**THE EUROPEAN**
**GREEN BUILDING PROGRAMME**

**Building Envelope Technical Module**

**Contents**

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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 *Building Envelope* systems.

**Energy Saving Potential**:
Heating, cooling and lighting systems have the major impact on the energy consumption in non-residential buildings. This energy demand is due to perform thermal and visual comfort in the indoor environment. The Envelope System strongly affect the energy demand of these active systems, since it regulates heating and cooling loads and daylight availability. With the help of *Building Envelope* renovations and refurbishment major energy savings can be achieved reducing thermal and electric loads. In some cases high performances Envelope Systems can completely avoid the use of active systems. Depending on existing performances of the envelope in your non-residential buildings, energy savings up to 50% may be achieved by means of a wide retrofit action. For instance adopting combined actions on various envelope components or moving to a complete renovation of the facade as far as the construction of a new “second skin”.

**Cost Effectiveness:**
The Internal Rate of Return (IRR) for energy efficiency investments in *Building Envelope* renovations typically ranges between 5% and 25%, depending on the present state of the building envelope and in your premises, cost of work, energy prices and financing frameworks.

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 *Building Envelope*. In particular, it explains what a Partner does for each of the following steps:

- **Inventory** of *Building Envelope* components and system functioning
- **Assessment** of the applicability of possible energy savings measures
- **Action Plan**, which defines what the Partner has decided to do to reduce operating costs by improving energy efficiency
- **Report** of progress on 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 sent to the GREENBUILDING project.

## 2. Inventory of systems

As a first step towards identifying applicable energy savings measures, a GB Partner should establish an inventory of the building envelope components state and major operating parameters as external climate conditions, the time schedule and use of the building and present heating, cooling and lighting systems consumption.
The Inventory is established in 3 phases.

### a. System Description

Sample data to be collected are:

**General information, location and use:**
- Geographical location
- Total (net) floor area and volume,
- Total (net) floor areas heated and cooled by active systems
- Shape and number of storeys
- Orientation and degree of shading (selfshading, shading by other buildings, trees,..)
- Report on external microclimate (presence of vegetation…)
- Operating time schedule and type of use.
- Total energy consumption per year.

**Information on building envelope components :**
Divide building in thermal zones (each zone being a part of the building which is intended to be maintained at the same thermal conditions) and for each zone describe:
Windows: type of glazing and frames, rate of transparent to opaque area and orientations.
External walls: actual or estimated stratification (from building drawings, building codes or engineering estimate), surface area and orientation, degree of thermal capacity (light, medium or high), surface reflectance.
Roof and floor: typology, geometry, stratification and surface reflectance.
Shading systems (if present): typology (internal or external…) and geometry, thermal and optical properties (IR emissivity, reflectance and transmittance).
a)

### b. Measurement of parameters

**Thermal Performances**
The structure and the characteristic of the components of walls are usually hidden in the built envelope. As a consequence engineering estimates of the thermal properties is often necessary (see for example Annex 2 for typical values of glazing and frame thermal transmittance).
Some additional supporting tools are:
- Infrared Thermography can be a very precise and not invasive investigating tool in revealing envelope performances and defects, as thermal bridges. Of course it needs expert technicians and standard procedure.

- When other means are insufficient to achieve reasonably good information, a perforation (about 10 cm diameter) of the external wall may give actual information on the effective structure and state of the envelope.

**Collection of measurements regarding operation of the system.**
- electricity/fuel consumption per year (better per month) for heating active systems
- electricity/fuel consumption per year (better per month) for cooling active systems
- electricity consumption per year (better per month) for lighting active systems
- monthly averaged air temperature
- monthly averaged solar irradiation.
- Hourly data on air temperature and humidity, direction and intensity of wind, direct and diffuse solar irradiation, etc. … are necessary when there is the decision to perform a dynamic simulation of the building in order to assess the effect of certain envelope improvements

### c. Indicators of system performance

The evaluation of the energy performance of a passive system, as the building envelope, is a complex matter that is usually faced in two ways.

In a former approach the evaluation of the building envelope can be related to the evaluation of its single components (for example through prescription of minimal requirements). In this case indicators will describe the performances of single components and will be used to check whether such performances satisfy the requirements.
This approach does not consider the interaction of the different parts of the system.

In fact the global effect on building thermal balance of different envelope systems may be compared only with simplified stationary calculation methods (included in national or European standards) or better with dynamic simulation tools (by expert consultants).
Stationary methods may be sufficient for heating dominated climates, but in cooling dominated seasons and when the building relies mainly on passive systems to achieve comfort conditions, dynamical effects should be considered, as for example daily temperature excursion. By way of this calculations it is possible to estimate the thermal loads associated with different envelope systems to obtain a specified indoor comfort condition.

**Standard and target values of components performances:**
The thermal performances of the following components may be compared to reference values in **Annex 1**.
- Vertical external wall
- Windows or equivalent transparent systems
- Roof
- Ground floor

Reference values for the air tightness performance of the whole building are also included in **Annex 1**.

**Normalised building energy consumption:**
Actually envelope performances indicators are related to thermal loads and "illuminance" demand of the corresponding active systems, but since these data need relatively complex calculation, in the inventory process you may refer to the energy consumption of the corresponding active systems.
The following data may be compared to reference values in **Annex 2**:
- electricity/fuel consumption per year and square meter for heating active systems normalised to temperature difference between external environment and internal set point (this can be done using Heating Degrees Day, HDD, of building location).
- electricity/fuel consumption per year and square meter for cooling active systems.
- electricity consumption per year and square meter for lighting active systems.

**Comfort indexes:**
In evaluating the level of comfort provided by the building, one can use both
- the comfort model originally proposed by Fanger or Predicted Mean Vote (PMV) model,
- and the model which takes into account the adaptation to the prevailing climate of occupants of buildings (especially useful in summer).

In the first model the optimum internal temperature for a building (that is the one at which occupants will report comfort) is correlated exclusively to parameters referring to conditions internal to the building (as air temperature and velocity, mean radiant temperature, air humidity) and to clothing level and metabolic rate of the occupants. Correlation is obtained through tests with occupants of controlled closed rooms and essentially prescribes a narrow band of temperature to be applied uniformly through space and time.

The second model proposes a correlation between comfort temperature for occupants of a building with the temperature of external air (or more precisely with a moving average of external temperatures over a period of time of the order of a few days). The underlying concept is the documented process of adaptation of the body and the metabolic rate to the climate and its variations, and hence the fact that the temperature reported as comfortable by occupants of a building varies with season and location. The correlation is studied in the field, with occupants of real buildings and leads to the conclusion that a wider range of temperatures are considered comfortable than prescribed by the Fanger model, especially during summer.
The adaptive model allows for a easier integration of passive cooling technologies.

Hence we suggest to use the adaptive model to calculate indicators of the comfort level achieved by the building, or to use both the Fanger and Adaptive model in order to deliver a more complete information to the building owner and occupants.

## 3. Assessment of energy saving technical measures

According with the climate situation, present state and operating conditions of your building, the energy efficiency of your envelope systems can be improved with the following measures:

a) Controlling heat loss and heat gains through transparent surfaces by use of suitable choice of frame and glazing.
b) Improve thermal insulation of walls, roofs and floors by use of insulating materials or larger thickness.
c) Improve thermal insulation of the entire building through double skin (opaque or transparent, the former being easier to design and control) facades.
d) Controlling heat gains of transparent surfaces by use of appropriate shading devices.
e) Reduction of air infiltration through the envelope (window and door frames, cracks in walls, joints between different envelope elements).
f) Reduction of room highness and of air thermal stratification (in cooling dominated climates).
g) Design and control of openings to allow ventilation and reduce heating/cooling waste (in case ventilation is mechanical, heat recovery on outgoing air).
h) Controlling heat gains of opaque surfaces by changing their albedo (or reflectance).
i) Use of vegetation to shade surfaces in summer and reduce air temperature around the building via evaporation and transpiration.

Highest energy savings result from finding an optimum combination[1] of different measures.
Thermal performance improvements of single components should be carried out achieving a uniform thermal insulation of the envelope surface in order to avoid thermal bridges.
Thermal insulation is of course fundamental in heating dominated climates, but it brings advantages also in cooling dominated climates, even if better results can be achieved combing insulation with wall thermal capacity and using natural ventilation, and shading systems.

### a. Glazing

First of all transparent systems as part of the building envelope need to have low thermal transmittance values (in combination with adequate light transmittance and light reflectance coefficients, to avoid daylight reduction). Heat Mirror glazing systems (with low emissive coatings) are able to provide thermal insulation values similar to opaque walls, and these solution are already part of Northern Europe standards and practise. Furthermore glazing systems and transparent facades are very important and critic elements of the building envelope because they permit daylight and solar radiation to enter directly in the building. This situation may have the draw back of summer overheating. Advanced glazing, with spectrally selective coatings, are designed to filter the visible spectrum of solar radiation in order to maximise light against heat gains. Even if the most common and flexible form of protection against heat loads driven by solar radiation is the use of shading devices.

Main parameter to select the suitable glazing or window system are:

- ***U thermal transmittance*** the heat power per surface area that is transmitted in/out the building due to temperature difference per each degree [$W/(m^2K)$]. Low values are important to reduce thermal losses in winter season.

1 Finding an optimum combination of measures always requires the involvement of an expert.

- ***g* solar factor** the fraction of incident solar energy which is transmitted to the interior of the building. Low values reduce solar gains.
- **$\tau_v$ visual transmittance** the fraction of incident solar light which is transmitted to the interior of the building. High values enhance the availability of daylight.

Typical values of glazing energy performances are reported in Annex 3.

**Single and double glasses**
Due to the relatively high thermal conductivity of the glass, a window mounting a single pane is a very weak point in the thermal insulation of the building. Moreover a single glass window offers a weak protection against external noises. For these reasons in many cases single glazed window have already been replaced with double glasses. In fact the air cavity between the two panes reduces the thermal transmittance at least of factor two. Moreover the closed cavity allows the use of "soft coatings" with low emissivity and/or selective properties on one of the panes and the use of low conductivity gases in the cavity, that improve considerably glazing performances.

**Heat mirror glazing**
Heat mirror double glazed unit are typically composed by an external clear glass and an internal coated glass with low emissivity properties in the Far InfraRed (FIR) with the coated surface facing to the internal cavity (soft coatings always needs to be protected into the cavity). The function of this kind of coating is to reduce the thermal radiant exchange between the two panes and it achieves a reduction of thermal transmittance of about 40%. An additional reduction of about 20% can be achieved by filling the cavity with a mix of air and a noble gas, such as Argon or Krypton, with a lower thermal conductivity than air.

**Solar control glazing**
Solar control double glazed unit have been often composed by an external reflective coated glass and an internal clear glass. The coated surface face to the external environment or the internal cavity according with the "hard" or "soft" coating deposition process. The function of this kind of coating is to reflect the incoming solar radiation. These glazing may have the drawback of a very low light transmittance and hence visual discomfort to occupants and increased use of electrical lighting.
To reduce heat gains in summer, the most interesting products are hence the "spectrally selective" coated glasses, which reflect most of the Near InfraRed (NIR) solar radiation but are transparent to light.
Selective glazing is most cost-effective (payback less than 10 years) if used in cooling-load-dominated building types, in warmer climates, and with daylighting controls. The degree of selectivity can be related to the LSG (Light to Solar Gain) ratio, $\tau_v / g$. The highest values in selectivity are typically achieved by thin metal "soft coating" which associate low FIR emissivity with low NIR emissivity, that can be cost-effective even in cold climates, since reduces cooling loads during the summer and heat losses during the winter. On the contrary spectrally selective products should not be installed in building with only heating needs.

**Other glazing**
Triple glazing and double windows and frames may also be considered to improve thermal insulation, with the only disadvantage of large thickness. One should

consider that a double glazed unit with low-e coated glass has thermal performance better than a triple glazed unit where the panes are simple clear glass.
A very thin and light transparent insulating technology is the vacuum glazing, even if it is not diffuse in Europe.

**Deposition of solar control and low-e films on existing glazing**
The replacement of glazing may be avoided by use of transparent film that can be applied on the internal (for low-e films) or on the external surface. This solution is of course less expensive that the glazing replacement, but also achieves lower energy performance and shorter lifetime.

**Frames**
Frame thermal transmittance affects the global window thermal transmittance (U value) proportionally to the rate of frame to glazed area of the window. Due to the high thermal conductivity of metal materials, plastic and wooden frames have always better thermal performance, even if new metal frames designed with the thermal break may be a good cost-effective compromise. Typical values of frame thermal transmittance are listed in Annex 3.

**b. Thermal transmittance of opaque surfaces**
Thermal transmittance of opaque surfaces can be reduced by insulation improvements, generally achieved by applying an additional slab or cover of insulating material. Commonly-used types of insulation in building construction include:
Fiberglass, Polyurethane foam, Polystyrene foam, Cellulose insulation and Rock wool.

A vapour barrier is often used in conjunction with insulation because the thermal gradient produced by the insulation may result in condensation which may damage the insulation and/or cause mould growth. The vapour barrier should always go on the warm side of the insulation. That is, on a heated house, the vapour barrier goes between the warm inside and the insulation.

After the identification of the major weak point in the insulation of your building envelope you can consider a list of typical actions to include in the retrofit/renovation plan:
improving vertical wall insulation from the external side
improving vertical wall insulation inflating an insulating material into the wall cavity (if it exists)
- improving vertical wall insulation from the internal side
- improving wall insulation of rooms partially under the ground level from the internal side
- improving wall insulation of rooms partially under the ground level from the external side
- improving ground floor slab insulation (in general of floor and ceiling which confine with unheated zones)
- insulation of walls behind heat radiators
- localize and minimize the effect of thermal bridges in the building envelope

- improving roof insulation by use of radiant barriers (a thin sheet or coating of a highly Infrared reflective material, usually aluminum, applied to one or both sides of a number of substrate materials)
- improving roof insulation by creation of ventilated cavity (this solution combined with radiant barriers in the roof cavity gives more effectiveness)

**c. Thermal mass, its position relatively to insulation, exposition**

This is actually a measure quite important and best applicable for new buildings, but in some cases it can be considered also for retrofits. Thermal mass is able to store energy and thus reduce diurnal and seasonal temperature fluctuations. Not all the mass is active in storing heat during diurnal variations, and the depth of wall interested to this phenomenon can be calculated, e.g. using UNI-CEN norms. Mass also introduces a time lag, that is a time difference between the external surface peak temperature and the internal surface peak temperature. It is thus a very important element of both passive/low energy heating strategies in winter and passive/low energy cooling strategies in summer.

It will influence thermal comfort since it affects both surface temperatures and air temperature (and occupants comfort is determined by both temperatures or their combination –called operative temperature-).

In order to be effective in this action, thermal mass should be in contact with the internal ambient and air. For this reason it is advisable:

- to locate insulation in such a way to allow a certain depth of the wall to be between the insulation and internal air (this can be achieved placing insulation between two layers of masonry or in an external position, close to the outer finishing),
- and to avoid false ceilings and floors, which introduce a layer of air between the mass and internal air and thus insulate to a large extent the internal environment from the action of the mass, making for example impossible the use of night ventilation as a means to passively cool a building.
- Moreover thermal mass which is intended to store energy entering the building in winter through transparent surfaces should have a surface with high absorption values

**d. Double skin facades**

Double skin facades and ventilated facades may be renovation or construction strategies useful for both cooling and heating dominated climates. Since these passive systems strongly influence ventilation, solar heat gains and heat losses, they need to be designed by experts with care to the needs of the specific building.

The secondary skin may be either transparent or opaque, according to heating, cooling and lighting needs of the interior building, and the cavity may be naturally or mechanically ventilated. Transparent double skin facades are quite difficult to design and operate, so extreme care should be taken before choosing this solution.

For example a simple naturally ventilated secondary skin, composed by external water resistant and insulated panels and double windows, may be a major alternative for insulation improvements of external vertical wall.

Double skin facades are also designed to prevent building overheating in hot climates.

The outer skin provides shade for inner opaque roof, walls, rood, and windows, while ventilation in the cavity between the skins removes excesses heat that passes

through the outer skin. The ideal system in this case is a light mass outer skin with a highly reflective outer surface (to reduce the absorption of solar radiation) and low Infrared emittance (low-e) inner surfaces, (to reduce heat exchange among the two layers of the double skin).
The open space created between the primary and secondary skin may also have other advantages as the protection of movable shading systems external to the primary envelope and the use of the natural convection mechanism for air circulation strategies inside and outside the building controlling windows and opening between the building and the cavity.

### e. Shading Devices

Various typologies have been developed to provide effective solar protection.
These can include proper orientation, sizing and location as well as entire wall protections through colonnades, balconies and roof overhangs.

The performance of a window shading device is expressed in terms of *Shading Coefficient* (*S.C.*), defined as the ratio *g_window/g_single glass*, where g is the solar factor.
Different types of shading devices are classified and presented below.

***Movable devices*** have the advantage that they can be controlled manually or through automation, adapting their function to Sun position and other environmental parameters.

**Internal blinds**
Inside blinds are very common window protection schemes. They are very easy to apply but their main effect is to help control lighting level and uniformity. They are generally ineffective in reducing the summer heating load because they block radiation when it is already in the room, but if well designed and combined with spectrally selective glazing in some situations can provide some advantage in solar control and daylighting strategies. This might be the only suitable solution where existing constraints impede the adoption of external shading devices

**External blinds**
They offer the advantage to stop solar radiation before it enters the room (as all external shading devices do) and for this reason are the best effective in solar control strategies.
The blinds should be made on low heat storage materials with reflective finishing, in order to reduce the amount of energy they store and radiate towards the building. It is also advisable to adopt solutions which allow the possibility of air movement between the blinds and the window in order to remove the energy absorbed by the blinds.
Some external blinds may have disadvantages related to maintenance problems or shorter lifetime, but new smart design that resist to high wind speed are available in the market.

**Blinds between two layers of glass**
This devices permit to have the blinds between the 2 glass layers of a window. As internal and external devices they are efficient in blocking both direct and diffuse radiation, as well as allow winter sun since slats can be tilted. They have medium

efficacy in the prevention of undesired solar gains. In fact solar radiation enters in the area in between the two glasses increasing the temperature and allowing, thus, some of the heat to reach the room.
A possible disadvantage is due to vapor condensation that might occur between the two layers of glass in winter.

**Awnings or movable fins**
In order to combine advantages of the fixed devices and the flexibility of the movable ones, awnings and movable fins have been created.

***Permanent devices*** are in general devices designed for a specific building, and are less flexible than movable ones.
Special care has to be taken with fixed shading systems that may reduce solar heat gains in heating dominated seasons or climates. Charts and software specialized for this task are available in order to optimize geometry to the objectives of summer shade without reduction in winter gains

**Overhangs**
They are relatively widespread in hot climates. Their major advantage is that if positioned correctly, they admit direct radiation when the sun is low in winter while blocking it in summer (they block also part of the diffuse radiation).
The main limit of their use is that they are appropriate only for south windows. East and west have low and variable sun angles, thus other (vertical) device have to be applied.
Side effects: they may interfere in the air flows inside as well as outside the building.

**Lightshelves**
A very interesting device that can combine both daylighting and shading is the lightshelve device. The lightshelve is a horizontal reflective surface placed quite high through the window or just outside it. By its appropriate position and by its interaction with overhangs, it shades the main part of the window but it allows light to reach the back of the room by reflection between the shelf and the ceiling.

**Louvres**
Although louvres are most commonly used as permanent devices, they can be used also as movable ones: they appear then as a 'giant' external Venetian blind. If they are movable, they can obviously block summer radiation (being partially effective also for the diffuse radiation) while allowing winter sun.
If they are fixed they may also efficiently contribute to security.
On the other hand they may have the following disadvantages: affect view (especially if they are permanent) and stress the need of artificial lighting. Also (as it may occur with all external devices) their maintenance may be difficult if it is not facilitated by incorporating access to the louvres into the design of the building.
Finally, louvres may modify air movements (either facilitate or hinder natural ventilation) depending of their geometry, their inclination and the environment of the building.
There are different types of louvres. Some types are formed of specially shaped reflective louvres who reject the high-angle direct sun but reflect lower-angle light up to the ceiling (increasing, thus, daylighting and allowing energy savings and comfort).

**f. Air tightness**

The reduction of air infiltration may account up to 20% of energy saving potential in heating dominated climates. Windows and doors are usually week points which need to be well designed, but also walls and joints between building elements.

**g. Reducing room height**

The reduction of room height reduces the effect of air stratification. In winter this geometric characteristic reduces the air volume that has to be heated.

**h. Design and control of openings**

List of measures that can control air ventilation (cross or stack ventilation) reducing waste of energy:

- manual (or automatic) control openings of door and windows.
- design of window openings for ventilation.
- control of openings of door between zones with different set point temperatures.
- use of stairs and atria for stack ventilation

It is possible to separate functions and have openings (or part of the usual openings) specialised for ventilation and protected from intrusion via grids and possibly other openings that are specialised for daylighting, while normal windows and doors continue to be used for view, daylighting etc…

**i. Albedo (or reflectance)**

The surface albedo is a fundamental surface property and one which can be relatively easily altered by simple surface treatment, as the deposition of reflecting paintings on the roof and vertical exposed walls. Albedo (or reflectance) is the ability of a surface to reflect incoming solar radiation and ranges from 0 to 1.

In warm climates vernacular architecture used very often external white surfaces (e.g. “white” villages in the mediterranean area). Traditional “cool” roofs and walls are white because light surfaces absorb less solar radiation than dark ones. Researchers, working with industry, have found that non-white “cool” roofs can be manufactured using colorants (pigments) that reflect the invisible, “near-infrared” radiation that accounts for more than half of the energy in sunlight. “Cool” roofs and walls reflect more of the sun’s radiation than do conventional roofs, lowering temperatures inside buildings, decreasing air-conditioning energy use, and reducing the “urban heat island,” an elevation of air temperatures in urban areas. If the envelope is well insulated and insulation is placed on the outside, heat gains in winter occurs mainly through transparent surfaces, hence high albedo surfaces don’t penalize winter performances.

**j. Use of vegetation**

External vegetation as trees can be used to partially shade the building facade and to reduce external air temperature in summer time. In fact plants absorb solar radiation and produce water evaporation which has cooling effect on the surrounding air.

It is also possible to use the vegetation creating “green” roofs and facades: ground, grass and plants that cover the building providing both insulation and thermal capacity with major effectiveness in cooling dominated climates. Deciduous plants are generally used in order not to reduce heat gains in winter. Metallic grid systems to support climbing plants (e.g ground ivy or Virginia creeper) at about 30-40 cm from the wall are used to provide ventilation and avoid damage to the wall surface by the plants.

## 4. Action Plan

Your company's Action Plan for envelope systems, as proposed in Annex 4, should indicate:

- the measures you have decided to implement;
- the time scale for their implementation;
- the expected energy savings[2]
- the calculation method used to for the determination of the expected energy savings
- the reasons for excluding the other measures.

The Action Plan for envelope 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 5 should be used for this purpose. The two left hand columns are copied from the Partner's Action Plan.

[2] The estimation of expected savings can be calculated considering performances of present heating, cooling and lighting systems, if these are not changing during the reporting period.
In the case are presenting other Action Plan concerning measures to improve the efficiency of your heating, cooling or lighting system, than energy interactions have to be considered.
If you don't have heating, cooling or lighting system. equivalent expected saving can be calculated considering the consumption of a suitable virtual system providing heating, cooling or lighting necessary to achieve the same thermal and visual comfort levels that you can warrant with the envelope improvements that you have planned. For the calculation of virtual consumption typical values of these system performances have to be used according to national market and standards.

# Annex 1: Reference and target values for performances of envelope components

**Table 1.1 Reference values for thermal transmittance of envelope components[3].**

| U values in W/( m²·K) | | | |
|---|---|---|---|
| Components: | **passive and low energy buildings** | ***Severe standards (North & mid EU)*** | ***weak standards (South EU)*** |
| **Outer walls** | U < 0.15 | 0.15 < U < 0.4 | 0.4 < U < 0.65 |
| **Windows/doors** | U < 0.7* | 1.25 < U < 2.5 | 2.5 < U < 3.25 |
| **Roof/ceiling** | U < 0.15 | 0.22 < U < 0.45 | 0.45 < U < 0.9 |
| **Floor/basement** | U < 0.15 | 0.15 < U < 0.4 | 0.4 < U < 0.65 |
| * for transparent elements (0.15 for opaque elements) | | | |

Typical U-values of the building envelopes components have been grouped in “severe” and “weak”, where this distinction generally correspond to Northern/central and Southern European Countries (with some exception as Belgium which belongs to the second). The U-values in the table are not required by the respective national regulations but normally applied to meet the energy performance requirements.

Note that any energy saving due to thermal transmittance improvement are proportional to the component area and the Heating Degree Day: $\mathbf{Q_{saving} \propto (U_{existing} - U_{improved}) \cdot A \cdot HDD}$.
It has to be stressed that uniform U values on the envelope surface have to be recommended in order to have addictive benefits and to avoid thermal bridges or discomfort effects due to internal asymmetric radiant temperatures.

[3] “TEBUC – Towards an European Building” final report. Research funded by DG TREN of the European Commission in the framework of the SAVE Programme (Contract N° C/4.1031/C/00-018/2000 – ENPER-TEBUC) 01/04/2001 - 30/09/2002.

**Table 1.2 Reference values for the air tightness of the whole envelope[4].**

| Air Tightness in $m^3/(hr \cdot m^2)$ at 50 Pa differential pressure | | | |
|---|---|---|---|
| Building types: | ***Best practices**** | ***Normal**** | **Typical**** |
| **Office –** Naturally ventilated | - | 10 | 21.8 |
| **Office –** Air Conditioned / low Energy | 3 | 5 | |
| **Factories/warehouses** | - | 10 | 35.9 |
| **Superstores** | 3 | 5 | |
| **Museums and archival stores** | 1.4 | 2 | |
| **Cold stores** | 0.5 | 1 | |
| **Dwellings** | 5 | 10 | |
| | *Recommendations and Regulations for new buildings in UK | | **UK average |

Specification of maximal values of Air Tightness for various building typologies in UK. It is defined as the air leakage rate ($m^3/hr$) per square metre of building envelope surface when a differential pressure of 50 Pascal is applied[5].

[4] Source: BSRTA “Air Tightness Specification” 10/98, that can be downloaded with other manuals from http://www.bsria.co.uk.
[5] The testing procedure to use is specified in Part L2 - *CIBSE Technical Memorandum 23 (TM23)*.

## Annex 2: Reference and target values for building energy demand

**Table 2.1 Annual delivered energy consumption of good practice and typical offices in United Kingdom[6].**

| **Delivered[7]** energy unit in **kWh/m²/y** | OFFICE TYPE 1 | | OFFICE TYPE 2 | | OFFICE TYPE 3 | | OFFICE TYPE 4 | |
|---|---|---|---|---|---|---|---|---|
| | *Good practice* | *Typical* | *Good practice* | *Typical* | *Good practice* | *Typical* | *Good practice* | *Typical* |
| **heating and hot water - gas or oil** | **79** | **151** | **79** | **151** | **97** | **178** | **107** | **201** |
| **Cooling** | **0** | **0** | **1** | **2** | **14** | **31** | **21** | **41** |
| **Fans, pumps, controls** | **2** | **6** | **4** | **8** | **30** | **60** | **36** | **67** |
| **Humidification** | **0** | **0** | **0** | **0** | **8** | **18** | **12** | **23** |
| **Lighting** | **14** | **23** | **22** | **38** | **27** | **54** | **29** | **60** |
| Office equipment | 12 | 18 | 20 | 27 | 23 | 31 | 23 | 32 |
| Catering, gas | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 9 |
| Cat., electricity | 2 | 3 | 3 | 5 | 5 | 6 | 13 | 15 |
| Other electricity | 3 | 4 | 4 | 5 | 7 | 8 | 13 | 15 |
| Computer room | 0 | 0 | 0 | 0 | 14 | 18 | 87 | 105 |
| **Total gas or oil** | **79** | **151** | **79** | **151** | **97** | **178** | **114** | **210** |
| **Total electricity** | **33** | **54** | **54** | **85** | **128** | **226** | **234** | **358** |

Where office buildings have been grouped in four typologies which are described below:

- **OFFICE TYPE 1: Naturally ventilated cellular.**
  - A simple building, often (but not always) relatively small and sometimes in converted residential accommodation.
  - Typical size ranges from 100 m² to 3000 m²
- **OFFICE TYPE 2: Naturally ventilated open-plan.**
  - Largely open-plan but with some cellular offices and special areas.
  - Typical size ranges from 500 m² to 4000 m².
- **OFFICE TYPE 3: Air-conditioned standard**
  - Largely purpose-built and often speculatively developed.
  - Typical size ranges from 2000 m² to 8000 m².

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[6] Source:*"Energy consumption guide 19"* Building Research Establishment Sustainable Energy Centre (BRESEC) – UK, 2002. http://www.bre.co.uk/brecsu/

[7] Thermal kWh for thermal end-uses and electrical KWh for electrical end-uses.. For conversion to primary energy a factor of 1 can be assumed for thermal energy and a conventional factor of 3 (1 kWh $_e$ = 3 kWh $_t$) or the corresponding national conversion coefficient has to be used for electricity.

- **OFFICE TYPE 4: Air-conditioned prestige**
- A national or regional head office, or technical or administrative centre.
- Typical size ranges from 4000 $m^2$ to 20000 $m^2$.

For heating and cooling consumption a meaningful comparison need normalisation of the values to climate conditions i.e. Heating Degrees Day (HDD) and equivalent Cooling Degrees Day (CDD). Reference heating consumption in Table 2.1 can be divided per U.K. average HDD (Table 2.2) and compared with your specific heating consumption ($kWh/m^2$) divided per the HDD of your location (country averaged values are reported in table 2.2, but if your climate differs significantly from your national average you should use local data). The same procedure can not be easily extended to cooling consumption since the contribute of Solar radiation and dynamical aspects have to be considered.

**Table 2.2 Heating Degrees Day averaged for some EU Countries[8].**

| **Heating Degrees Day for some EU Countries** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Austria | Belgium | Denmark | Finland | France | Germany | Greece | Ireland | Italy | Lux. | Netherlands | Portugal | Spain | Sweden | UK |
| **HDD** | 4068 | 3259 | 3191 | 5978 | 2850 | 3845 | 1711 | 2979 | 2234 | 3259 | 3550 | 1800 | 1600 | 4355 | 3210 |
| national averaged values, based on an internal setpoint of 20°C | | | | | | | | | | | | | | | |

[8] Source MURE (*A comparison of Thermal Building Regulation in European Union)* database of national thermal insulation regulations, project financed by SAVE programme - EU, 1999

## Annex 3: Typical energy performances of common and advanced window components

**Table 3.1 Typical values of glazing (center of glass) thermal and optical properties:**

| Glazing (ext. pane / gas / int pane ) | $U_{c.o.g.}$ W/($m^2$ K) | ***g*** | $\tau_v$ | ***LSG*** |
|---|---|---|---|---|
| Single clear (3mm float glass) | 5.9 | 89% | 90% | 1.0 |
| Clear Double Glazed Unit (6mm float + 12mm Air + 6mm float) | 2.6 | 75% | 81% | 1.1 |
| Heat mirror Double Glazed Unit (6mm float + 12mm Air + 6mm “low-e coated” glass) | 1.5 | 58% | 71% | 1.2 |
| Heat mirror Double Glazed Unit (6mm float + 16mm Argon + 6mm “low-e coated” glass) | 1.1 | 56% | 71% | 1.3 |
| Solar control Double Glazed Unit “soft coating” (6mm spectral selective + 16mm Argon + 6mm float) | 1.1 | 31% | 54% | 1.7 |
| Solar control Double Glazed Unit “hard coating” (6mm spectral selective + 12mm Air + 6mm float) | 2.6 | 46% | 48% | 1.0 |
| Triple Glazed Unit (6mm low-e glass + 16mm Argon + + 6mm float glass + 16mm Argon + 6mm low-e glass} | 0.6 | 36% | 62% | 1.7 |

**Table 3.2 Typical values of frame thermal transmittance:**

| Frame material | $U_f$ [W/($m^2$K)] |
|---|---|
| Aluminum without thermal break | 7,0 |
| Aluminum with thermal break | 3,5 |
| Plastic | 2,5 |
| Wood | 1.7 |

Where:

**U** **Thermal transmittance**
**g** **Solar factor** (also Total solar direct transmittance)
$\tau_v$ **Visual (light) transmittance**

## Annex 4: Action Plan for the Building Envelope

| Energy Savings Measures | Feasibility [1] | Specific Actions [2] | % Covered [3] | Time table [4] | Expected HEATING savings [5] (MWh/year) | Expected COOLING savings [5] (MWh/year) | Expected LIGHTING savings [5] (MWh/year) |
|---|---|---|---|---|---|---|---|
| ***Improving insulation*** | | | | | | | |
| localisation and elimination of thermal bridges | | | | | | | |
| Improving insulation of opaque external walls, roofs, ground floor… | | | | | | | |
| Improving insulation of window and transparent facades | | | | | | | |
| addition of a new envelope | | | | | | | |
| … | | | | | | | |
| ***Improving Air Tightness*** | | | | | | | |
| of windows and doors, walls, joints… | | | | | | | |
| … | | | | | | | |
| ***Reducing unwanted solar heat gains by installation*** | | | | | | | |
| of permanent or movable shading devices | | | | | | | |
| of solar control glazing | | | | | | | |
| … | | | | | | | |
| ***Installing/improving control systems*** | | | | | | | |
| of openings and shading | | | | | | | |
| … | | | | | | | |
| ***Modifying geometry:*** | | | | | | | |
| *- Volume/Surface rate* | | | | | | | |
| *- Transparent/Opaque rate* | | | | | | | |
| … | | | | | | | |
| ***Using Thermal storage*** | | | | | | | |
| ***Using vegetation…*** | | | | | | | |

(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 improving insulation can be done on external or internal surfaces or in cavity walls, with different materials,etc.
(3) **% Covered.** Proportion of the envelope for which the specific actions will be implemented. It should be calculated in terms of areas of a certain components subject to the action compared to total area of that component. Moreover for solar control implementation the orientation of the surfaces has to be described.
(4) **Time table.** The time scale at which the action will be implemented. This might be a specific period or date, or might depend on some other action.
(5) **Expected savings** in MWh/year (primary energy). These can be estimated on generally accepted engineering practice or with detailed building simulation carried out by experts. Negative values may occur for actions that can increase the energy consumption in some of these voices even if the total expected saving is positive.

## Annex 5: Reporting Form for Building Envelope

| Approved Action Plan | | 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) |
| ***Increasing insulation*** | | |
| Action 1 | | |
| Action 2 | | |
| … | | |
| ***Improving Air Tightness*** | | |
| … | | |
| ***Reducing unwanted heat gains*** | | |
| … | | |

(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 to the Challenge. They are invited (but not required) to submit the Synthesis to GREENBUILDING.

| Report synthesis | | |
|---|---|---|
| | Since commitment | This year |
| Percentage of actions in Action Plan completed | | |
| Estimated total investment for Plan ( kEUR) (1) | | |
| Estimated change in non energy O&M costs (kEUR) (1) | | |
| Estimated energy savings (MWh) (2) | | |
| Heated floor area ($m^2$) | | |
| Cooled floor area ($m^2$) | | |
| Lighted floor area ($m^2$) | | |
| Indicative energy related heating costs per square meter (EUR/$m^2$) (3) | | |
| Indicative energy related cooling costs per square meter (EUR/$m^2$) (3) | | |
| Indicative energy related lighting costs per square meter (EUR/$m^2$) (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 treated areas, number of occupants, degree of utilisation and comfort levels.

(3) **Energy costs per treated area** is a relevant indicator of the efficient use of heating and cooling systems