers or prismatic panels with reflector systems. Alternatively, reflectors may be added to the luminaire, retaining the existing light control components. In some cases this can be accompanied by a reduction in the number of lamps to produce the same luminance, with consequential saving (energy savings from 20 up to 50% are estimated to be achievable through improvements in reflectors and shielding).

### Control Systems

Appropriate lighting controls can yield substantial cost-effective lighting energy savings, reducing the power consumption for lighting in offices by 30% to 50%. Simple payback can often be achieved within 2-4 years.

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[12] Ballasts are divided into efficiency classes. For definition of classes and implications of a. m. EU directive see <http://www.celma.org/pdf_files/BallastGuideEN200212.pdf> for details.

Lighting controls are devices that regulate the operation of the lighting system in response to an external signal (manual contact, occupancy, clock, light level). Energy-efficient control systems include:

- Localised manual switch
- Occupancy linking control
- Time scheduling control
- Day lighting responsive control

The impact on automatic or manual switching of lamps can be typically neglected. This effect is minimal and is more than overcompensated by the associated energy savings. Choosing a lighting system with high-quality electronic ballast (see above) will reduce this effect to insignificance.

Lighting control systems can combine a number of the strategies outlined here. Presence detectors which are fitted within each luminaire or a small group of luminaires can also include daylight sensing. This type of integrally fitted control may solve a problem of specially shaped spaces or where other linked control is difficult.

It is important that the permanent occupants of a space are aware of the existence of the lighting control system, how it works and how they can interact with it. This is particularly important in retrofit installations, where resistance to the introduction of controls can be produced if the occupants are not consulted and fully informed about the new system.

**Maintenance**

With the passing of time, luminaries and room surfaces get dirty. In addition the light output from lamps decreases as they age. The luminance from a lighting installation therefore decreases. Lack of maintenance means that a lighting installation is not performing at its best, energy and money are being wasted. Many installations are poorly maintained and simple cleaning of lamps and luminaires can often improve the lighting of the space. Maintenance requirements should be considered when installations are designed. Luminaires that are easily accessible are more likely to be cleaned regularly and have their lamps replaced. Some luminaires are designed specifically to reduce the need for maintenance, e.g. self-ventilated luminaries resist the accumulation of dirt on optical surfaces.

**Design Aspects & Energy Managment**

Improvements in energy efficiency and reductions in costs can be obtained by properly sizing the lighting system and placing the light sources, by introducing lighting controls and by utilising daylight. This can be achieved by a system of localised lighting, where luminaires are related to the work stations. An alternative approach is to install a uniform array of luminaires and then to adjust the light output of each individual luminaire to match the requirements of the area it lights.

Daylight within a building has a major effect on the appearance of the space, and can have considerable energy efficiency implications. Building occupants generally prefer a well-daylight space, provided that problems such as glare and overheating are avoided. To utilise fully the benefits of daylight in the interior, it is important to ensure that the electric lighting is dimmed or turned off whenever daylight provides adequate illumination. This is achieved by the use of appropriate lighting controls, and may involve some degree of automation.

Additionally, efficient lighting has positive side effects: By reducing electricity consumption for lighting, the thermal load (from lighting) is reduced simultaneously. In buildings with air conditioning, power consumption for cooling will decrease.

Improving the lighting quality at the workplace will typically improve the productivity, too.

## 4. Action Plan

Your company's Action Plan for lighting systems, as proposed in Annex 1, should indicate:

- the measures you have decided to implement;
- the time scale for their implementation;
- the expected energy savings
- the reasons for excluding the other measures.

The Action Plan for lighting systems is presented to GreenBuilding. After approval of all relevant action plans your organisation will be recognised as a GreenBuilding Partner.

## 5. Reporting

The Report to GreenBuilding specifies the results of carrying out the Action Plan. The reporting form in Annex 2 should be used for this purpose. The two left hand columns are copied from the Partner's Action Plan.

# Annex

## Annex 1: Action Plan for Lighting Systems

| Energy Savings Measures | Feasibility (1) | Specific Actions (2) | % Covered (3) | Time table (4) | Expected savings (5) (MWh/year) |
|---|---|---|---|---|---|
| ***Selection of energy efficient lamps*** | | | | | |
| Fluorescent lamps replacing incandescent lamps | | | | | |
| Other discharge lamps replacing incandescent lamps | | | | | |
| Fluorescent lamps replacing inefficient fluorescent lamps | | | | | |
| ***Connecting devices*** | | | | | |
| Electronic ballasts replacing magnetic ballasts | | | | | |
| | | | | | |
| ***Improvement of luminaires*** | | | | | |
| Aluminium reflectors replacing white painted reflectors | | | | | |
| Introduction of luminaires with light direction, reducing the number of luminaires needed | | | | | |
| Improving older luminaires by replacing diffusers or prismatic panels with reflector systems | | | | | |
| | | | | | |
| ***Control Systems*** | | | | | |
| Introduction of occupancy linking controls | | | | | |
| Introduction of time scheduling controls | | | | | |
| Introduction of daylight responsive controls | | | | | |
| | | | | | |
| ***Maintenance*** | | | | | |
| Regular cleaning of luminaires | | | | | |
| Replacement of aged lamps with insufficient luminace | | | | | |
| | | | | | |
| ***Design*** | | | | | |
| ‘Localized lighting’, e.g. of work places | | | | | |
| Improved daylight utilization | | | | | |
| | | | | | |

(1) **Feasibility.** Indicate obstacles to application by one or more of the following codes:
- NA Not applicable for technical reasons
- NP Not profitable
- NC Not considered, because evaluation would be too expensive

If this field is left blank, the measure is considered to be both applicable and profitable.

(2) **Specific Actions.** Several specific actions may be adopted to implement one energy saving measure. For instance, specify lamp type by which incandecent or inefficient fluorescent lamps have been replaced (e.g. T5 is replacing T16 lamp-type)

(3) **% Covered.** If the Partner's proposed commitment covers several lighting systems, this column should be used to indicate the proportion of the systems for which the specific actions will be implemented. This can be evaluated according to the most convenient indicator: number of systems; power; energy consumption. Specify the indicator used, as by: "%"; "%kW", %kWh"

(4) **Time table. T**ime scale within which the action plan will be implemented. This might be a specific period or date, or might depend on some other action, for instance "When luminaire is replaced", or "When floor is refurbished".

(5) **Expected savings** in MWh/year. This will often be an estimate, based on generally accepted practice.

## Annex 2: Reporting Form for Lighting Systems

| Approved Action Plan | | Annual report for year 20xx |
|---|---|---|
| Actions decided upon to implement energy savings measures | Agreed upon time scale for action | Progress on action, as percentage achieved, and comments where appropriate (1) |
| ***Selection of energy efficient product*** | | |
| Action 1 | | |
| Action 2 | | |
| … | | |
| ***Selection of energy efficient devices*** | | |
| … | | |
| ***user specific saving potentials*** | | |
| … | | |

(1) The **percentage achieved** could refer to an indicator such as the proportion of systems in the scope of the Action Plan for which the specific action has been completed.

Partners may find it useful to produce the following Synthesis of the results of commitment. They are invited (but not required) to submit the Synthesis to GreenBuilding.

| Annual report synthesis | | |
|---|---|---|
| | Since commitment | This year |
| Percentage of actions in Action Plan completed | | |
| Estimated total investment for Plan (T€) (1) | | |
| Estimated change in non energy O&M costs (T€) (1) | | |
| Estimated energy savings (MWh) (2) | | |
| Number of workplaces | | |
| Indicative energy related lighting costs per workplace (Euros/workplace) (3) | | |

(1) **Investment and O&M** costs are estimates of changes in costs, with respect to what would have been spent without Partner commitment to the Challenge. This may be, for instance, additional investment for higher performance equipment, or increase/decrease in maintenance costs.

(2) **Energy savings** are estimated by calculating the implementation of the measures as well as increasing/decreasing number of equipments.

(3) **Energy related lighting costs per workplace** is a relevant indicator of the efficient use of IT

## Annex 3: Luminance and Installed lighting loads per area

### Performance indicator No. 1

| nominal luminance values | guiding values for lighting loads | |
|---|---|---|
| | standard | advanced standard |
| 50 lx | 3.2 W /$m^2$ | 2.5 W /$m^2$ |
| 100 lx | 4.5 W /$m^2$ | 3.5 W /$m^2$ |
| 300 lx | 10.0 W /$m^2$ | 7.5 W /$m^2$ |
| 500 lx | 15.0 W /$m^2$ | 11.0 W /$m^2$ |
| 750 lx | 20.0 W /$m^2$ | 16.0 W /$m^2$ |
| 1.000 lx | 25.0 W /$m^2$ | 21.0 W /$m^2$ |

Table 1: Simple and improved guiding values for lighting loads per area connected with nominal luminance values.

The goal should be to achieve the respective luminance with the lighting load of the right hand column.[13]

[13] Source: „Institut für Wohnen und Umwelt“ by order of Ministry for Environment and Agriculture of the federal state Hesse (Germany): *Leitfaden Elektrische Energie im Hochbau (Guideline electric energy in building construction)*, Juli 2000, S. 28.

## Annex 4: Electricity demand and boundary values / target values for electricity demand per area

### Performance Indicator No. 2

| occupancy | service life [h/a] | nominal luminance values [Lux] | use of daylight* | frequency of use | boundary value [kWh/m²a] | target value [kWh/m²a] |
|---|---|---|---|---|---|---|
| Office | 2.750 | 300 | predominantly | continuous | 10 | 3,5 |
| | | 500 | partially | continuous | 22 | 12 |
| | | 500 | not used | continuous | 40 | 25 |
| open-plan office | | 750 | not used | continuous | 55 | 35 |
| Classroom | 2.000 | 300 | predominantly | frequent | 7,5 | 3 |
| | | 500 | partially | frequent | 15 | 8 |
| | | 500 | not used | frequent | 30 | 20 |
| Sports hall | 2.000 | 300 | partially | frequent | 10 | 5,5 |
| Sales room | 3.600 | 300 | not used | continuous | 35 | 25 |
| | | 300+**) 5W/m² | not used | continuous | 55 | 42 |
| Restaurant | 3.600 | 200 | predominantly | frequent | 9 | 6 |
| | | 200 | partially | frequent | 13 | 7 |
| | | 200 | not used | frequent | 16 | 11 |
| Hotel room | 2.000 | 200 | predominantly | | 3,5 | 2 |
| Hospital | 8.760 | 200 | predominantly | | 10 | 5 |
| Street lighting | 2.750 | 100 | predominantly | frequent | 4,5 | 1,8 |
| | | 100 | not used | frequent | 12 | 8 |
| Storehouse | 2.750 | 100 | not used | minor | 2,2 | 1,0 |
| | | 100 | not used | frequent | 4,5 | 2,5 |
| | | 200 | not used | continuous | 18 | 11 |
| Garage (i.e. repair shop) | 2.750 | 300 | predominantly | continuous | 10 | 3,5 |
| | | 300 | partially | continuous | 15 | 8 |
| multi-storey car park | 2.750 **) | 100 | not used | frequent | 12 | 7,5 |
| | 6.500***) | 100 | not used | frequent | 28 | 18 |

* "predominantly illuminated" means: distance to window < 5 m and proportion (surface window / surface floor > 30%)

** private car park in office buildings *** public car park

Table 2: Target values and boundary values of the electricity demand for lighting in Germany in selected non-residential situations.[14]

[14] Source: „Institut für Wohnen und Umwelt" by order of Ministry for Environment and Agriculture of the federal state Hesse (Germany): *Leitfaden Elektrische Energie im Hochbau (Guideline electric energy in building construction)*, Juli 2000, S. 27.

## Annex 5: Simple and improved guiding values for full load lighting hours

### Performance indicator No. 3

| occupancy | service life [h/a] | nominal luminance values [Lux] | use of daylight* | frequency of use | guideline value for full load-illuminance ordinary [h/a] | advanced [h/a] |
|---|---|---|---|---|---|---|
| Office | 2.750 | 300 | predominantly | continuous | 1.000 | 500 |
| | | 500 | partially | continuous | 1.500 | 1.100 |
| | | 500 | not used | continuous | 2.750 | 2.400 |
| open-plan office | | 750 | not used | continuous | 2.750 | 2.400 |
| Classroom | 2.000 | 300 | predominantly | frequent | 750 | 400 |
| | | 500 | partially | frequent | 1.000 | 750 |
| | | 500 | not used | frequent | 2.000 | 1.800 |
| Sales room | 3.600 | | | continuous | 3.600 | 3.000 |
| Restaurant | 3.600 | 200 | predominantly | frequent | 2.000 | 1.700 |
| | | 200 | partially | frequent | 3.000 | 2.000 |
| | | 200 | not used | frequent | 3.600 | 3.300 |
| Hotel room | 2.000 | 200 | predominantly | | 500 | 400 |
| Hospital | 8.760 | 200 | predominantly | | 1.500 | 1.000 |
| Street lighting | 2.750 | 100 | predominantly | frequent | 1.000 | 500 |
| | | 100 | not used | frequent | 2.750 | 2.400 |
| Storehouse | 2.750 | | not used | minor | 500 | 300 |
| | | | not used | frequent | 1.000 | 750 |
| | | | not used | continuous | 2.750 | 2.200 |
| Garage (i.e. repair shop) | 2.750 | 300 | predominantly | continuous | 1.000 | 500 |
| | | 300 | partially | continuous | 1.500 | 1.100 |
| multi-storey car park | 2.750 **) | | not used | frequent | 2.750 | 2.200 |
| | 6.500***) | | not used | frequent | 6.500 | 5.500 |

* "predominantly illuminated" means: distance to window < 5 m and proportion (surface window / surface floor > 30%)

** private car park in office buildings

*** public car park

Table 3: Standard and improved guiding values for full load lighting hours.[15]

[15] Source: „Institut für Wohnen und Umwelt" by order of Ministry for Environment and Agriculture of the federal state Hesse (Germany): *Leitfaden Elektrische Energie im Hochbau (Guideline electric energy in building construction)*, Juli 2000, S. 29.