"Technical background study in support of the development of the EU Ecolabel and GPP criteria for office buildings"

Contract number: 151935-2010-A08-ES

Development of European Ecolabel and Green Public Procurement Criteria for Office Buildings JRC IPTS Draft Preliminary Study

Draft Technical Analysis

October 31th 2011

Coordinator **Partners**

EXECUTIVE SUMMARY

The present document reports the results of the "*Technical analysis in support of the development of European Ecolabel Criteria for Office Buildings*". The purpose of the European Ecolabel is the identification and communication of the top best environmental performance products to the consumers. According to the EU Ecolabel Regulation, only the top 10-20% of the current market can be awarded by the EU Ecolabel. The applied methodology and obtained results for the development of the EU Ecolabel criteria for the office building product group are reported herewith.

Previously to this report, a definition and categorization of the existing office buildings in Europe and an economic and market analysis were developed. An office building is defined in the "Definition and Categorization" report as "a building which **contains administrative, financial, technical and bureaucratic activities as core representative activities**. The office area must make up a vast majority of the total buildings gross area dedicated to this purpose providing a service to other companies or to individuals. Therefore, it could have associated other type of spaces, like meeting rooms, training classes, staff facilities, technical rooms, etc". Office buildings were also categorized according to its age and the climate zone where they are located.

The results of the "Market and economic analysis" showed that more than 18,700,000 office buildings exist at present in the EU-27. Due to the unique characteristics of each office building and in order to derive a model for each of the abovementioned categories, a flexible base case office building model was designed. The influence of parameters (i.e. climate zones, age of the existing and to be renovated buildings, percentage of glazing area, U-values for both walls and windows, and the installation or not of a lighting control system, thermal solar system and PV system) was assessed by introducing modifications to the generic model. In addition, the assessment of different scenarios allowed identifying key design factors that strongly influence the environmental performance of office buildings. The different scenarios resulting from the adaptation of the generic model to different climatic areas and situations constitute a representation of the real situation allowing the identification of the 20% best environmental performing office buildings. This is a necessary step to define the benchmarks of the Ecolabel criteria. Sensitivity analyses of the type of energy source, transportation distance, orientation of the building, materials composition of the building structure, end of life scenario and water consumption were carried out to ensure the initial assumptions do not compromise the final conclusions of this study.

Applying the LCA methodology, according to ISO 14040-44 and CEN TC 350 standards, the environmental impacts of the generic office building model throughout the whole life cycle (production, construction, use and end-of-life phases) were analysed. The Life Cycle Inventory data was carried out using EU-27 representative data when possible (from the ELCD database). For the Life Cycle Impact Assessment step, the CML 2002 impact assessment methodology has been applied.

The main results from the LCA pointed out that the use phase causes the highest environmental impact being not significant the differences observed in the different locations (climatic zone) or selection of construction materials or techniques (the percentage of glazing area or U-values). Therefore, any improvement in the environmental performance of the office building should be related to the use of more energy efficient construction materials, technologies or cleaner energy sources.

Among the energy consumption shares, lighting causes the highest environmental impacts, in particular, when no lighting control strategies are implemented. Any lighting control systems will considerably reduce the energy consumption of office buildings and, consequently, to improve its overall environmental performance.

Results suggest that the definition of Ecolabel criteria and benchmarks for the development of Ecolabel criteria of office buildings should be focused on reducing the energy consumption of the building and the use of polluting energy sources. However, some environmental aspects of other life cycle phases, such as the production phase or the end-of-life phases should also be considered.

To identify the buildings within the group of the 10-20% of the best performance office building on the EU market, the normalized and weighted LCA results of the base cases were multiplied by the number of the office buildings estimated in the "Economic and market analysis". The ranking of the buildings gives a general idea of the environmental impact caused by the front-runners office buildings in Europe and allowed the determination of the benchmarks of the top best environmental performing office buildings. Because of the relative importance of the environmental aspects, the estimated benchmarks were weighted accordingly. Only all the benchmarks together reach the 20% top best environmental performing buildings.

Apart from the environmental impacts identified through LCA studies, other environmental issues related to office buildings were identified by the revision of existing MS labels and literature. Criteria related to non-LCA environmental aspects are either qualitative criteria or quantitative criteria with benchmarks based on the harmonization of the existing member states labels. These criteria are related to the indoor air quality and well-being, avoidance of hazardous substances and materials, facilities for bikes or the information provided to the end users.

SUMMARY – CONTENTS

1. Introduction

The purpose of this pilot project is to collect a joint evidence base from which EU policy making in the area of buildings can be developed. The present document reports the results of the "*Technical analysis in support of the development of European Ecolabel and Green Public Procurement Criteria for Office Buildings*".

In this project, EU Ecolabel and Green Public Procurement criteria will be devised for office buildings. As part of the criteria development process, the life cycle assessment (LCA) methodology and other methodologies will be used to demonstrate the key environmental life cycle impacts. The LCA methodology requires identification of one or several base cases for the product group. The base case is used to represent a typical product.
In order to create a base case, a classification of the existing office buildings across Europe and an economic and market analysis were carried out. The results of these studies are summarized in the "Definition and classification" and "Economic and market analysis" reports, respectively. Unfortunately, each office building is characterized by its design, construction materials, locations, etc and therefore, each office building is unique. Consequently, this work is based on some assumptions to model a generic office building that introduce a certain amount of uncertainty in the results. In addition, the introduction of parameters in the base case model allows performing different sensitivity analysis and creating different scenarios that will help to identify the key environmental criteria and to propose the corresponding benchmarks.

The literature revision came out that not all the environmental impacts caused by an office building can be pointed out by a LCA study. These environmental aspects are caused beyond the system boundaries of the LCA studies and will be called as non-LCA environmental aspects in this work.

The results of these studies are the basis for the proposal of Ecolabel and GPP criteria and for the estimate of the benchmarks. Finally, the improvement potentials can also be proposed.

2. Methodology

The methodology followed in this study to propose the EU Ecolabel and GPP criteria based on scientific evidences and the harmonization of the existing legislation in the Member States is explained in detail in this section.

The purpose of the European Ecolabel is the identification and communication of the top best environmental performance products to the consumers. This information helps them to make the most conscious environmental decision. According to the EU Ecolabel Regulation (EC No 66/2010) only the top 10-20% of the current market can be awarded by the EU Ecolabel.

The identification and quantification of the top 20% best environmental performing office buildings across Europe is a challenging task due to several reasons:

- the construction techniques, designing and materials used in the construction of the office buildings differ significantly among the Member States, being each office building a singular product
- the environmental impacts caused by the office building depend on its location. The location determines the importance of the environmental impacts and the environmental aspects that are likely to be used in the office building

Keeping these differences in mind, the following methodology was followed:

2.1 Definition and categorization of office building

Before starting the study it is important to define clearly what is considered as an office building. The definition establishes the scope and consequently the boundaries of the study. Due to the large differences among the buildings, also the office buildings across Europe, a categorization of the office buildings regarding several aspects seems to be needed.

According to the study reported in the "Definition and categorization report" an office building will be considered as: "An **office building** is a building which **contains administrative, financial, technical and bureaucratic activities as core representative activities**. The office area must make up a vast majority of the total buildings gross area dedicated to this purpose providing a service to other companies or to individuals. Therefore, it could have associated other type of spaces, like meeting rooms, training classes, staff facilities, technical rooms, etc" Excluded from this definition are parking areas that are not counted in this total buildings gross area.

After regarding the main differences of the office buildings and the main categorizations of buildings carried out in the official standards, two categorization aspects were proposed:

- age of the building. The construction date determines construction aspects such as techniques and materials, but also other environmental aspects of the buildings such as the energy consumption during the use phase or the recyclability potential of the materials used.
- location of the building. The climatic conditions across Europe are completely different from one region to another one having a key role on the construction designs and techniques used in the buildings.

2.2 Market description

As commented before the variety of office buildings across Europe is huge. This variety is reported in detail in the "Economic and market analysis report". The results of this study show that more than 1870000 office buildings exist at present in EU-27. However, due to the different locations where they are built, the different national and regional regulations, praxis, types and quantities of materials, shapes, orientations, etc that were applied, each office building could be considered as a singular product.

The aim of this report is the identification of the most typical office buildings to be proposed as base cases. In this sense, after analysis the scarce information available on the office market in Europe the following base cases were proposed for this study.

2.3 Identification of the base cases (Office building generic model)

A generic office building was proposed as base case based on the revision of the literature and the statistical information collected in the previous step. A detailed description of this base case is reported in section 3.

It is not possible to derive a representative office building neither at EU-27 level nor at national one. Thus, the identification of the key environmental aspects was done through the development of flexible LCA models. The introduction of parameters in a generic model allows performing different sensitivity analyses and scenarios to identify the key environmental aspects in the wide range of situations that exist in the current market (i.e. climatic conditions, technical requirements, design options, etc.).

2.4 Identification of the key environmental aspects and environmental impacts

The identification of the environmental aspects that cause the key environmental impacts of the office buildings is achieved following three methodologies:

2.4.1 LCA studies: LCA studies according to CEN 350 and ISO 14040-44 standards allow the identification of most of the environmental impacts caused by the office buildings.

The goal and scope of a LCA study was defined, including aspects such as the functional unit, system boundaries, impact assessment methodology, hypothesis and assumptions, etc (see section 3.1). The goal and scope of the LCA study determines its boundaries and consequently the environmental aspects that are going to be identified.

The environmental information was gathered and processed to develop the LCI of the base case by using GaBi software1 and ELCD and GaBi databases. In the LCI assessment, the overall results and the specific results of different scenarios are presented allowing identifying the key environmental aspects.

2.4.2 Revision of the existing Member State labels

2.4.3 Revision of the literature

Apart from the environmental impacts identified through LCA studies, other environmental issues related to office buildings were identified by the revision of existing MS labels and literature. These environmental aspects are caused beyond the system boundaries of the LCA studies and are called in this work as non-LCA environmental aspects.

2.5 Estimation of the overall LCA-environmental impact of each office building category

In order to estimate the overall environmental impact of each office building category the number of the office buildings estimated in the "Economic and market analysis" was multiplied by the overall environmental impact estimated by using a LCA analysis. The overall environmental impact allows ranking the buildings in decreasing order.

From the three abovementioned sources of information, only the first one allows the quantification of the environmental impacts caused by the office buildings. In order to determine the relative importance of the key environmental impacts, the results from the LCA analyses should be normalized and weighted getting a single figure that allows the ranking of the models.

Moreover, the normalization and weighting of the environmental impacts allow determining the related importance of each LCA environmental aspect. This breakdown of the environmental aspects will allow the determination of the benchmarks to get the top best environmental performing office building (Step 2.6 of this methodology)

On the other hand, the non-LCA environmental impacts are difficult to be quantified and therefore most of the criteria related to these environmental aspects were proposed as qualitative ones.

[1] More information in: http://www.gabi-software.com

2.6 Determination of the criteria and benchmarks of the LCA environmental aspects

Once the environmental aspects are identified, the next step is to formulate a criterion to reduce/limit the environmental impact caused. Depending on the environmental aspect, the criterion can be formulated to limit/restrict it totally, partially or completely. For example, the energy related criteria can be formulated to restrict the overall energy consumption of the building, to restrict the energy consumption partially e.g. heating or cooling, lighting, etc or to avoid the consumption of energy e.g. allowing only natural ventilation.

Moreover, most of the LCA-environmental aspects needs for a benchmark as the environmental aspect can be easily measured. In these cases, the benchmarks should be estimated to be awarded by around 20% of the best environmental performing office buildings.

Because of the relative importance of the environmental aspects, the benchmarks should be weighted according to the relative importance of the environmental aspects. Only all the benchmarks together should be reached by the best environmental performing buildings.

2.7 Determination of the criteria and benchmarks of the non-LCA environmental aspects

The criteria and benchmarks related to the non-LCA environmental aspects are either qualitative criteria or quantitative criteria with benchmarks based on the harmonization of the existing legislation and Member states labels. In this sense, the proposed criteria should always regard the current legislation without introducing any contradiction. In addition, the benchmarks proposed for the non-LCA environmental aspects should aim at covering as many existing Member States labels as possible.

3. Identification of the base case (generic model)

The results of the "Market and economic analysis" carried out in this study showed that more than 18,700,000 office buildings exist at present in the EU-27 [IPTS, 2011B]. Each of these buildings is unique, as was designed for a specific location following the applicable local construction or renovation regulations and praxis, using different types and quantities of materials, adopting different shapes, orientations, etc. These differences make difficult to define a unique model for all the office buildings in EU-27. Taking this into account and, in order to derive a model for each office building categories defined in ''Definition and categorization report'', it is needed to start with a flexible generic model which can be later modified to represent specific office buildings located in different climate zones and having different construction characteristics (such as heat transfer coefficient values, percentages of glazing, etc.). The flexibility of the generic model also allows assessing key design factors which may have an important influence on the environmental profile of office buildings.

3.1 Definition of a generic model

There are a number of parameters needed on the definition of a generic office building:

a) **Size**: As shown in the Economic and market analysis report[2], buildings over 1,000 m^2 represent the majority of the non-residential stock. Particularly for office buildings, there is a classification in the Energy Consumption Guide 19 [ECON 19] of the former UK Energy Efficiency Best Practice Programme (now CarbonTrust), which summarizes the most typical office building types, and describes an Air–Conditioned Standard building size ranging between 2,000 m^2 to 8,000 m^2.

b) **Geometry and layout**: The geometry and layout of a building influence amongst other aspects its functionality. Both, geometry and layout determine the use of the spaces, materials and resources used in the life cycle. Particularly during the use phase, they determine the heat transfer and loss through the envelope, the potential for natural ventilation, daylight availability, etc. According to the results of the Economic and market analysis, it is not possible to establish a typical geometry and layout, at EU-27 level. However, in this study a base-case consisting on a rectangular building shape was defined. The base case presents an open plan layout and a total area of **4,620 m^2 in three floors**.

[2] See Table 6, ''Economic and market analysis report'' report.

This model is based on the generic office building presented in the paper "Life-Cycle Energy Use in Office Buildings" [Cole and Kernan 1996].

c) **Orientation and glazing area:** Both existing and new office buildings face all types of situations regarding the orientation. Orientation is as frequently influenced by location and site factors as well as by issues regarding environmental factors such as daylight, sunlight or wind. For this reason, in this study, the orientation of the generic building model was considered as east –west, with equal amount of glazing was in all façades. The influence of the orientation of the building in the overall environmental impact of the building was assessed in a sensitivity analysis.

On the other hand, the percentage of glazing is a key issue, as it influences daylight availability and visual comfort, lighting energy consumption, thermal losses and gains, solar gains, ventilation, etc. At EU-27 level there is a wide variation on the percentage of glazing used. For this reason, in this study, a basic model whose glazing area was set initially as 30% of the external wall area was chosen. Variations on the value of this parameter were assessed in the LCA sensitivity analysis. Figure 1 shows the details on geometry and layout of the modelled generic office building.

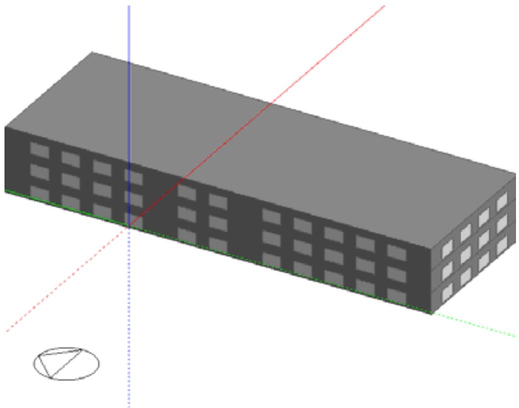

Figure 1: Geometry and orientation of the generic office building model (30% of glazing area)

d) **Construction details and materials**: According to the results of the ''Economic and market analysis report'', at EU-27 level there is no typical construction details and materials. However, some aspects of the office buildings, such as the thermal transmission values, can be related to the building age or location. For this reason, the base cases modelled in this study are based on the national construction codes of their respective locations and [Petersdorff et al. 2005a, Petersdorff et al. 2005b]. U values showed in Table 1 and used in the models of the base cases are based on the national constructions code values and on mean insulation values for the three climate zones categorized in the ''Definition and categorization report'. For each of the three climate zones a city was selected to better define the specific U-value for walls, floor, roof and glazing. The Heating Degree Days (HDD) and Cooling Degree Days (CDD) values provided by CELECT project for different European cities [CELECT 2008] was used in this study to characterize the climatic conditions across Europe. On the other hand, **it was assumed that new buildings and buildings to be renovated fulfill the same U-values**, whereas higher U-values for existing buildings were estimated. U-values were based on was [Petersdorff et al. 2005] and other references provided in table 1.

Table 1: U values proposed for the classification of the office buildings

Building Age	Climate zone	City	U-Value (W/m²K) Walls	Floor	Roof	Glazing	Reference
New Buildings / Buildings to be Renovated	A1	Tallinn (Estonia)	0.2	0.2	0.15	1.2	NORTHPASS Project.
	B1	London (UK)	0.3	0.25	0.2	2.0	National Calculation Methodology (NCM) [DCLG 2008]. UK Building Regulations (Part L, 2010) [HM Government 2000].
	C2	Madrid (Spain)	0.66	0.49	0.38	2.9	Código Técnico de la Edificación [Ministerio de Vivienda 2006].
Existing Buildings	A1	Tallinn (Estonia)	0.25	0.3	0.2	2.0	NORTHPASS Project .
	B1	London (UK)	0.45	0.45	0.5	3.3	National Calculation Methodology (NCM) [DCLG 2008]. UK Building Regulations (Part L, 2010) [HM Government 2000].
	C2	Madrid (Spain)	0.8	0.49	0.38	2.9	Código Técnico de la Edificación [Ministerio de Vivienda 2006].

Regarding the construction materials the following characteristics were considered in the model:

- Walls: Insulated cavity wall, outer layer brickwork and concrete block as indoor layer.
- Floor: Insulated concrete, screed and timber flooring.
- Roof: Plasterboard, insulation and asphalt flat roof.
- Structure: Concrete and reinforcement steel.
- Glazing: Wooden frame and double layer.

Table 2 shows the specific construction materials used in the generic office building model. Quantities correspond to the office building model located in London, whereas the amount of insulation materials differs from one climate zone to other (see section 3.2).

Table 2: Construction materials used in the generic office building model (located in London)

Construction elements	Material	Area (m²)	Mass (kg)
Exterior walls	Gypsum Plastering	1,314.00	17,082.00
	Extruded polystyrene (XPS)	1,314.00	4,392.05
	Concrete Block	1,314.00	183,960.00
	Brick	1,314.00	234,548.99
Interior walls	Interior plaster (lime-gypsum)	2,184.00	49,140.00

Roof	Bitumen	1,541.00	32,361.00
	Gypsum plasterboard	1,541.00	56,092.40
	Extruded polystyrene (XPS)	1,541.00	8,460.60
Floors/Ceilings	Timber flooring	4,623.00	90,148.50
	Floor / roof screed	1,541.00	129,444.00
	Gypsum plasterboard	3,082.00	112,184.80
	Extruded polystyrene (XPS)	1,541.00	6,416.90
Windows	Wooden frame double-glazing	576.00	23,213.38
Structure	Concrete (forge)	-	2,970,000.00
	Reinforcement steel (forge)	-	189,000.00
	Reinforcement steel (structure)	-	69,000.00
	Reinforced concrete (structure)	-	907,000.00
		TOTAL	5,082,444.62

e) **Building use, settings and occupancy schedules**: Building occupancy schedules, density, lighting and temperature requirements, heat gains due to additional equipment, hot water usage and other additional parameters which influence the energy performance of a building. These parameters are generally defined on national regulations and standards and are based on EPBD 2002. The UK National Calculation Method [DCLG] and the Spanish Technical Construction Code [IDAE 2009] were used to define these parameters in this study, as shown in Table 3

Table 3: Use scenario for the generic office building model

Characteristic	Generic Office Space	Units
Occupancy Hours	7h to 19 h	Hours Monday to Friday
Occupancy days per year	260	days/year
Density of occupation	0.11	person/m^2
Metabolic rate	120	W/person
Set point cooling	25	Celsius degrees
Set point heating	21	Celsius degrees
Water consumption[3]	55.5	l/person*day
Ventilation	10	l/person*second
Equipment	12	W/m^2

f) **Heating, Ventilating and Air Conditioning (HVAC) and lighting systems:** The study of HVAC performance is not the aim of this study, but some standard values are needed to be assigned to calculate the energy performance of the building during the use phase. In this study, it was assumed that: firstly the cooling demand of the building is covered by heat pumps with a coefficient of performance (COP) of 3 and secondly, natural gas fuelled heating systems with an efficiency rate of 80% are used to heat up the building (the influence of the type of fuel used in the overall environmental impact of the office building was assessed in a sensitivity analysis).

Lighting Systems are a key factor in offices since it largely affects the electricity demand of the building as well as the heating and cooling demands. Their consumption depends on the

[3] According to the preliminary results of the SuperBuildings Project, the water consumption of an office building in Europe is between 11 and 100 litres per person and day. Source: [SuperBuildings, 2011].

installation quality (luminaries control, etc), the office layout and the availability of daylight. As all those factors significantly differ at EU-27 level, in this study a “good practice” benchmark of 12 W/m^2 was used was [ECON 19].

g) **Operation life.** According to the ‘Economic and market analysis report’ the estimated service life of office buildings is 50 years.

3.2 Development of the bases cases using flexible parameters

The “Definition and categorization of office buildings”, proposed a categorization of office buildings based on two main characteristics: the building age and the climate zone where it is located. The influence of both parameters as well as other construction characteristics such as the glazing surface, U-values, lighting control or use of renewable energy systems were assessed by introducing modifications to the generic model. In addition, the assessment of different scenarios allowed identifying key design factors that strongly influence the environmental performance of office buildings.

The following parameters were assessed (see section 3.2.2):

- Climate zones: A1 (Tallinn), B1 (London) and C2 (Madrid).
- Age of the building: existing and new/to be renovated[4] (i.e. fundamental remodelling or adaptation of existing elements of the building envelope, structure or key building services).
- Percentage of glazing area: 30% and 50%.
- U-value of walls: three different options for each location.
- U-value of windows: double window (U=3.157) and triple window (U=1.776).
- Installation or not of a lighting control system (only for new/to be renovated buildings).
- Installation or not of thermal solar system with different areas: (0), 10, 20, 30, 40, 50 and 60 m^2; both for existing and new/to be renovated buildings.
- Installation or not of PV system with different areas: (0), 20, 40, 60, 80, 100 and 120 m^2; both for existing and new/to be renovated buildings.

Moreover, for each location, a building with the following characteristics: 30% glazing, minimum U-values, total lighting control system and 120 m^2 PV panels was assessed PV. Annex 1 lists the characteristics parameters of each base case.

[4] As mentioned before, it waswas assumed that the building characteristics of both building arethe same.

On the other hand, several sensitivity analyses were carried out to ensure that the initial assumptions, such as the environmental influence of the electricity mix, do not compromise the final conclusion of this study.

4. Identification of the key environmental impacts and environmental aspects

4.1 Identification of the key LCA environmental impacts and LCA environmental aspects

The identification of the key LCA environmental impacts and environmental aspects was carried out through a simplified LCA of the generic model. In order to ensure that the needed assumptions do not comprise the obtained results, sensitivity analyses were performed.

4.1.1. Goal and scope of the LCA

The **goal of this LCA** study is to identify the environmental impacts caused by office buildings in each individual phase of their life-cycle and the causes behind the impacts (the identification of the environmental aspects). This is important to propose the environmental criteria and the improvement measures.

The function of an office building is, according to the definition provided in the ''Definition and categorization report'' to allocate administrative, financial, technical and bureaucratic activities to provide service to other companies or to individuals.

The **functional unit** selected for the evaluation of the environmental impacts of the different office building categories is the "**use of 1 m^2 office area over the period of 1 year**".

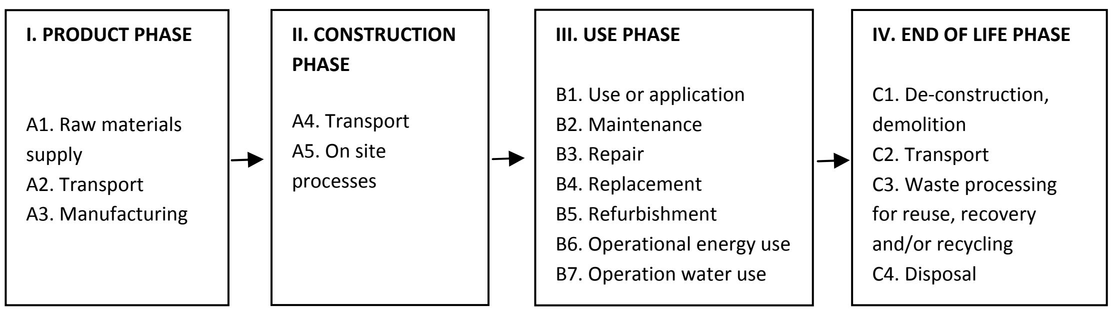

Figure 2: Life cycle phases for building assessment. Source: [prEN 15804:2010]

The **system boundary** determines the processes are considered in the study. In this study the system boundaries are restricted to the building and its site. This includes all the upstream and downstream processes needed to establish and maintain the function of the building. That means, from the acquisition of raw materials to their disposal or to the point where materials exit the system boundary either during or at the end of the building life cycle.

According to CEN/TC normalization works [prEN 15804:2010; prEN 15643-2:2009] the assessment of the environmental performance of a building should follow the division in phases and modules shown in

Figure 2. All the office related activities occurring during the use phase of the building are not included within the system boundaries.

In this study, the following simplifications were applied:

- **Product phase** includes the production of the following basic elements: basement, exterior walls, interior walls, floors/ceilings, roof and windows. Other elements such as fittings, heating and cooling systems, etc. were not considered.

- **Construction phase**: includes only the transportation of the construction materials to the different production sites and to the building site (module A4). The onsite processes (module A5) are considered to have a low environmental impact in comparison to other processes and phases of the building life cycle [IPTS 2008].

- **Use phase**: includes processes related to operational energy use (B6) and operational water use (B7). Regarding the energy use (B6) it was included the energy consumption for heating and cooling, hot water production, auxiliary equipment, lighting and ventilation[5]. The rest of the modules (B1, B2, B3 and B4) were considered to have a relatively low impact.

- **End of life phase**: includes transport (module C2) of the construction waste to the landfill facility (C4). The de-construction and demolition processes (module C1) were not included in the generic model because of a lack of data. No reuse, recovery or recycling scenarios were considered in the sake of simplification but their environmental influence was checked in a sensitivity analysis.

4.1.2. Life Cycle Inventory analysis (LCI)

Background data were used to develop the LCI of construction materials and energy, materials transportation and waste management processes. Following the methodology used in the Impro Building study [IPTS 2008], background data from European average datasets were used whenever possible. This fact ensures the consistency of the study and avoids biasing the analysis of the life cycle models. The background datasets of the required construction materials

[5] The energy consumption of the office equipment and white appliances that eventually could be used within the building exceeds the system boundaries of this LCA study, as it was agreed in the 1st AHWG meeting on office buildings, held in 29th June 2011 in Sevilla (Spain).

were created using the GaBi software's DB as well as the ELCD whenever possible (see Figure 3).

The model building was simulated as a "stand alone" scenario, and therefore it does not include any potential effects of overshadowing by neighbouring buildings, potential effects of urban wind patterns, infrared radiation, urban heat island effects, availability of daylight, etc.

The total water demand or "operation water use" is the other key parameter in the use stage), has been estimated as 6.1 litres (55.5 litres*0.11persons/m2) per working day and square meter (see Table 3), being the total 1,587.3 litres per year and square meter.

Table 4 shows the source of the data used in each case. It was assumed that construction materials were transported 50 km by road from the production site to the building location (the influence of this assumption in the overall environmental results will be assessed in a sensitivity analysis).

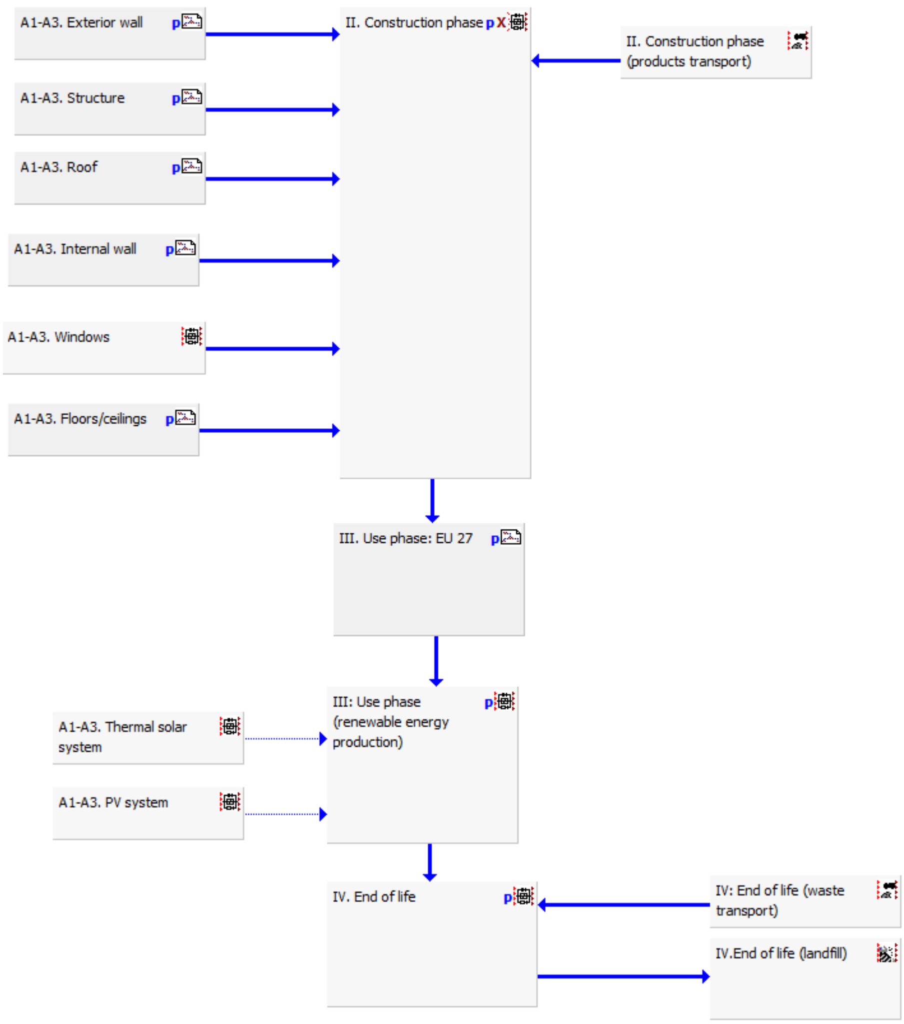

Figure 3: Image of the LCA flexible model developed using GaBi software

The use phase scenario described in Table 3 was used to estimate water and energy consumption of the office buildings. Models and scenarios were done by using DESIGNBUILDER software[6] which acts as an interface for running the EnergyPlus simulation tool[7]. Energyplus allows a detailed and accurate energy consumption calculation for heating and cooling, hot water, lighting, ventilation and even office equipment energy consumption. A detailed study of the performance of the building during summer to prevent overheating is also possible. Each location was simulated using the corresponding IWEC (International Weather for Energy Calculations) file was [ASHRAE 2001]. Annex 2 provides as an example a description of one of the simulations.

The model building was simulated as a "stand alone" scenario, and therefore it does not include any potential effects of overshadowing by neighbouring buildings, potential effects of urban wind patterns, infrared radiation, urban heat island effects, availability of daylight, etc.

The total water demand or "operation water use" is the other key parameter in the use stage), has been estimated as 6.1 litres (55.5 litres*0.11persons/m^2) per working day and square meter (see Table 3), being the total 1,587.3 litres per year and square meter.

Table 4: Data sources used in the development of the life cycle inventory

Life Cycle Phase	Module	Process	Data source	Reference name
I. Product phase	A1. Raw materials supply A2. Transport A3. Manufacturing	Gypsum Plastering	[GaBi DB]	DE: Gypsum board PE
		Bitumen	[GaBi DB]	EU-15: Bitumen at refinery PE
		Brickwork Outer Leaf production	[GaBi DB]	DE: Light-weight brick PE
		Concrete, Concrete Block, Reinforcement concrete	[GaBi DB]	DE: Concrete C20/25 PE
		Floor / roof screed	[GaBi DB]	DE: Floor screed (cement) PE
		Gypsum Plasterboard	[GaBi DB]	DE: Gypsum board PE
		Interior plaster	[GaBi DB]	DE: Interior plaster (lime-gypsum) PE
		Reinforcement steel	[GaBi DB]	DE: Steel forging part (0.4 to 1.0kg) PE
		Timber flooring	[GaBi DB]	DE: Timber pine (12% humidity / 10,7% moisture content) PE
		Wooden frame and double-glazing	[GiGa-ESCI 2011], [GaBi DB]	-
		Extruded polystyrene (XPS)	[EXIBA 2010]	-
		Solar thermal system	[Ecoinvent DB]	CH: solar system, flat plate collector, multiple dwelling, hot water
		PV system	[Ecoinvent DB]	CH: 3kWp flat roof installation, multi-Si, on roof
II. Construction phase	A4. Transport	Transportations of all construction materials from the fabrication site to the building location	[ELCD]	RER: Lorry (22t) including fuel

[6] More information in: http://www.designbuilder.co.uk/

[7] More information in: http://apps1.eere.energy.gov/buildings/energyplus/

III. Use phase	B6. Operation energy use	Electricity (EU-27)	[ELCD]	EU-27: Power grid mix ELCD/PE-GaBi
		Thermal energy (EU-25)	[ELCD]	EU-25: Thermal energy from natural gas ELCD/PE-GaBi
	B7. Operation water use	Tap water	[GaBi DB]	DE: Potable water from groundwater PE
IV. End of life phas	C2. Transport	Transportation	[ELCD]	RER: Lorry (22t) including fuel
	C4. Disposal	Landfill	[GaBi DB]	RER: Landfill for inert matter (Unspecific construction waste) PE

4.1.2.1 Definition of scenarios

Different scenarios were developed to identify the key environmental aspects of buildings across the EU-27 territory. As [Adalberth et al 2001], [Norman et al 2006], [Blengini 2009], [Junnila &Horvath 2003], [Kofoworola&Gheewala 2008] and [Michiya&Tatsuo 1998] pointed out the use phase causes the highest environmental impacts. The following scenarios were developed to evaluate the use phase of the buildings. Comparisons between the obtained results should only be made on the basis of a functional equivalency [prEN 15643-2:2009].

a) **Building location and age:** Three cities London (climate zone B1), Madrid (C2) and Tallinn (A1) represent the three different climate zones in the EU-27. For each model the thicknesses of insulation materials changes according to the typical practice and national regulations shown in Table 1. Taking into account the location of the building, the following characteristics were modified in each scenario based on t eh local regulations: a.1) Quantity and thickness of insulation materials used in the building's envelope (while the rest of the materials remain constant) and a.2) energy demand of the building in terms of heating and cooling.

Table 5 and Table 6 show the variations introduced in the generic model to assess the influence of the location and age in environmental performance of the buildings. The electricity demand for lighting remains constant, as no lighting control was considered. The lighting demand represents a significant share of the total energy consumption accounting for around 30-40% of the final energy use of buildings [IEA, 2010].

Table 5: Variations (in bold) related to the amount of insulation materials in the generic building model depending on the climate zone where it is located. New/to be renovated buildings

Changing parameters	Units	London	Madrid	Tallinn
Extruded polystyrene (XPS) (exterior walls)	Kg	4,392.05	1,549.86	6,999.68
	cm*	9.5	3.4	15.2
Extruded polystyrene (XPS) (floors/ceilings)	Kg	6,416.90	2,824.19	8,250.71
	cm*	11.9	5.2	15.3
Extruded polystyrene (XPS) (roof)	Kg	8,460.60	4,117.39	11,516.90
	cm*	15.7	7.6	21.3
Office equipment consumption[8]	kWh/year	174,073.20	174,073.20	174,073.20
Lighting	kWh/year	180,270.40	180,270.40	180,270.40

[8] Office equipment consumption was included with the aim of taking into account its influence (in terms of internal heat loads) on the overall heating and cooling energy demand, but its environmental impact will not be assessed.

Auxiliary energy (pumps, fans, etc.)	kWh/year	15,070.98	15,070.98	15,070.98
Heating	kWh/year	79,388.83	59,930.00	245,309.50
Cooling	kWh/year	46,680.53	92,629.33	35,409.30
Domestic Hot Water	kWh/year	17,976.31	17,976.31	17,976.31

*of thickness

Table 6: Variations (in bold) related to the amount of insulation materials in the generic building model depending on the climate zone where it is located. Existing buildings

Changing parameters	Units	London	Madrid	Tallinn
Extruded polystyrene (XPS) (exterior walls)	Kg	2,658.22	1,135.95	1,026.00
	cm*	5.8	2.5	11.8
Extruded polystyrene (XPS) (floors/ceilings)	Kg	3,156.85	1,701.46	5,194.40
	cm*	5.8	5.2	9.6
Extruded polystyrene (XPS) (roof)	Kg	2,959.21	2,347.95	1,541.00
	cm*	5.5	3.1	15.7
Office equipment consumption[9]	kWh/year	174,073.20	174,073.20	174,073.20
Lighting	kWh/year	180,270.40	180,270.40	180,270.40
Auxiliary energy (pumps, fans, etc.)	kWh/year	15,070.98	15,070.98	15,070.98
Heating	kWh/year	140,745.38	74,821.96	284,598.13
Cooling	kWh/year	33,882.07	91,940.90	33,391.37
Domestic Hot Water	kWh/year	17,976.31	17,976.31	17,976.31

* of thickness

b) **Percentage of glazing**: The percentage of the total glazed area is a design parameter that influences the overall environmental performance of the buildings. Depending on the percentage under study, the following characteristics of the model should be modified: b.1) quantity of construction materials used in external walls (while the rest of materials remain) and b.1) energy demand for heating and cooling.

Table 7, Table 8 and Table 9 show the modifications introduced to assess the influence of the glazing. Although calculations were carried out considering an increase up to 50% in the glazing surface in the three climatic zones, no changes in the lighting consumption were considered. This aspect is addressed in the lightning control scenario.

Table 7: Variations on the % of glazing office buildings located in London

		New/to be renov. buildings		Existing buildings	
Changing parameter	Units	30% glazing	50% glazing	30% glazing	50% glazing
Gypsum plastering (exterior walls)	kg	17,082.00	13,338.00	17,082.00	13,338.00
Extruded polystyrene (XPS) (exterior walls)	kg	4,392.05	3,429.41	2,658.22	2,075.60
Concrete block (exterior walls)	kg	183,960.00	143,640.00	183,960.00	143,640.00
Brick (exterior walls)	kg	234,548.99	183,140.99	234,548.99	183,140.99
Window area	m^2	576.00	864.00	576.00	864.00
Window mass	kg	23,213.38	34,820.06	23,213.38	34,820.06
Heating energy consumption	kWh/year	79,388.83	83,610.09	140,745.38	153,658.13
Cooling energy consumption	kWh/year	46,680.53	55,859.43	33,882.07	38,927.47

Table 8: Variations on the % of glazing office buildings located in Madrid

		New/to be renov. buildings		Existing buildings	
Changing parameter	Units	30% glazing	50% glazing	30% glazing	50% glazing

[9] Office equipment consumption was included with the aim of taking into account its influence (in terms of internal heat loads) on the overall heating and cooling energy demand. However, its associated environmental impact is not included in the life cycle assessment results.

Gypsum plastering (exterior walls)	Kg	17,082.00	13,338.00	17,082.00	13,338.00
Extruded polystyrene (XPS) (exterior walls)	Kg	1,549.86	1,210.17	1,135.95	886.98
Concrete block (exterior walls)	Kg	183,960.00	143,640.00	183,960.00	143,640.00
Brick (exterior walls)	Kg	234,548.99	183,140.99	234,548.99	183,140.99
Window area	m²	576.00	864.00	576.00	864.00
Window mass	Kg	23,213.38	34,820.06	23,213.38	34,820.06
Heating energy consumption	kWh/year	59,930.00	60,734.16	74,821.96	75,167.53
Cooling energy consumption	kWh/year	92,629.33	106.724,40	91,940.90	107,725.63

Table 9: Variations on the % of glazing office buildings located in Tallinn

Changing parameter	Units	New/to be renov. buildings 30% glazing	New/to be renov. buildings 50% glazing	Existing buildings 30% glazing	Existing buildings 50% glazing
Gypsum plastering (exterior walls)	kg	17,082.00	13,338.00	17,082.00	13,338.00
Extruded polystyrene (XPS) (exterior walls)	kg	6,999.68	5,465.50	5,436.02	4,244.56
Concrete block (exterior walls)	kg	183,960.00	143,640.00	183,960.00	143,640.00
Brick (exterior walls)	kg	234,548.99	183,140.99	234,548.99	183,140.99
Window area	m²	576.00	864.00	576.00	864.00
Window mass	kg	23,213.38	34,820.06	23,213.38	34,820.06
Heating energy consumption	kWh/year	245,309.50	255,791.88	284,598.13	304,912.38
Cooling energy consumption	kWh/year	35,409.30	43,827.53	33,391.37	41,139.93

c) **U-values**: Three levels of improvement of the U values of the opaque walls were simulated at each location and (50% and 30%) glazing scenarios. An improvement in the window U-value was simulated too (see Table 10, Table 11 and Table 12)

Table 10: Variations on the U-values (W/m²K) for walls and windows in office building model in London

Changing parameter		Units	Scenario: 30% glazing			Scenario: 50% glazing		
			U_{wall}=0.3	U_{wall}=0.18	U_{wall}=0.12	U_{wall}=0.3	U_{wall}=0.18	U_{wall}=0.12
Extruded polystyrene (XPS) (exterior walls)		kg	4,392	7,868	12,212	3,429	6,137	9,525
		cm	9.5	17.1	26.5	9.5	17.1	26.5
U_{window}	$E_{heating}$	kWh/year	79,389	73,129	70,108	83,610	79,036	76,727
	$E_{cooling}$	kWh/year	46,680	48,000	48,703	55.859	56,994	57,594
U_{window}	$E_{heating}$	kWh/year	69,767	63,524	60,250	68,956	64,307	61,952
	$E_{cooling}$	kWh/year	42,127	43,408	44,096	49,834	50,973	51,570

Table 11: Variations on the U-values (W/m²K) for walls and windows in office building model in Madrid

Changing parameter		Units	Scenario: 30% glazing			Scenario: 50% glazing		
			U_{wall}=0.66	U_{wall}=0.29	U_{wall}=0.15	U_{wall}=0.66	U_{wall}=0.29	U_{wall}=0.15
Extruded polystyrene (XPS) (exterior walls)		kg	1,545	2,309	3,525	1,210	1,801	2,749
		cm	3.4	5.0	7.7	3.4	5.0	7.7
U_{window}	$E_{heating}$	kWh/year	59,930	50,810	47,250	60,734	54,091	51,501
	$E_{cooling}$	kWh/year	92,629	94,396	95,199	106,724	108,605	109,402
U_{window}	$E_{heating}$	kWh/year	48,244	39,287	35,803	44,312	37,937	35,410
	$E_{cooling}$	kWh/year	95,151	97,355	98,363	111,640	114,075	115,124

Table 12: Variations on the U-values (W/m²K) for walls and windows in office building model in Tallinn

Changing parameter		Units	Scenario: 30% glazing			Scenario: 50% glazing		
			U_{wall}=0.2	U_{wall}=0.14	U_{wall}=0.10	U_{wall}=0.2	U_{wall}=0.14	U_{wall}=0.10
Extruded polystyrene (XPS) (exterior walls)		kg	6,999	10,350	14,817	5,465	8,073	11,558
		cm	15.2	22.5	32.2	15.2	22.5	32.2
U	$E_{heating}$	kWh/year	245,310	238,503	233,873	255,792	250,632	247,174

	$E_{cooling}$	kWh/year	35,409	35,959	36,325	43,828	44,325	44,662
U_{window}	$E_{heating}$	kWh/year	238,827	231,901	227,271	245,399	240,147	236,630
	$E_{cooling}$	kWh/year	32,551	33,061	33,414	39,591	40,059	40,379

d) **Lighting control**: Lighting control strategies can be applied in buildings to reduce the use of artificial lighting, particularly when daylight is available. A stepped lighting control was introduced in the model, which allows switching lighting on/off according to the availability of natural daylight in discrete steps (see Table 13). The availability of daylight varies depending on the location and the glazing area and type. The lighting control reduces the internal heat loads what was taken into account in the case studies. Lighting control was simulated, as a partial (50%) and a total (100%) automatic lighting control (see Table 14, Table 15 and Table 16).

Table 13: Lighting control characteristics

Daylight luminance (lux)	Fraction of lights that are on
0-200	1.0
200-400	0.66
400-600	0.33
600 and above	0.0

Table 14: Variations on the luminance control in the new/to be renovated office building model located in London and for different U-values for walls

Changing parameter		Units	Scenario: 30% glazing			Scenario: 50% glazing		
			U_{wall}=0.3	U_{wall}=0.18	U_{wall}=0.12	U_{wall}=0.3	U_{wall}=0.18	U_{wall}=0.12
Without lighting	$E_{lighting}$	kwh/year	180,270	180,270	180,270	180,270	180,270	180,270
	$E_{heating}$	kWh/year	79,389	73,129	70,108	83,610	79,036	76,727
	$E_{cooling}$	kWh/year	46,680	48,000	48,703	55,859	56,994	57,594
With lighting	$E_{lighting}$	kWh/year	86,924	86,924	86,924	70,030	70,030	70,030
	$E_{heating}$	kWh/year	101,425	94,316	90,679	110,997	105,646	103,035
	$E_{cooling}$	kWh/year	29,429	30,371	30,882	36,183	37,008	37,437
With partial	$E_{lighting}$	kWh/year	133,597	133,597	133,597	125,150	125,150	125,150
	$E_{heating}$	kWh/year	90,407	83,722	80,393	97,303	92,341	89,881
	$E_{cooling}$	kWh/year	38,054	39,185	39,792	46,021	47,001	47,515

Table 15: Variations on the luminance control in the new/to be renovated office building model located in Madrid and for different U-values for walls

Changing parameter		Units	Scenario: 30% glazing			Scenario: 50% glazing		
			U_{wall}=0.66	U_{wall}=0.29	U_{wall}=0.15	U_{wall}=0.66	U_{wall}=0.29	U_{wall}=0.15
Without lighting	$E_{lighting}$	kwh/year	180,270	180,270	180,270	180,270	180,270	180,270
	$E_{heating}$	kWh/year	59,930	50,810	47,250	60,734	54,091	51,501
	$E_{cooling}$	kWh/year	92,629	94,396	95,199	106,724	108,605	109,402
With lighting	$E_{lighting}$	kWh/year	51,575	51,575	51,575	42,394	42,394	42,394
	$E_{heating}$	kWh/year	84,559	73,936	69,656	86,228	78,247	75,131
	$E_{cooling}$	kWh/year	69,075	69,993	70,409	81,637	82,829	83,327
With partial	$E_{lighting}$	kWh/year	115,922	115,922	115,922	111,332	111,332	111,332
	$E_{heating}$	kWh/year	72,244	62,373	58,453	73,481	66,169	63,316
	$E_{cooling}$	kWh/year	80,852	82,194	82,804	94,180	95,717	96,364

Table 16: Variations on the luminance control in the new/to be renovated office building model located in Tallinn and for different U-values for walls

Changing parameter		Units	Scenario: 30% glazing			Scenario: 50% glazing		
			U_{wall}=0.2	U_{wall}=0.14	U_{wall}=0.10	U_{wall}=0.2	U_{wall}=0.14	U_{wall}=0.10
Without lighting	$E_{lighting}$	kwh/year	180,270	180,270	180,270	180,270	180,270	180,270
	$E_{heating}$	kWh/year	245,310	238,503	233,873	255,792	250,632	247,174
	$E_{cooling}$	kWh/year	35,409	35,959	36,325	43,828	44,325	44,662
With lighting	$E_{lighting}$	kWh/year	92,459	92,459	92,459	78,518	78,518	78,518
	$E_{heating}$	kWh/year	270,823	263,636	258,811	287,011	281,588	277,950
	$E_{cooling}$	kWh/year	20,405	20,761	21,012	26,783	27,139	27,381
With partial	$E_{lighting}$	kWh/year	136,364	136,364	136,364	129,394	129,394	129,394
	$E_{heating}$	kWh/year	258,066	251,069	246,342	271,401	266,110	262,562
	$E_{cooling}$	kWh/year	27,907	28,360	28,668	35,305	35,732	36,021

e) **Share of renewable energy sources:** The integration of active solar technologies was assumed to evaluate the improvement potential of these technologies. Solar installations were considered with a south orientation and 40 degree slope. Radiation levels correspond to PV Geographical Information System (PVGIS), Geographical Assessment of Solar Resource and Performance of PV Technology (JRC-EC), as indicated in Table 17.

Table 17: Solar radiation levels for the three locations

LONDON		MADRID		TALLINN	
Month	Daily global solar irradiation [Wh/m²]	Month	Daily global solar irradiation [Wh/m²]	Month	Daily global solar irradiation [Wh/m²]
Jan	1,297	Jan	3,434	Jan	1,005
Feb	2,061	Feb	3,965	Feb	2,097
Mar	2,772	Mar	5,705	Mar	3,325
Apr	4,084	Apr	5,383	Apr	4,252
May	4,611	May	6,097	May	5,215
Jun	4,576	Jun	6,400	Jun	4,942
Jul	4,737	Jul	6,663	Jul	5,087
Aug	4,446	Aug	6,562	Aug	4,733
Sep	3,463	Sep	5,980	Sep	3,408
Oct	2,480	Oct	4,742	Oct	2,479
Nov	1,535	Nov	3,480	Nov	1,101
Dec	917	Dec	2,781	Dec	671
Year	3,086	Year	5,106	Year	3,199

Source: http://re.jrc.ec.europa.eu/pvgis/

The thermal and/or electricity energy produced by using solar systems were assumed to be consumed within the building, reducing the external demand. An electricity balance between electricity sold to and bought from the electricity grid was considered.

Energy savings due to solar thermal energy systems were based on the standard [EN 15316-4-3:2007]. "Typical values", such as a zero-loss collector efficiency of 0.8 and a linear heat loss coefficient factor of 3.5 were assumed. The considered scenarios were:

- DHW provided by a solar thermal installation (see Table 18). As the generic model assumes an equal hot water demand for all cases, the only variation is the energy input from the solar thermal systems that depends on the location and the area of panel installed.
- DHW and Space Heating were provided by a solar thermal system. As the heating demand also depends on the location and the age of the building, there is a range results that are shown in Table 18.

Table 18: Energy production for DHW using solar thermal systems

Surface of the solar panel (m^2)	Energy production for DHW (kWh/year)		
	London	Madrid	Tallinn
10	6,991	11,128	7,097
20	10,453	13,729	10,176
30	11,448	14,277	11,008
40	11,997	14,363	11,406
50	12,353	14,381	11,695
60	12,618	14,381	11,993

Solar PV installations were considered, according to [IEA-PVPS, 2009] with a performance ratio of 75% and a life expectancy of 30 years. The solar radiation was calculated per m^2 according to the [EN 15316-4-6:2007]. The main assumptions were the use of multi crystalline silicon panels with a peak power coefficient of 0.13 kW/m^2.

Table 19: Delivered electricity using PV systems

Surface of the PV panel (m^2)	Delivered electricity (kWh/year)		
	London	Madrid	Tallinn
20	2,196	3,634	2,277
40	4,393	7,268	4,554
60	6,589	10,903	6,831
80	8,786	14,537	9,108
100	10,982	18,171	11,384
120	13,179	21,805	13,661

4.1.3 Life Cycle Impact Assessment (LCIA)

The impact categories and category indicators showed in Table 20 were selected in this LCA study based on scientific robustness and relevance. Besides, the primary energy consumption and the water consumptions were also quantified.

Following ISO 14040-44 guidelines, the LCI results were assigned into the selected impact categories (classification) and then aggregated into the category indicators (characterization). In this study mid-point indicators were chosen and the characterization factors provided by the CML 2002 methodology [Guinée et al 2002] were applied[10].

Table 20: Impact categories and indicators used in the LCIA

Impact Category	Category indicators
Global Warming Potential (GWP)	kg CO_2 equiv
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 equiv
Acidification potential of land and water (AP)	kg SO_2 equiv
Eutrophication Potential (EP)	kg $(PO_4)^{3-}$ equiv
Photochemical ozone formation (POF)	kg Ethene equiv
Abiotic depletion potential (ADP)	kg Sb equiv
Environmental indicator	**Unit**
Primary energy consumption (PEC)	MJ
Water consumption (WC)	m^3

The environmental impact assessment was completed with the normalisation and weighting factors shown in Table 21. The weighting steps are based on value-choices and different parties with different preferences reach different weighting results based on the same indicator results. However, in this study the use of normalisation and weighting factors allow ranking the models and their estimated overall environmental impacts to calculate the benchmarks that characterize the top best environmental performing buildings.

Normalised LCIA results give for each impact category the relative share of the environmental impact accounted for the functional unit. These results help to identify to which impact categories the analysed system contributes relatively more and to which relatively less. Normalised results were obtained by a normalisation basis which is different for each impact category [IES, 2010].

On the other hand, weighting factors assign quantitative weights to all impact categories expressing their relative importance. During the weighting process, the normalised results are multiplied by the relative weighting factor and, finally, summed up [IES, 2010].

Table 21: Normalisation and weighing factors used in the LCIA.

Impact Category	Normalisation factors*		Weighting factors**
Global Warming Potential (GWP)	5.21E+12	kg CO_2 equiv	0.67
Depletion potential of the stratospheric ozone layer (ODP)	1.02E+07	kg CFC 11 equiv	0.58
Acidification potential of land and water (AP)	1.68E+10	kg SO_2 equiv	0.14
Eutrophication Potential (EP)	1.85E+10	kg $(PO_4)^{3-}$ equiv	0.10
Photochemical ozone formation (POF)	2.66E+09	kg Ethene equiv	0.36
Abiotic depletion potential (ADP)	6.04E+06	kg Sb equiv	0.44

*factors corresponding to CML 2001-Nov.09, EU25+3 [GaBi-DB]
**factors corresponding to the average between CML2001 - Dec. 07, Experts IKP (Southern Europe), CML2001 - Dec. 07, Experts IKP (Central Europe) and CML2001 - Dec. 07, Experts IKP (Northern Europe) [GaBi-DB]

[10] These factors can be downloaded from: http://cml.leiden.edu/software/data-cmlia.html

4.1.3.1 General results at building level

Characterisation results:

Table 22 and Figure 4 show the characterisation results of the LCIA of the generic model located in **London**. Results are referred to the functional unit. The use phase accounts for the majority of the environmental burdens but the Abiotic Depletion Potential (ADP) which is related to the extraction of natural resources and, consequently, to the product phase.

Table 22: Total environmental impact of 1m^2 of office area during 1 year according to life cycle phases. Characterisation results

Impact Category/ environmental indicator	Units	TOTAL	I. Product phase	II. Construction phase	III. Use phase	IV. End of life phase
GWP	kg CO_2 equiv	4.07E+01	3.53E+00	7.30E-02	3.65E+01	5.34E-01
ODP	kg CFC 11 equiv	7.67E-06	1.06E-07	1.46E-10	7.56E-06	4.04E-09
AP	kg SO_2 equiv	2.52E-01	6.45E-03	3.29E-04	2.44E-01	1.97E-03
EP	kg $(PO_4)^{3-}$ equiv	1.02E-02	1.12E-03	7.66E-05	8.69E-03	3.17E-04
POF	kg Ethene equiv	1.36E-02	6.72E-04	3.76E-05	1.26E-02	3.26E-04
ADP	kg Sb equiv	1.96E-05	1.72E-05	1.54E-09	2.38E-06	4.35E-09
PEC	MJ	7.69E+02	4.55E+01	1.04E+00	7.18E+02	4.80E+00
WC	m^3	1.51E+04	1.08E+01	1.94E-02	1.51E+04	5.86E+00

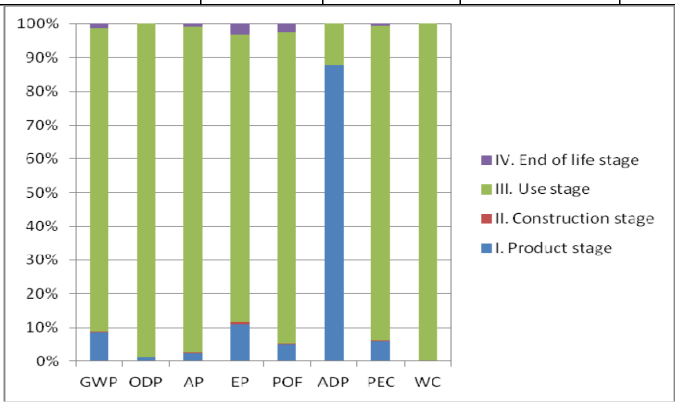

Figure 4: Relative contribution of the different life cycle phases to the environmental impact of 1m^2 of office area during 1 year located in London

Figure 5 illustrates the contribution of the individual building elements to the environmental impact of the product phase. The structure followed by floors/ceiling are, the building elements with the highest environmental impacts. The influence of the structure composition in the overall environmental impacts of the building was assessed in a sensitivity analysis.

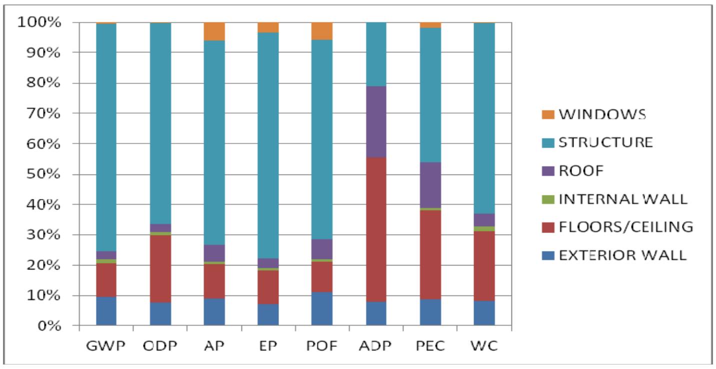

Figure 5: Contribution of the different building elements to the overall environmental impact of the construction of 1m^2 of office area

Figure 6 indicates the contribution of both energy and water consumptions to the environmental impact during the use phase of the building located in London. Lighting is responsible for 60-70% of the overall environmental impacts of the use phase. This value would be even higher if the electricity use for office equipment was accounted and no lighting control was present.

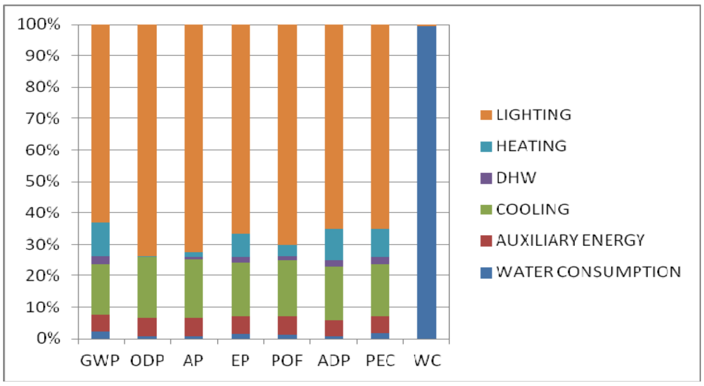

Figure 6: Contribution of the different use processes to the environmental impact of 1m^2 of office area during 1 year in London

<u>Normalisation and weighting results</u>: Table 23 and Figure 7 summarize the normalisation and weighting results per product phase.

Table 23: Total environmental impact of 1m^2 of office area during 1 year according to life cycle phases. Normalisation and weighting results.

Impact Category/ environmental indicator	Units	TOTAL	I. Product Phase	II. Construction phase	III. Use phase	End of life phase
GWP	-	5.20E-12	4.52E-13	9.34E-15	4.67E-12	6.83E-14
ODP	-	4.39E-13	6.07E-15	8.34E-18	4.32E-13	2.31E-16
AP	-	2.14E-12	5.48E-14	2.79E-15	2.07E-12	1.67E-14
EP	-	5.51E-14	6.03E-15	4.14E-16	4.70E-14	1.71E-15
POF	-	1.85E-12	9.13E-14	5.11E-15	1.71E-12	4.44E-14
ADP	-	1.44E-12	1.26E-12	1.13E-16	1.75E-13	3.20E-16

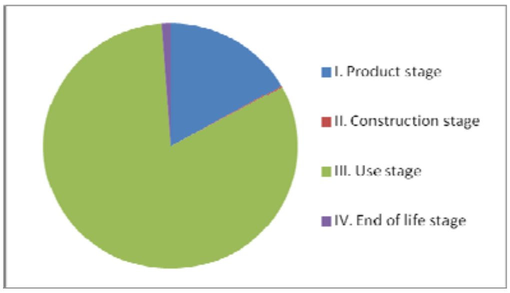

Figure 7: Contribution of the different life cycle phases in the overall normalised and weighted results

Figure 8 shows the contribution of the building elements to the overall normalised and weighted results, whereas Figure 9 shows the results related to the use phases. Floors and structure are the building elements which mostly determine the environmental impact of the office building in its construction phase. In the other hand, lighting (without a lighting control in this model) is responsible for the major part of the environmental impact during the use phase and, consequently, during the complete life cycle. It is remarkable that despite the total energy consumption for cooling which is almost half of its heating consumption, the environmental impact of the first almost triplicates the second. The reason is that electricity (with higher environmental burdens) is used for cooling, whereas heating systems is assumed to work with natural gas.

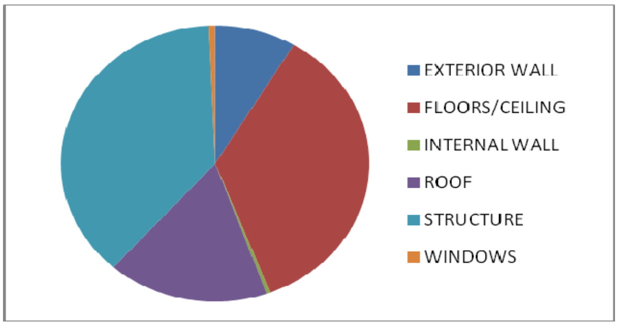

Figure 8: Contribution of the different building elements to the overall normalised and weighted environmental impact of the construction of 1m^2 of office area

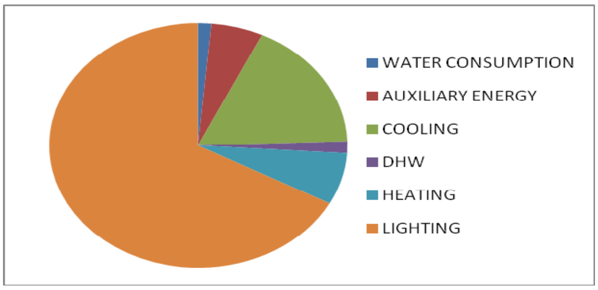

Figure 9: Contribution of different energy consumptions to the normalised and weighted environmental impacts during the use phase of 1m^2 of office area during 1 year

4.1.3.2 Scenarios related to the building location and age

Figure 9 compares the overall characterization results per each impact category and location according to assumptions explained in 3.2.2.1. Results were normalizes by the location of London to highlight the differences between climatic zones. New/to be renovated buildings have lower environmental impacts due to the lower energy consumption for heating and cooling (derived from a reduction of the U-values). Results differ between 2 and 23% depending on the location and impact category.

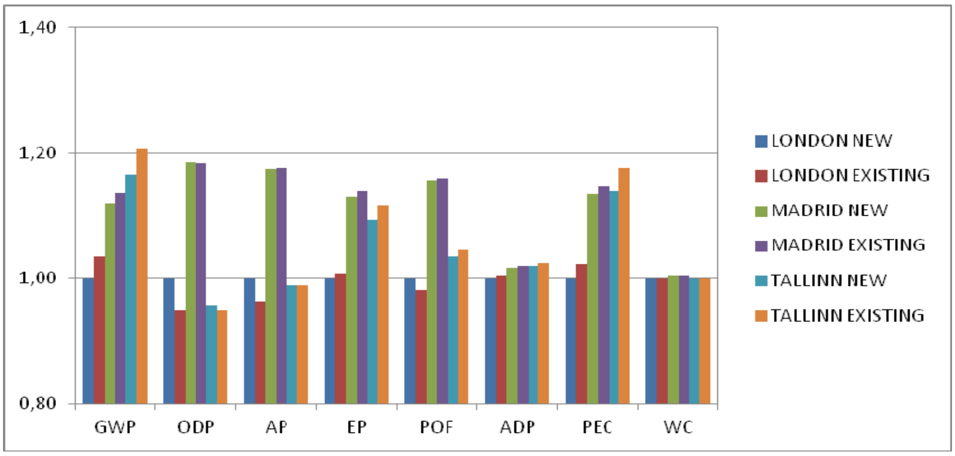

Figure 10: Comparison of the overall characterization results per each impact category and location for both new/to be renovated and existing buildings

Figure 11 draws the overall normalised and weighted results. The office building located in London presents the lowest overall environmental impacts, followed by Tallinn (10% higher) and Madrid (15% higher). The use phase is the highest environmentally relevant phase and it is responsible for the variations observed in the different locations, whereas the other life cycle phases remain equal.

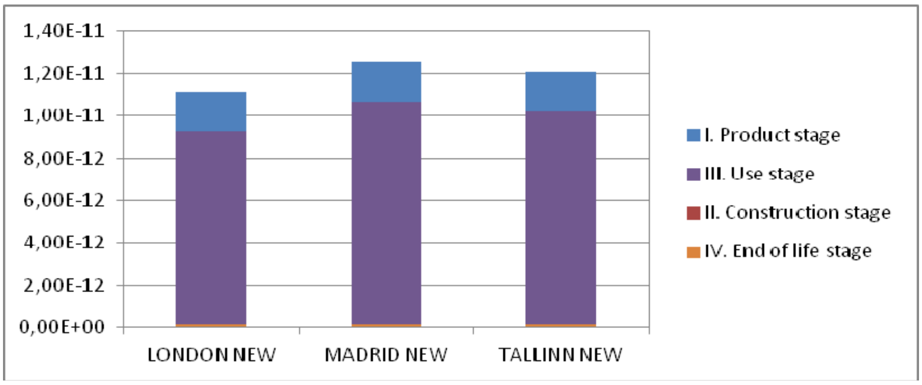

Figure 11: Comparison of the normalised and weighted overall results for each location

Finally, Figure 12 indicates the normalised and weighted results of the use phase, showing the contribution of the different processes involved. As expected, and mainly due to the absence of lighting control, lighting water consumptions and DHW production remain constant regardless the location, whereas the differences in cooling and heating consumptions explain the differences in the total results.

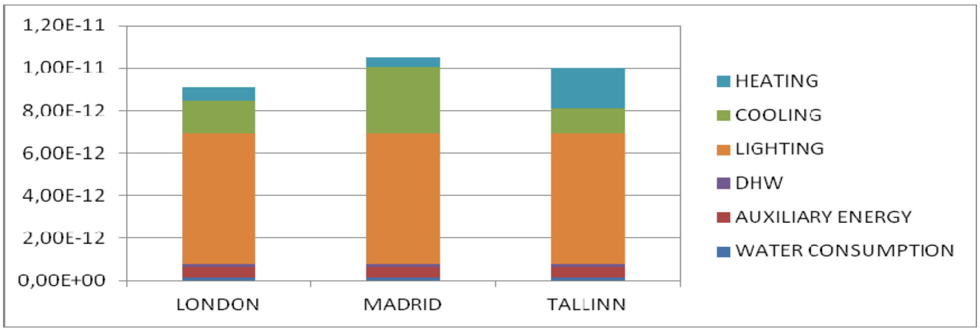

Figure 12: Comparison of the normalised and weighted results of the use phase for each location

4.1.3.3. Scenarios related to the percentage of glazing

Figure 13 and Figure 14 show the environmental profiles of different glazing area percentages and locations divided by the ones of the base case of 30% glazing located. Generally, the increase of the glazing surface conducts to higher environmental impacts due to higher energy consumption of energy for heating and cooling. These base cases were modelled without lighting control, therefore the benefits of larger glazing areas increasing the daylight availability are not taken into consideration in this section but in section 3.3.6.

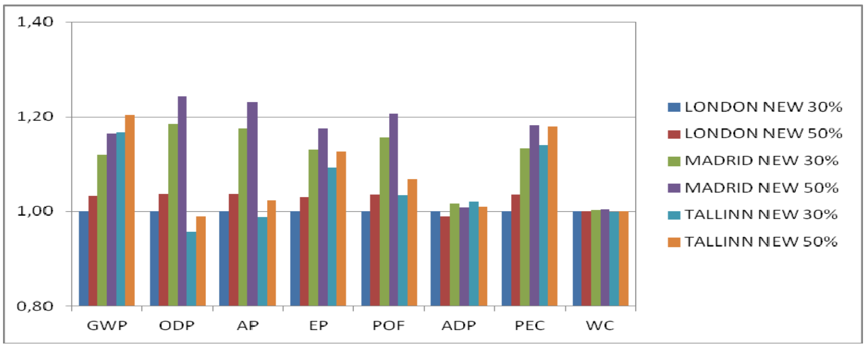

Figure 13: Comparison of the overall characterization results per each impact category, location and percentage of glazing of new buildings/to be renovated

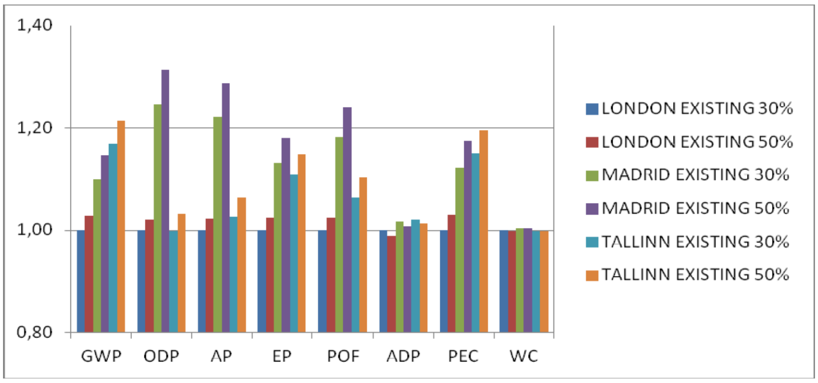

Figure 14: Comparison of the overall characterization results per each impact category, location and percentage of glazing of existing buildings

Figure 15 shows normalised and weighted results. According to the methodology used, GWP accounts for the major part of the environmental impact generated by the office building along its life cycle. The normalised and weighted results show a slight difference lower than 2% between new/to be renovated and existing buildings.

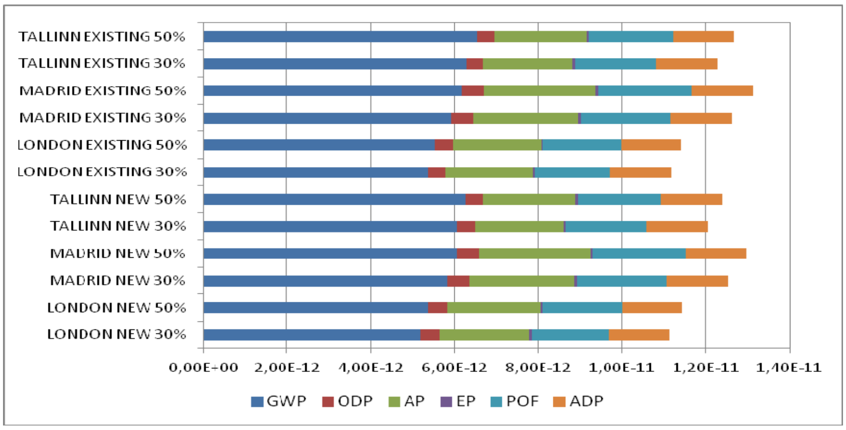

Figure 15: Comparison of the normalised and weighted results for each location, age and percentage of glazing

4.1.3.4 Scenarios related to U-value variations

Figure 16 compares the environmental profile of the buildings depending on the variation of the U-values of walls and windows. Changes in the U-value of walls and windows do not imply a significant variation of the overall environmental profile of the buildings. The main cause is, once again that the lighting energy consumption dominates the environmental profile of buildings being not affected by the change in the U-values. Further analysis is given in the following scenarios assessments.

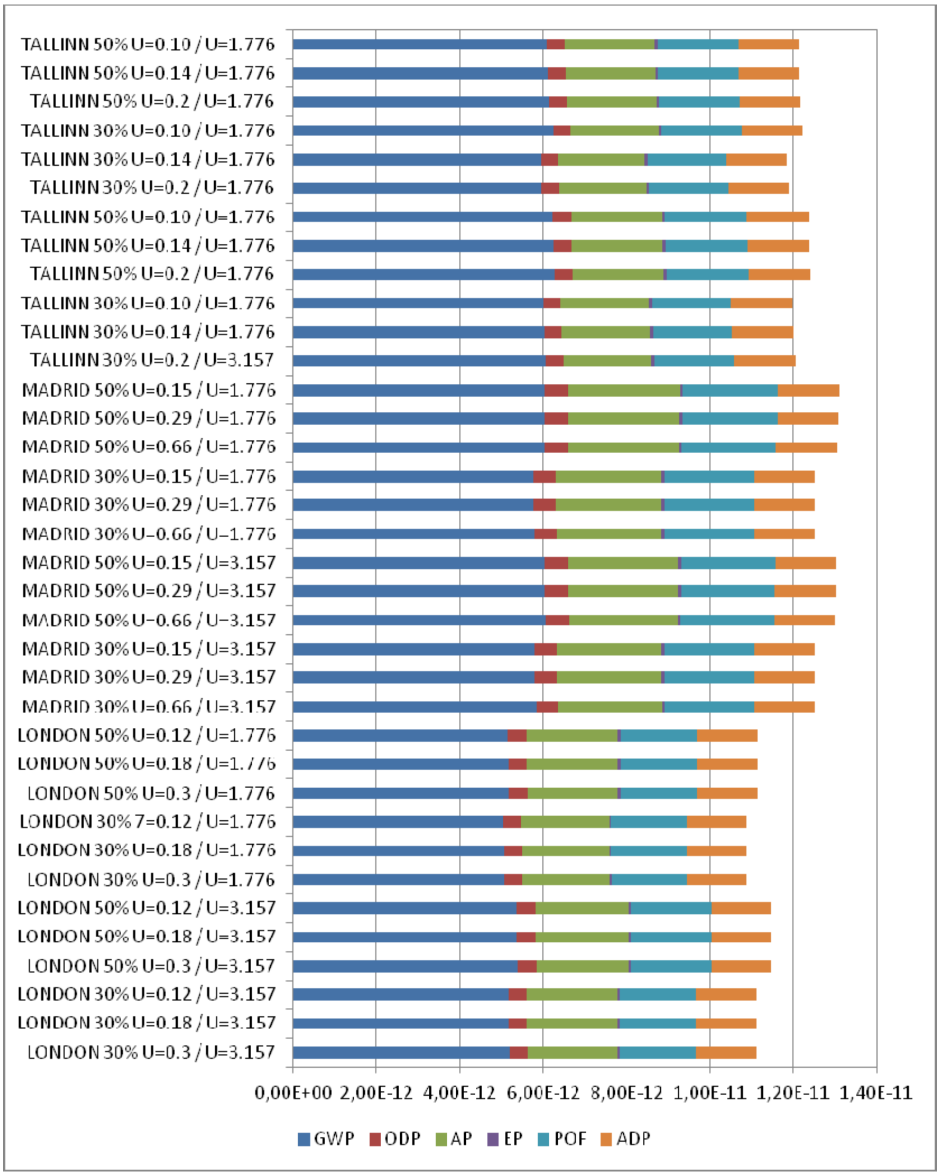

Figure 16: Comparison of the normalised and weighted results for each location, percentage of glazing and variation of the U-values of walls and windows

Note: the name of each series describes the location (London, Madrid or Tallinn), the percentage of glazing (30 or 50%) and the U-value of walls (different possibilities depending on the location) and of windows (1.776 or 3.157).

4.1.3.5 Scenarios related to lighting control

Figure 17 illustrates the comparison of the environmental profile of the new/to be renovated office buildings with and without lighting control. Lighting control allows reducing the energy consumption depending on the availability of natural daylight. The lighting control reduces remarkably the environmental impact of the building (30'% reduction is achieved in the London and Madrid locations, and 20% in Tallinn). The installation of a total lighting control for the entire office building area clearly entails major environmental benefits than partial lighting control (i.e. only for half of the inner area) in both London and Madrid locations, whereas in the case of Tallinn the difference is slight.

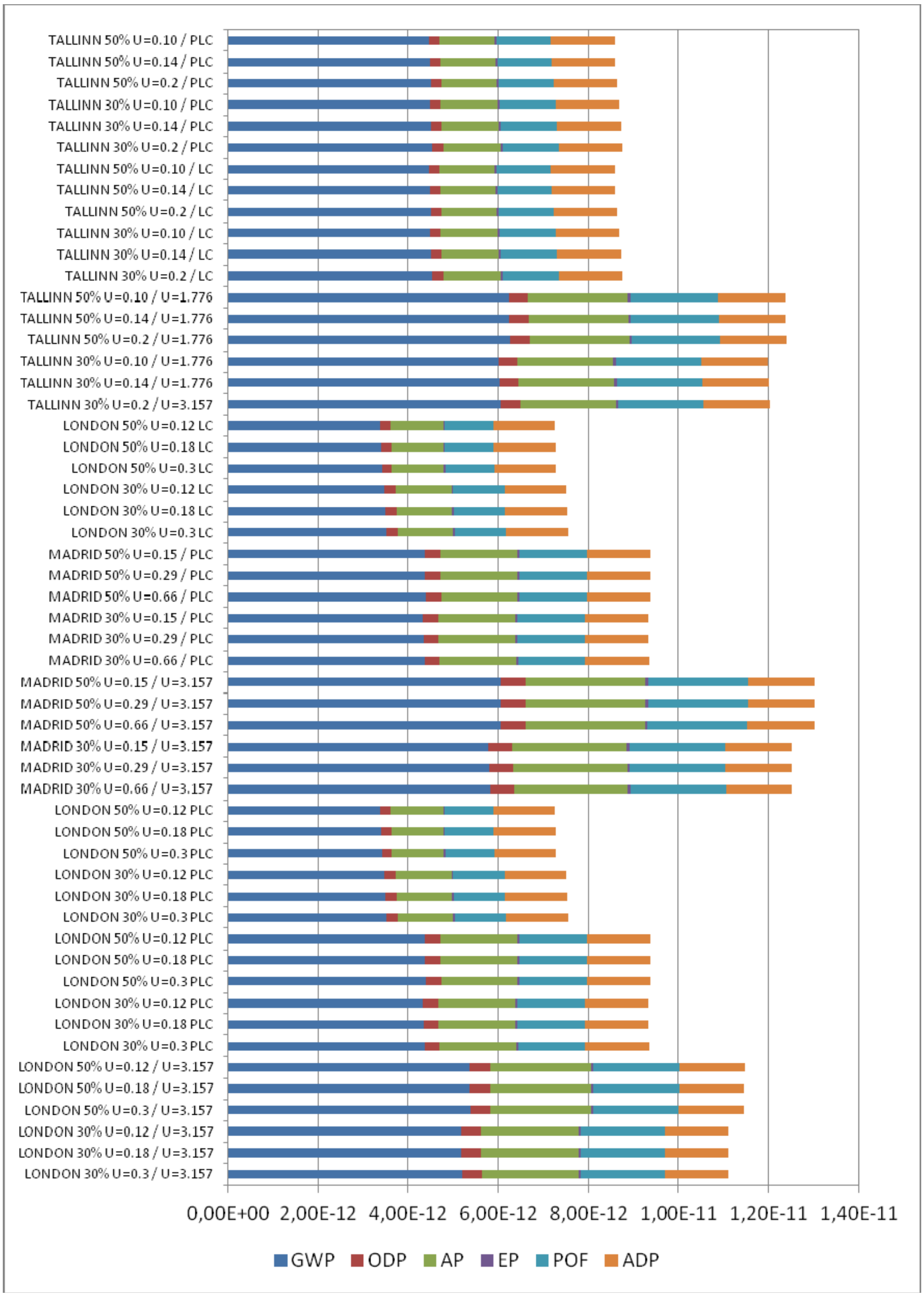

Figure 17: Comparison of the normalised and weighted results of the building with lighting control depending on each location and U-value of walls

Note: the name of each series describes the location (London, Madrid or Tallinn), the percentage of glazing (30 or 50%), the U-value of walls (different possibilities depending on the location) and of windows (1.776 or 3.157) and PLC and LC stands for partial lighting control and lighting control, respectively.

The lower environmental benefits achieved in the location of Tallinn while a lighting control is installed is due to the higher heating needs. Lighting produces internal heat loads that decrease the overall heating energy needs of the building. Therefore, a reduction of the lighting is particularly beneficial in locations where there is lower heating demand and higher cooling demand. The increase of glazing percentage when including lighting control strategies brings in general environmental benefits because of the increase daylight area offset although the heat losses and gains are also increased due to the higher glazing.

4.1.3.6. Scenarios related to renewable energy

The environmental benefits of the installation of thermal solar or PV panels were studied in this section. The introduction of solar technologies is an example of the environmental benefits that can be achieved by using renewable energy sources. The results can be qualitatively extrapolated to the use of other renewable energy sources such as biomass, hydroelectric or even wind power. The most suitable renewable energy source to be established depends on the location and building design. Therefore, the designer/construction is the responsible of this selection.

Figure 18 highlights only the most relevant scenarios showing the normalised and weighted overall results of the building life cycle. Results summarized the installation of 10, 30 or 60 m^2 of solar thermal panels, 20, 80 or 120 m^2 of PV panels and the combination of 60 m^2 of solar thermal panels and 120 m^2 of PV panels. The base case consisting in 30% of glazing with no solar system installed was added for the sake of comparison.

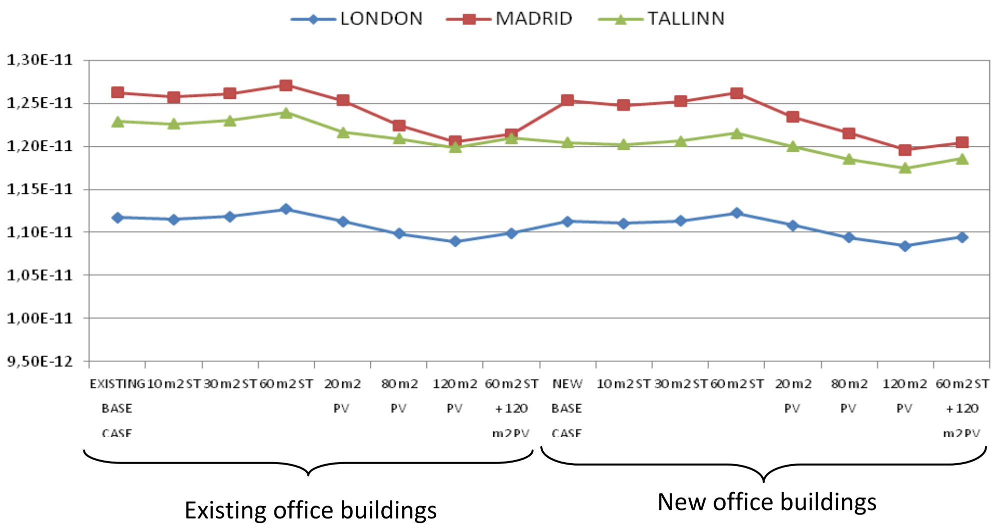

Figure 18: Comparison of the normalised and weighted results of existing and new buildings in different locations and with renewable energy systems installed

Note: ST stands for “solar thermal energy” and PV for “PV energy”.

In general the installation of PV panels slightly reduces the environmental impact of the building being the reductions sharper in Madrid (but, lower than 5%). However, the installation of PV panels reduces the environmental impact of the building proportionally to their surface. This fact is due to: a) solar thermal panels has little influence on the overall results. The installation of a small area of solar thermal panels (10 m^2) also reduces slightly the environmental impact because of the low thermal demand during a large part of the year and b) an increase in the solar panel area does not bring any additional environmental benefits as the performance of the solar panels decrease. Even in some cases the environmental impact of the solar thermal panels can be higher than the obtained benefits.

4.1.4. Life Cycle Interpretation Sensitivity analysis

The objective of the sensitivity analysis is to assess the reliability of the final results and conclusions by determining how they are affected by uncertainties in the data, assumptions, etc. For the sake of simplicity, each sensitivity analysis was performed for a maximum of three office building models. When only one model was needed, the model located in London new construction and 30% of glazing (B1-N-01 according to Annex 1) was selected. The following aspects may have a relevant influence on the results and were proposed for sensitivity analyses:

a) **Type of energy source** (e.g. electricity, diesel, etc.) used for heating. In the base case was assumed that natural gas is used instead of other sources such as electricity, light fuel oil, biomass, etc. A sensitivity analysis replacing the natural gas by light-fuel oil demonstrated that the overall environmental impact of the building was slightly increased (4%). Therefore, it was concluded that the heating energy sources do not comprise the general results of this study.

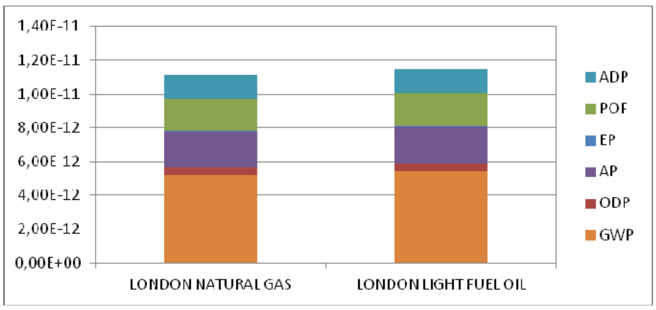

Figure 19: Assessment of the effect of the change in the energy source used for heating in the overall results

b) **Type of energy source for the production of electricity**. The assumed EU-27 average grid mix was substituted by the national grid mixes of the countries where the buildings were located. The environmental impacts of the national grid mixes for UK, Spain and Estonia are showed in Table 24.

Table 24. Energy mix for the production of electricity in EU-27 and in the countries where the office buildings are located. Source: [ELCD] and [GaBi DB]

Grid Mix (%)	UE-27	London (UK)	Madrid (Spain)	Tallinn (Estonia)
Hard Coal	18.3	32.71	10.66	90.60
Heavy Fuel Oil	6.0	1.82	1.04	0.30
Hydropower	11.1	1.96	11.53	0.10
Lignite	11.3	40.03	1.80	0.00
Natural Gas	17.0	23.16	40.91	8.40
Nuclear	31.7	0.33	19.73	0.00
Wind	1.1	0.00	14.33	0.00
Peat	0.2	0.00	0.00	0.20
Others	3.3	0.00	0.00	0.40

Figure 20 illustrates that the power grid mix does have a significant influence in the overall results if the mix of the national grid is close to the European mix. In line with this observation, The Estonian power grid mix (mainly based on coal and other fossil fuels) has the biggest environmental impact while the other two present similar environmental impacts.

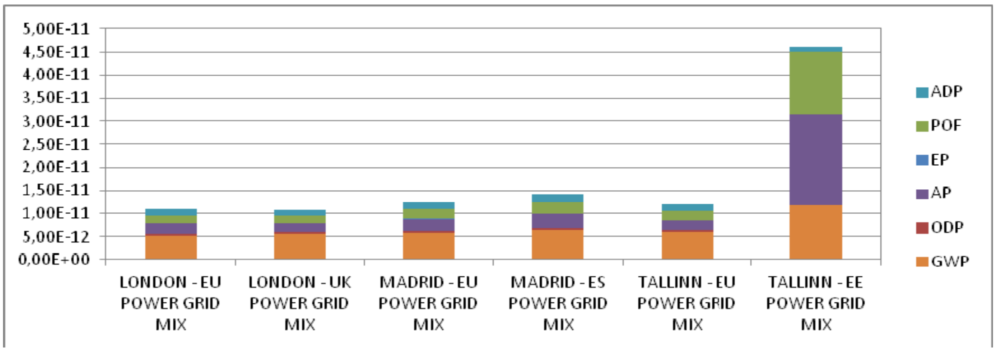

Figure 20: Assessment of the effect of the power grid mix in the overall results

c) **Transportation distance** of the building components between factories or landfill and the office building, was changed to from 50km assumed in the base case to 150 or 300km. This assessment of increasing the transportation distance during the construction phase is associated to the module A4 while the increase transportation distance during the demolition phase is associated to the module C2. **Error! Reference source not found.** shows that the transportation distance has a negligible effect on the overall building life-cycle environmental profile. Therefore, this assumption does not compromise the general results.

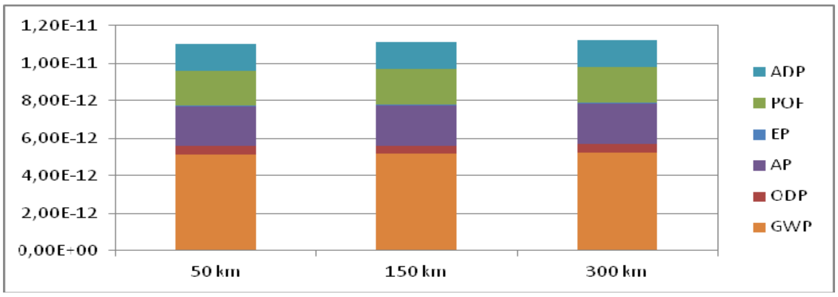

Figure 21: Assessment of the effect of the change in the materials and waste distance transportation in the overall results

d) **Orientation of the building.** The east-west orientation assumed in the base case was changed to south-north orientation. In particular, the energy consumption of the B1-N-01 building (London, new, 30% of glazing) was simulated with an orientation north-south. The energy performance of this building with an orientation south-north are provided in Table 23**.**

Table 25 Energy consumption of the building located in London associated to its orientation

Energy use kWh/year	East-West orientation	North-South orientation
Lighting	180,270.40	180,270.40
Auxiliary energy (pumps, fans, etc.)	15,070.98	15,070.98
Heating	79,388.83	72,169.59
Cooling	46,680.53	45,062.27
Domestic Hot Water	17,976.31	17,976,31.

As this variation does not affect the lighting consumption, which determines hugely the environmental impact of the building, the change in the orientation of the building does not compromise the general results

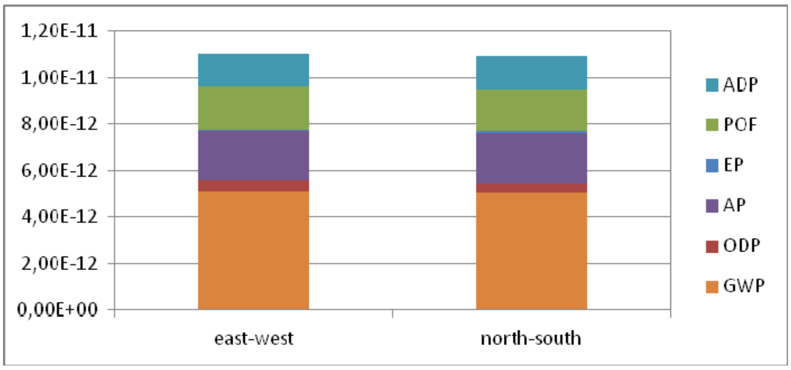

Figure 22: Assessment of the effect of the orientation in the overall results

e) **Materials composition of the building structure** was changed to check the influence of replacing a structure of reinforced concrete assumed in the base case by, one of reinforcement steel.

Table 26. Materials composition of the assessed building structure

Material	Reinforced concrete structure (kg)	Reinforced steel structure (kg)
Concrete (forge)	2.970.000	2.970.000
Reinforcement steel (forge)	189.000	189.000
Reinforcement steel (structure)	69.000	133.310
Cast concrete (structure)	907.000	686.000
Total	4.135.000	3.978.310

Although the structure was identified as the building element with a higher environmental impact Figure 23 shows that the change in the materials composition of the building structure does not influence the overall results and, consequently, this assumption does not compromise the assessment.

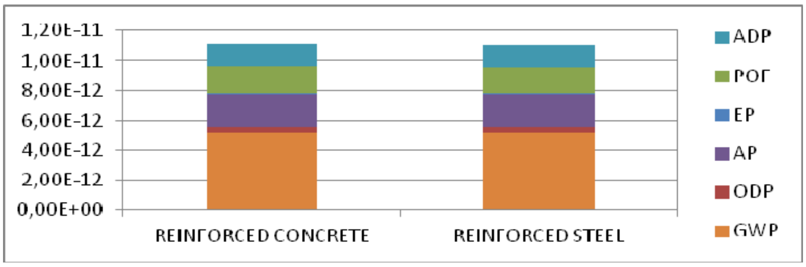

Figure 23: Assessment of the effect of a change in the structure materials in the overall results

f) **End-of-life scenario.** The base case LCA analysis was performed assuming that all the building materials are deposited in landfill. In order to check the environmental benefits of recovering the construction and demolition waste, LCA analyses were performed assuming a high rate of recycling (90% of the steel). In the base case analysis it was considered that the waste generated in the end-of-life phase ends in a landfill facility. This hypothesis was changed by an alternative scenario in which all recyclable materials of the building are recycled avoiding the extraction of raw materials. Considering the recycling potential of the materials, their amount and use within the building, a recycling up to 90% of concrete, brick and steel (83% of the total weight of the building) was considered. Then, it was assumed that concrete and brick avoid the production of aggregates, whereas the steel is reintroduced as scrap in the production of steel products. In both cases, a 95% efficiency rate for the recycling processes was assumed. Figure 24 shows that the overall impact results are slightly lower (2%) in the recycling scenario and, therefore, the assumption made in relation to the end-of-life scenario does not affect the general conclusions of this study. When, in the future, the use phase will lose its predominance in the overall life cycle of buildings, the recycling efforts will have a higher influence on the overall environmental profile of the office buildings.

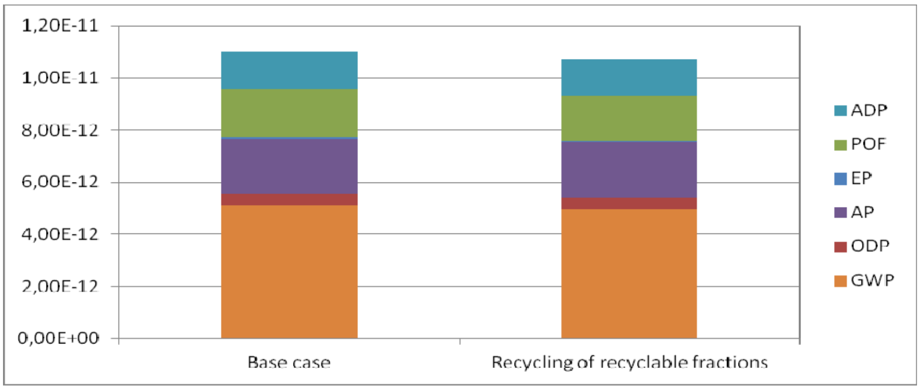

Figure 24: Assessment of the effect of a change in the end-of-life scenario in the overall results

g) **Water consumption** the base case LCA analysis was performed assuming 55l/p/day of water consumption. This amount corresponds to the medium value within the range from 11 to 100 l/p*d identified in [Superbuildings, 2011] as the average water consumption of office buildings in Europe. This figure was modified to assess its influence on the overall environmental impact of the building. Figure 25 shows the characterised impact results of the B1-N-O1 model building with a water consumption equals to 55.5 l/p*d (base case), 11 l/p*d (lowest consumption) or 100 l/p*d (highest consumption). The water consumption indicator varies remarkably (as expected), while the primary energy consumption indicator and the environmental impact categories remain unchanged. For this reason, the normalised and weighted results do not change due to a change in the water consumption of the office building, as illustrated in Figure 26.

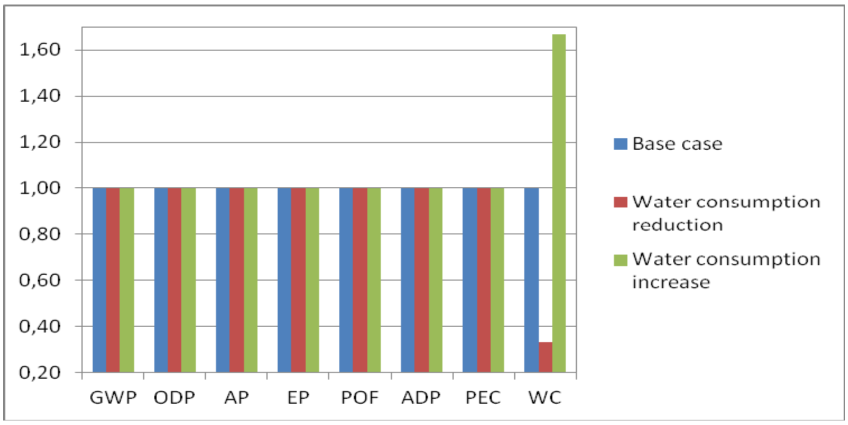

Figure 25: Assessment of the effect of a change in the water consumption in the overall results (characterised results)

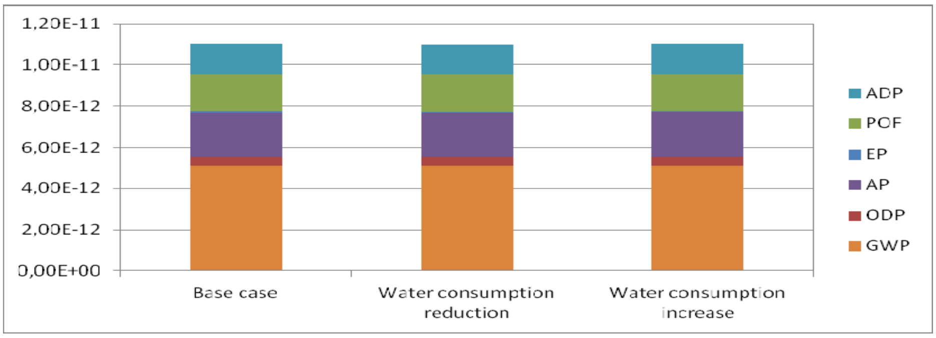

Figure 26: Assessment of the effect of a change in the water consumption in the overall results (normalised and weighted results)

4.1.5 Summary and conclusions

The LCA analysis of a simplified generic model was performed in this section. This analysis allowed the identification and quantification of the LCA-environmental impacts and pointing out the following remarks:

Not significant differences were observed between the overall environmental impacts of the office buildings depending on the different locations (climatic zone) or selection of construction materials or techniques (the percentage of glazing area or U-values).

Moreover, there are several environmental aspects such as transportation distance of the building materials and the C&D waste, the end-of-life scenario (landfill or recovery of the C&D waste) and the amount of water consumption that cause relatively low overall environmental impacts. These results were obtained by means of sensitivity analyses. These analyses demonstrated the reliability of the final results and that the conclusions are not affected by those assumptions.

Regarding the overall environmental impacts cause during the life-cycle phases of the building, the use phase causes the highest environmental impact because of the energy consumption during this long phase (50 years). Therefore, any improvement in this area should be related to the use of more energy efficient construction materials and technologies and the use of cleaner energy sources. Among the energy consumption shares, lighting causes the highest environmental impacts, in particular, when no lighting control strategies are implemented. Thus, any lighting control systems will help to considerably reduce the energy consumption of office buildings and, consequently, to improve the overall environmental performance of the building.

The use of cleaner energy sources was also studied. The installation of solar technologies (thermal and PV) was selected as a representative of the renewable energy sources. PV panels reduce the overall environmental impact of office buildings proportionally to the installed PV area, whereas solar thermal panels have an optimal installed area. This fact is due to the low hot water demand in office buildings.

The use of cleaner energy sources can be achieved by using cleaner electricity as well. However, this option is, until a certain extent, not under the control of the developer/owner as it depends on the location of the building. The environmental profile of a specific building may differ enormously from one country to other, not only due to a different heating and cooling energy demands but mainly to the differences in the environmental impacts associated to the applicable energy grid mix.

In comparison to the environmental impacts caused by the energy consumption, the production phase has lower environmental impacts. In this study, the analysis of a simplified generic building does not allow the exact quantification of the environmental impacts caused during this phase, but it points out that the difference between both life cycle phases must be significant. These results are consistent with other previous studies such as [IMPRO 2008].

Despite the abovementioned limitations of the study, results suggest that the definition of Ecolabel criteria and benchmarks for the development of Ecolabel criteria of office buildings should be focused on reducing the energy consumption of the building and the use of high polluting energy sources

However, and because of the trend of getting nearly zero building in the coming years and consequently the significant reduction of the environmental impact caused by this aspect, some environmental aspects of other life cycle phases, such as the production phase or the end-of-life phases should be considered.

4.2 Identification of the key non-LCA environmental impacts and non-LCA environmental aspects

Four main environmental criteria areas were identified by means of the revision of non-based LCA studies: a) the content and release of hazardous substances from the construction products, b) the indoor air quality and well-being, c) facilities to decrease the energy consumption of the employees while commuting and finally d) the user's information. The two first environmental areas are both of them directly related to the comfort and human health of the occupants of the building.

The need of identifying the hazardous substances and the avoidance of these materials in the ecolaballed products is explicitly expressed in the EU Ecolabel Regulation No CE 66/2010.

Moreover, the use of hazardous substances in the construction sector is strongly regulated at European level by several directives regulations and voluntary standards, such as the Construction Product Declaration (CPD), the REACH regulation EC 1907/2006 or the CEN TC 351 standards (Technical report TR 16045:2010 “Construction Products - Assessment of release of dangerous substances - Content of regulated dangerous substances -Selection of analytical methods).

The current EU Ecolabel Regulation No EC 66/2010 states an aim to exclude problematic chemicals and is based on the application of the precautionary principle. This exclusion principle is stated by Article 6.6 of this Regulation and proposed to be carried out according to several classifications, but mainly by the R-phase reference system. Moreover, and due to the inherent properties of the substances some other concerning chemicals should be excluded if classified as dangerous to human health, environment, carcinogenic, mutagenic, reproductive toxic, neurotoxic, immunotoxic, allergenic or sensitivers, endocrine disrupting, persistents, bioaccumulative or substances with other problematic hazardous properties.

Finally, the indoor air quality (IAQ) is the last environmental criteria area identified in this work. Generally speaking, office buildings have a poorer IAQ due to the additional emissions coming from the office equipment installed there, as reported by [Bjarne 2006]. This fact has been previously identified and therefore there are several CEN standards at European level whose main goal is the improvement of the IAQ of buildings [EN 15251:2007 “Criteria for the indoor environment including thermal, indoor air quality (ventilation) light and noise” and CEN/TC 156 - Ventilation for buildings].

IAQ has traditionally been linked to the provision of adequate ventilation, and it was not until the 1990s that sources of pollutants other than the occupants were seriously considered. In office buildings, and as a result of the rapid introduction of new building materials, furnishings, the increase on office equipment and generally a reduction of the product replacement rate, the indoor concentration of various chemicals are likely to be increased [Bluyssen 2010]. Therefore, the development of criteria on IAQ is of key importance to reach Ecolabeled office buildings with an outstanding performance.

In the well-being criteria area the inclusion of noise and daylighting related criteria are typically addressed. Daylighting related criteria seem to be of especial importance in this kind of Ecolabel because of the high number of employees whose daily activities are related to clerk and administrative work. The daylighting criteria address aspects such as the sufficient amount of daylighting, the distribution of the light, non-glazing, etc.

The construction of facilities to reduce the energy consumption of the commuting of the employees is another environmental criteria area addressed in several existing member state labels. Studies summarized that the energy required for commuting is typically higher than the energy consumption of the office building itself. Therefore, the promotion of more sustainable commuting means, such as bicycles or public transportation, will bring great environmental benefits. Cycling seems to be the most sustainable commuting mean. The enhancement of cycling is possible if proper facilities are provided to the employees. For this reason, some criteria are developed in this area.

Finally, and as commented in the identification of the LCA environmental aspects and LCA environmental impacts, the energy consumption during the use phase causes the highest environmental impact all over the life cycle of the office building. This energy consumption is strongly dependent on the users behavior. Therefore, end users should be informed about the installed technologies and how they should be used. Information to the end users is usually communicated by:

a) posters which contain the information related to the Ecolabel and the criteria complied by the office building

b) user's manual which includes the information related to the technologies installed and how to use them

c) posters with environmental pieces of advice

5- Estimation of the overall LCA- environmental impacts of the office buildings

5.1. Identification of the buildings with best environmental performing buildings

Figure 27 compares the overall environmental impact associated to the base cases studied. The normalized and weighted results were put in order from least to most. To identify the buildings within the group of the 10-20% of the best performance office building on the EU-market, the normalized and weighted life cycle assessment results of the 189 base cases were multiplied by the number of existing units according to the ''Economic and market analysis report'' estimates.. Then, the results of the multiplications were summed up and, finally, it was calculated the % in which each base case contributes to the total amount. The bases cases shown in Table 28 are the ones with a lower environmental impact and, in total, sum up the 20% of the total value.

Table 27. Number of buildings of each type

Base case codes	Number of units	%
B1, existing (20 types in total): B1-E-01 to B1-E-20	6,626,946 (331,346 per type)	62
B1 new and to be renovated (43 types in total): B-N-01 to B-N-43	2,084,540 (48,478 per type)	20
C2, existing (20 types in total): C2-E-01 to C2-E-20	761,185 (38,059 per type)	7
C2, new and to be renovated (43 types in total): C2-N-01 to C2-N-43	222,545 (5,175 per type)	2
A1, existing (20 types in total): A1-E-01 to A1-E-20	722,385 (36,119 per type)	7
A1, new and to be renovated (43 types in total): A1-N-01 to A1-N-43	203,703 (4,737 per type)	2
TOTAL	10,621,304	100

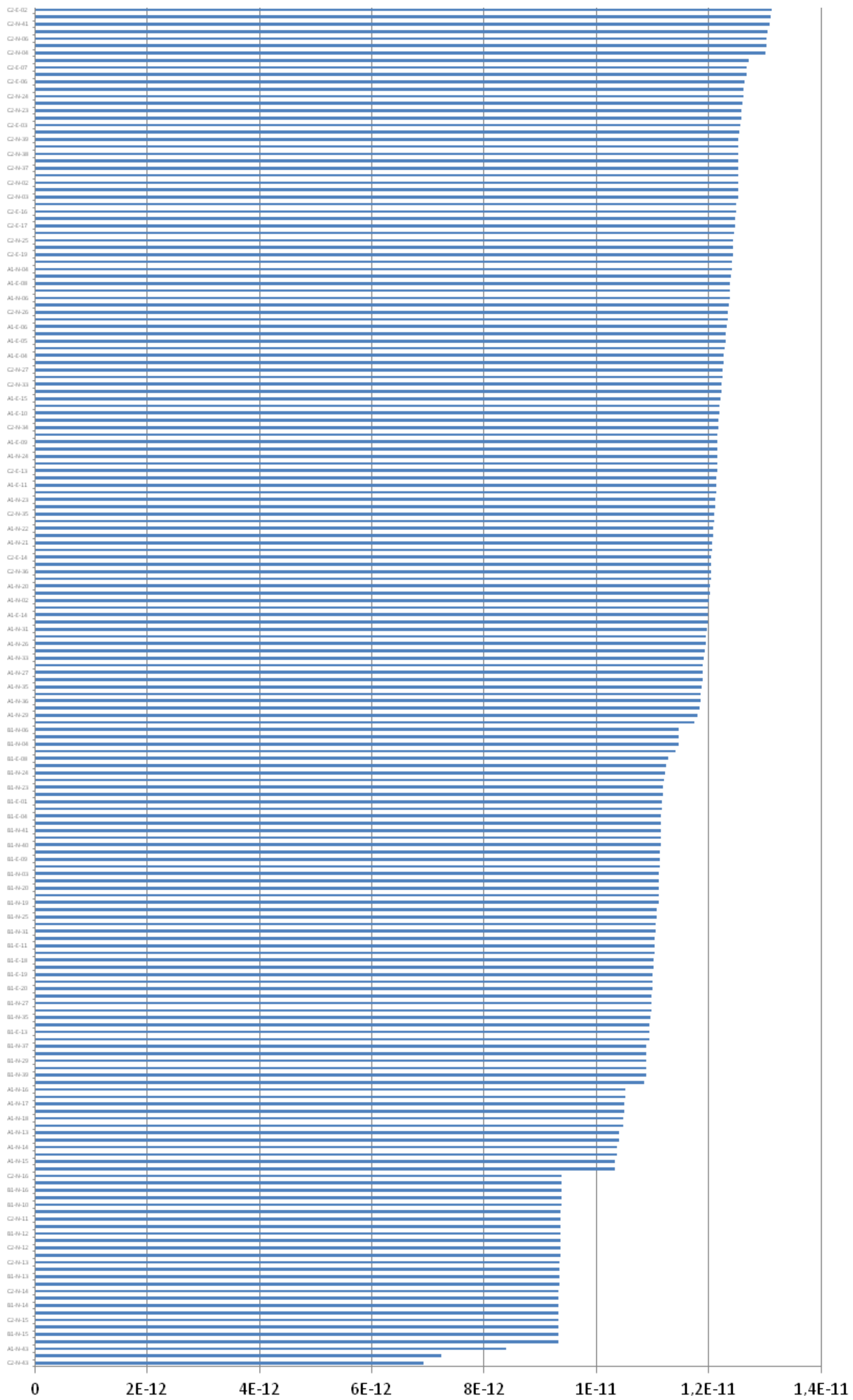

Figure 27: Comparison of the normalised and weighted results of all the assessed base case

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Table 28. Group of the 10-20% of the best performance new office buildings

Position (best models)	Base case code	% of buildings in relation to the total	% accumulated
1	C2-N-43	0,21%	0,21%
2	B1-N-43	1,93%	2,14%
3	A1-N-43	0,19%	2,33%

4	B1-N-09	1,93%	4,26%
5	B1-N-15	1,93%	6,19%
6	C2-N-09	0,21%	6,39%
7	C2-N-15	0,21%	6,60%
8	B1-N-08	1,93%	8,53%
9	B1-N-14	1,93%	10,46%
10	C2-N-08	0,21%	10,67%
11	C2-N-14	0,21%	10,87%
12	B1-N-07	1,93%	12,80%
13	B1-N-13	1,93%	14,73%
14	C2-N-07	0,21%	14,94%
15	C2-N-13	0,21%	15,15%
16	B1-N-18	1,93%	17,08%
17	C2-N-12	0,21%	17,28%
18	C2-N-18	0,21%	17,49%
19	B1-N-12	1,93%	19,42%
20	B1-N-17	1,93%	21,35%

According to these table, those buildings that are awarded EU Ecolabel for office building should have an overall environmental impact similar to that of the office building labels as B1-N-14, if the EU Ecolabel threshold is set up in the top 10% best performing office buildings or similar to that of B1-N-17, if the EU Ecolabel threshold is set up for the 20% best environmental performing buildings.

The ranking of the overall best performing buildings gives a general idea of the environmental impact caused by the front-runners office buildings in Europe. However, this information is too aggregate to determine the needed criteria and their benchmarks. For this reason, this procedure was repeated but just taking into account the environmental impact caused by the environmental aspect under study.

5.1.1 Determination of the criteria and benchmarks related to the LCA-environmental impacts

5.1.1.1 Criteria and benchmarks related to the energy consumption and energy sources

The environmental impact assessment conducted throughout LCA studies along the office building life cycle, showed that the highest environmental benefit which can be achieved is related to energy savings, mainly during the use phase. This reduction results in lower greenhouse gas emissions (GHG) and resource savings. Moreover, lower energy consumption during the use phase will bring economic benefits for end users reducing their expenses on energy bills.

The criteria proposed in the area of energy consumption aim at reducing it and its GHG emissions through application of various already known and innovative technologies or the use of less pollutant energy sources. Nevertheless, it can not be forgotten that the application of these criteria should neither decrease the end-user comfort nor the well-being of the users of the building. Because of the importance of end-user's behaviour, the monitoring of the energy consumption and the information of the best practice to the workers are proposed to ensure an optimal energy performance of the office building during the use phase.

According to the aim of the EU Ecolabel, freedom is left to the designers and architects to choose the most suitable technologies and design for each location. No trade restriction should be created through technology discrimination and therefore any kind of technology, building material or construction technique will be promoted in this EU Ecolabel for office buildings.

The energy performance of an office building is assessed by means of three criteria. The first criterion aims at designing office buildings in a way that reduces the overall energy consumption during its use phase. The overall energy consumption of the office building shall account for all the demands of the office building independently of the energy source. The purpose of this criterion is the promotion of high energy efficiency office buildings.

The second energy related criterion aims at limiting the overall CO_2 emissions, what will reduce the environmental impacts caused by the energy consumption during the use phase. The amount of CO_2 emissions strongly depends on the energy source used to provide the needed energy. In this sense, fossil fuels are considered to emit higher amounts of kg of CO_2 per kWh delivered than other less polluting energy sources such as renewables. Therefore, this criterion aims at complementing the previous one by promoting the use less polluting energy sources while maintaining the high efficiency energy performance of the building.

Finally, the third energy related criterion aims at identifying the improvement potentials of the office building during the use phase. It is well-known that the energy performance of office buildings can significantly differ from the estimated energy performance at the design phase, due to mainly the user’s behaviour. The identification of the improvement potentials is proposed by the monitoring, comparison to the design values and communication of the information to the end users.

a) Determination of the maximum overall energy consumption

The overall energy consumption during the use phase is the environmental aspect that has the highest importance in the whole life cycle of an office building. The overall energy consumption of an office building usually consists in the energy consumed in heating and cooling, lighting, domestic hot water, auxiliaries, ventilation, etc.

Apart from local climate conditions, heating energy demand is influenced by parameters that describe the thermal specifications of a building: average U-values, compactness, airtightness of the building, avoidance of thermal bridges, ventilation losses and passive solar gains, cooling energy demand by size of windows and passive cooling measures (like shading devices, thermal capacity of the building mass, night ventilation), etc.

Due to the complexity of regional and local specifics and market availability of components no recommendations in the assessment of any partial energy consumption is suggested under this Ecolabel criterion.

The benchmark for the overall energy consumption of the office building was calculated considering the energy performance of the 20% best energy performing office building across Europe. In order to get this value two inputs were needed:

- The energy consumption of each of the office building types, identified in the report "Definition and categorization"[11]. The energy consumption of each model was calculated by using Energyplus.
- The number of each office building type that was estimated in the report "Economic and market analysis"[12]

In all the cases the design of the building and the use scenario remain constant (floor area, number of stocks, occupancy hours, density of occupation, metabolic rate, set points of heating and cooling, temperature of the domestic hot water, ventilation rates and heat loading of the office equipment) while the climatic conditions, the insulation properties and the materials used for the construction are the typical ones from the area where the building is located.

In order to identify the buildings within the group of the 20% best energy performing office building on the EU-market, the overall energy consumption results of the numerous base cases studied were multiplied by the number of estimate units. Then, the results of the multiplications were summed up and finally, it was calculated the share in percentage in which each base case contributes to the total amount. The office building model that corresponds to the 20% best energy performing building is shown in Table 29

Table 29 . Energy performing of the office building with the 20% best energy performance

Energy consumption ($kWh/m^2/a$)	best energy performing office building (C2-N-43)	10% best energy Performing office building (B1-N-14)	20% best energy performing office building (B1-N-17)
Lighting	11	19	15
Auxiliary energy	3	3	3
Heating	15	20	23
Cooling	15	7	8

[11] Draft report: Product definition and scope under:
http://susproc.jrc.ec.europa.eu/buildings/stakeholders.html
[12] Draft report: Economic and market analysis under
http://susproc.jrc.ec.europa.eu/buildings/stakeholders.html

Domestic Hot Water	4	4	4
Total energy consumption	49	53	53

Although this table shows the partial energy consumptions in the office building within an energy performance rated as the 20% best energy performance, only the overall value is proposed as benchmark.

The reason why the partial energy consumptions are not proposed as partial benchmarks, although they were used for the calculation of the general benchmark is because this Ecolabel criterion aims at leading freedom to designers and engineers to adapt the building and technologies to the location.

The overall energy consumption related criteria have been broadly discussed by the stakeholders of this project. There is a general agreement on the idea of setting up just the maximum energy consumption as primary energy leading freedom to the designers and engineers to choose the most suitable technology to each location and specific conditions of the office building. The goal of this criterion could also be reached limiting the maximum emission of GWP. In this sense, regarding the energy consumption criteria, stakeholders opinion suggested that the only mandatory criteria should be the overall energy consumption of the building – requirements for heating, cooling, ventilation, DHWC and lighting should all be optional, or preferably just for guidance, as well as minimum values for "renewable" or "passive systems".

However, in this study the overall energy consumption is proposed to be measured as final energy demand in kWh/m^{2}a. Where:

- kWh is the total final energy consumption of the office building including the energy consumed in heating and cooling, lighting, auxiliary equipments, ventilation, domestic hot water. This consumption can be provided by renewable or non-renewable energy sources
- m^2 is floor area, the floor area is considered the conditioned floor areas that are the rooms inside the building that are heated and/or cooled. It should not include parking car places, unfinished basements, storage space, stepcases, lounges, etc
- a is the natural year

The overall energy consumption is proposed to be measured as final energy demand because the final energy consumption allows setting up a benchmark that can be applicable to different Member States, whereas the primary energy consumption will depend on their specific grid mix for electricity production (consumption that accounts for 50% of the total energy consumption of the building). On the other hand, both the calculation and the verification of the final energy consumption will be easier than the estimation of the primary energy consumption

In contrast to the previous idea, some comments raise the possibility of including *maximum energy consumption for separate areas of the office building* but without assessing too much into details and without going to the individual materials level. However, some other comments discuss the risks of sub-optimization when setting maximum requirements for parts.

In this sense, *ceiling maximum energy consumption for cooling* is proposed as cooling requires much more energy than heating and overloads are oft in office buildings due to the heat released by the office equipment among other reasons.

Regarding the goal of the present Ecolabel and the necessity of considering the office building as a single product and not a group of building components, considered as intermediate products, the set up of maximum energy consumption for separate areas is not considered. In this sense, e.g. the solar gains through the windows, which have a significant contribution to the energy balance of building, should be considered to assess the overall energy consumption but any criteria related to neither the minimum U-value nor the g-value of the windows to be used would be developed. *The main reason for this decision is that the most suitable solution to decrease the energy consumption depends on the location, orientation, etc of the office building.* In addition, the proposed criteria should be technology neutral criteria allowing both manufacturers and consumers to find the best solution to their problem. This is the only way to not hamper the development of innovative products and solutions or in this case even innovative combinations of products enabling the development of high performance buildings.

Taking into account the previous reasons, the suggestion of prioritizing solutions that are positively contributing to the EUs long term goal of moving towards competitive low carbon economy are disregarded in this Ecolabel. However, and according to the methodology to calculate the overall CO_2 emissions of the office building explained in the next rationale for the next criterion in this section, not all the energy carriers that can be used in a building contribute exactly the same. Fossil fuels, for example, have a higher conversion factors that low carbon energy sources and therefore, the use and/replacement by systems making use of low carbon energy sources and technologies is until a certain extend on the side of this Ecolabel. Likely, the technologies that make use of the renewable energy sources for the generation of heating/cooling, hot water or even lighting are stimulated.

The setting up of *maximum U-values, neither for the overall U-value of the office building nor for the separate building components,* is not highly recommended. The minimum U-values do not ensure that the optimum energy performance of the building since it depends not only on the building components themselves but also on the assembly of these components.

The main problem related to this criterion seems to be due to the variety of calculation methods and the various main indicators used for the energy performance certificates. Several options are suggested by the stakeholders and after analysis the multiple possibilities in this study:

a) Referring to EN ISO 13790. In this case uniform parameters have to be defined where national adaptations are allowed in principle to guarantee the compatibility of calculated figures for an EU-wide labelling of office buildings

b) Referring to the energy calculation methodology developed in each Member State according to the EPBD 2002 (proposed as option A in the criterion 5.1.1)

c) Use the method "passive house planning package 2007"

d) Use a reference calculation method as could be those used in Energyplus or any other energy calculation tool software that have been through the BesTest (proposed as option B in the criterion 5.1.1). The tests and validation procedures that should have gone through to be accepted are the following:

1) Analytical tests: HVAC tests based on ASHRAE Research Project 865 and the building fabric tests based on ASHRAE Research Project 1052

2) Comparative tests: ANSI/ASHRAE Standard 140-2007, International Energy Agency Solar Heating and Cooling Programme (IEA SHC), BESTest (Building Energy Simulation Test) methods not yet in Standard 140, EnergyPlus HVAC Component Comparative tests or EnergyPlus Global Heat Balance tests

3) Release and executable tests. The BESTest suites compare the results of multiple simulation programs for a series of load-related attributes. EnergyPlus testing reports are available for many of these test suites.

According to stakeholders opinion, in defining benchmarks for rating energy performance an EU-wide Ecolabel must not neglect regional climate conditions (HDD/CDD, solar radiation, etc). A differentiation into at least three zones (cold, moderate and warm climate zones) within Europe is recommended by some stakeholders. Regarding the calculation methodologies, comments were received from the stakeholders. On one hand, it is considered *the calculation methodology should not be based on national calculations methods*. Several MS models tend to certain technologies or solutions over others by excluding the input of certain types of data and consequently many parameters are not harmonized.

Consequently, they considered that the Ecolabel should develop its own calculation methodology, applicable to all buildings. Differences between MS (due to the climatic conditions) specific parameters should be integrated which allow for specific input. This could even include a correction factor addressing the increased or decreased heating or cooling needs depending on the location of the building.

Finally, they pointed out that as the calculation methodology should be accepted by all the MS and as far as possible harmonized within the national calculation methodologies, the application of the same methodology or similar methodologies is important to ensure that all the awarded buildings are on the top best environmental performance.

On the other hand, the development of an Ecolabel calculation methodology, without being based on the MS calculation methodologies, would imply the necessity of carrying out two energy performance calculations of the office building and consequently and increase of the costs of the Ecolabel. In this sense, some stakeholders expressed their concerns about the harmonization of the Ecolabel criteria and consequently of the harmonization of the calculation method (with consideration of specific national/local elements). They welcome the idea of the introduction of a limited amount of climatic zones in the frame of this proposal. They suggested clearly defining the energy consumption e.g. primary or final energy, etc and recommended the exclusion of the energy consumption of the office equipment into this calculation.

The first option (Option A) proposed for this criterion relies on the Member States energy calculation methods. At present all the Member states have already developed an energy calculation method that allows getting an overall energy consumption figure. It is called the Energy Performance Certificate (EPC) of the building.

Generally, there are two types of certificates in the Member States, stepped labels or continuous colored band strips. The pros and cons of these two main forms of certificates seem to be balanced, so it is not likely that any MS will use another option than that already selected. Apart from this, the physical unit used in different MS to identify energy performance differs a lot. The physical unit kWh/m^2a differs from MS as some of them consider, for example, primary or delivery energy, total or partial consumptions and coming along with CO_2 emissions or not.

In the top categories, it is reasonable to have narrow categories in the case of stepwise labels, although 30, 15 or 0 kWh/m^2a do not represent a great difference, as far as the absolute figures are concerned, it is clear that the difference is astonishing from the point of view of the building and the mechanical systems.

However, the advantage of this option is that according to the EPBD 2002, every five years the energy performance for new buildings should be reviewed to investigate if it is possible to tighten the requirements. Therefore, a new building accomplishing class A is for sure a top best energy performing building at the point when it awards the EU Ecolabel.

In the case of the continuous scale an indication of where the actual building is located on the scale must be provided. There are thus no separate categories. The only question with respect to this aspect is how the interpretation of the reported value should be carried out. For these cases, the option of demonstrating the top best energy performance of the building based on a database of the office building of the MS is suggested.

A comparison of the benchmarking of some MS was carried out in this study and summarized in table 30. This comparison should be regarded carefully as not all the MSs differ the energy consumption depending on the function of the building and in addition, some assumptions were considered to transform primary energy into delivery energy, approximate continuous ratings to stepped ones, extrapolate energy consumption rates of residential buildings to non-residential ones, etc.

Table 30. Estimate of the primary energy performance of building awarding an Energy rating class A. (kWh/m^{2}a)

	A++	A+	A	B	C	D	E	F	G	Type of building
Austria	<10	15,00	25,00	50,00	100,00	150,00	200,00	250,00	>250	non-residential
Belgium	0,00	0,00	77,00	190,00	304,00	418,00	531,00	645,00	645,00	public
Bulgaria										
Croatia										
Cyprus			185,53	371,05	556,58	742,11	927,63	1113,16		general
Czech Republic			62,00	123,00	179,00	236,00	293,00	345,00	345,00	office
Denmark		50,26	70,38	95,52	135,75	175,99	227,21	266,53		non-residential
UK										
Estonia		53,51	65,41	83,24	107,03	136,76	172,43	220,00	220,00	
Finland										
France		50,00	90,00	150,00	230,00	330,00	450,00	>450		residential
Germany		104,17	208,34	312,51	416,68	520,86	625,03	729,20	833,37	residential
Greece	47,67	72,22	108,33	144,44	203,66	262,88	327,88	394,32	394,32	general
Hungary		55,00	75,00	95,00	100,00	120,00	150,00	190,00	250,00	general
Ireland										
Italy										
Latvia			104,17	208,34	312,51	416,68	520,86	625,03	729,20	
Lithuania										
Luxemburg			93,75	156,26	177,09	208,34	322,93	468,77	583,36	multi-family
Malta										
Norway			175,01	262,51	350,02	447,94	547,94	822,95		office
Poland										
Portugal										
Romania			187,51	375,02	562,52	750,03	937,54	1125,05		general
Slovak Rep			168,76	335,43	493,77	652,11	814,62	977,13		trade service
Slovenia										
Spain			103,80	168,68	259,50	337,35	415,20	519,00		large non-residential
Sweden			104,17	208,34	312,51	416,68	625,03	833,37		
The Netherlands			171,78	212,68	261,76	327,20	392,64	474,44		

These values of the primary energy were calculated into delivery energy thanks to the correction factors provided in the standard ISO 15603 and considering an average energy consumption of the office buildings similar to that achieved in the energy performance simulations carried out in this study. The results are provided in the following table

Table 31. Estimate of the delivery energy performance of building awarding an Energy rating class A. (kWh/m^2a)

Energy rating A-G	A	B	C	D	E	F
Primary energy demand	115,33	196,78	281,24	369,38	471,16	555,50
Delivery energy demand	55,36	94,45	134,99	177,30	226,15	266,63

As regarded the average value of the delivery energy in the buildings awarding a class A is considered to be lower than 55 kWh/m^2a. This value is extremely close to the benchmark calculated by means of the software Energy simulations. Therefore, buildings with an energy performance class A or lower are proposed to award the EU Ecolabel for office buildings.

b) Determination of the Overall CO_2 emissions during the use phase

Another way of taking into account the renewable rate in the energy demand is by using the CO_2 emission indicator. Energy generation and supply is one of the main sources of CO_2 emissions. CO_2 based assessment of buildings is recommended although not all the member states have already implemented a CO_2 calculation method. In this case, the calculated overall energy consumption can be used to calculate the CO_2 emissions when taking into account the CO_2 correction factors.

Generally speaking, office buildings have a high consumption of electricity, which accounts for 50% of the total energy consumption, according to the simulations carried out in this study. Electricity in the office buildings is used for lighting, auxiliaries, cooling and in some cases even for heating and domestic hot water.

The provision of renewable energy sources, the type of source of the production of electricity, and the type of source for the production of heating and hot water can decrease the overall environmental impact of the office building. Energy renewable sources are considered to be environmentally friendlier than the conventional energy sources. Conventional energy sources are mainly based on fossil fuels and consequently the shift towards renewable sources would have environmental benefits. This hypothesis was analyzed by a sensitivity analysis where part of the energy demand of the building was provided by thermal or PV solar panels. Three combinations were analyzed: just thermal solar or just PV solar panels and the combination of both. In all the cases the amount of the energy provided by these sources of energy is highly dependent of the area of the solar panels. In this sense, three areas were analyzed. According to the results, in general, the installation of PV solar panels reduces the environmental impact of the building, being the reductions sharper in the case of Madrid (but, inferior to a 5% environmental impact reduction in all the cases). Further information can be found in "Technical analysis" report.

Likely, the *type of energy source* (e.g. electricity, diesel, etc) used for heating and hot water and that for electricity (different electricity mixes depending on the member state where it is produced) have an influence in the overall environmental impact of the office building. The energy source used for heating and hot water in the base case is natural gas. Two sensitivity analyses were carried out to analysis the influence of the type of energy source. The first one analyzed the influence of the type of fossil fuel used for the heating of the building. The results showed that changing the natural gas supply to oil supply, the overall results were slightly modified (up to 4%) and thus it was concluded that the type of fossil fuel used to cover the demand of heating and hot water of the office buildings is not important.

The influence of the *type of electricity source* is however much more remarkable. The base cases analyses were performed assuming that the electricity required was supplied by different EU electricity mixes (the electricity mix of the member state where the building is located). The results showed that the overall environmental impact of the office building is highly influenced by this aspect being due to:

- The high consumption of electricity in all the base cases

- The high environmental impact of some electricity mixes analyzed in this study. Those electricity mixes with higher shares of coal and oil present a higher environmental impact than those with higher shares of renewable sources.

Taking into account these results, it was estimated the best energy performing office building should be partly provided by the renewable energy sources. The percentage of energy renewable sources was estimated to be at least 5% of the overall energy consumption. As commented, the case study with the lowest environmental impact due to the inclusion of renewable energies is located in Madrid and accounts for 15% of the electricity coming from PV solar panels. This location is favoured with exceptional weather conditions (southern Europe) and therefore the environmental benefits are considered to be almost unachievable in Northern Europe. For this reason, a lower benchmark (of 5% of the total energy consumption) coming from renewable sources is considered to be much more appropriate across Europe.

The CO_2 overall emission indicator seems to be appropriate to quantify this criterion. Similarly to the calculation of the overall energy consumption, the CO_2 emission calculation methodology is the main problem related to this criterion. Several options are proposed:

- The calculation method proposed by each member state. However, for the time being not all the member states have developed this kind of calculation methods and moreover, the methods are not completely equivalent among the member states
- Following the calculation method proposed by the standard ISO 15630, where correction factors for most of the conventional and non-conventional energy carriers are supplied.
- Follow the methodology chosen for calculating the overall energy consumption of the office building. Then, identify the different energy sources in the office building, the amount of energy carrier or fuel needed in each energy source share and finally, use the emission factors resulting from a combination of e European Life Cycle Database (ELCD) life cycle datasets and the characterization factors of the CML 2002 [Guinée et al 2002] method to calculate the overall CO_2 emissions.

Applying the last method an overall CO_2 emissions benchmark of 20 $kgCO_{2eq}/m^2a$ was estimated, considering that at least a 5% of the final electricity demand is covered by renewable sources, where:

- CO_{2eq} is calculated following the conversion factors shown in the table 33

Table 33. CO_2 eq emission factors of the energy carriers (ELCD and CML 2002)

Energy carrier	CO_2 eq (kg/kWh)
Electricity	0,59
Natural gas	0,23

- m^2 is considered to be the conditioned area considered to calculate the overall energy consumption of the office building.

- a is a natural year

c) *Need of an energy consumption monitoring and rise of user's awareness*

As briefly commented in the rationale of this criterion, the proper use of the energy related technologies plays a key role in decreasing the overall energy consumption of the office building.

The energy breakdown of a modeled office building shows that lighting is the most important energy consumption share. Because of the restricted scope of the Ecolabel for new and major renovated office building, a partial (50%) or total (100%) lighting control has been considered. This fact reduces significantly the overall energy consumption of the office building and consequently its environmental impact. According to the results obtained in this work, an office building without lighting control and a permanent lighting during the working time (8h/each working day) reached energy consumption for lighting of $39kWh/m^2a$ which accounts for around 35% of the overall energy consumption. If a lighting control is included depending on the climatic and designing conditions (amount of glazing), the lighting energy consumption dramatically decreases to 10-20kWh/m^{2}a which accounts for 12-25% of the total energy consumption. In addition, the electricity consumed by the office equipment, auxiliaries and cooling is also outstanding.

As observed, the decrease in the overall energy consumption of the building is remarkable and therefore some measures to promote the reduction in the lighting consumption and in the electricity in general should be proposed in an energy management plan.

In several studies, it has been reported that arising the user's awareness about the energy consumption of the office building and the environmental benefits of a proper behaviour is one of the most effective ways to comply within the benchmarks.

Information about the following aspect is recommended to be provided to the end-users:

- the benefits of using daylighting when appropriate. The potential of energy saving by means of daylighting is enormous (around 70%). User's should be informed of the importance of switching off lighting when appropriate daylighting is available
- the importance of GPP criteria for lighting and the procurement of the light bulbs, lighting controls, etc. Saving energy bulbs can bring benefits such as lower procurement costs as they last until 10 times as long as conventional bulbs, lower over-heating, lower free mercury, and the most important fact higher energy efficiency as their energy consumption is around 1/3rd to 1/30th of the incandescent or CFL bulbs.
- The proper use of the lighting when lighting controls are installed in the rooms.
- The proper use of the heating and cooling systems. The control of the cooling systems is of especial importance as office buildings are characterized by higher cooling demands due to the following reasons among others:
    - The overheating coming from the office equipments
    - The inefficiency of conventional cooling systems (e.g. reduction of indoor temperature with conventional cooling techniques from 21 to 20C consumes approximately three times the energy than heating from 20 to 21C)
    - the thought requirements on indoor comfort
    - a misconduct of the occupants (misappropriate ventilation by the occupants in the cooling period)
- the proper use of the ventilation system of the office building and which is the best practice to use it

5.1.1.2 Determination of the criteria and benchmarks related to the water consumption

Different factors (such as climate conditions, presence of water-saving equipment, number of occupants, applicable legislation, existing facilities, etc.) influence on the operation water use within office buildings. In the case of office buildings, water is used basically for taps, toilets and drinking, and eventually for showers in some cases.

A limited number of studies or statistical data is available concerning current operational water consumption within office buildings. Moreover, these available data reflect a rather large variation between minimum and maximum values and between countries[13]. [Superbuildings 2011]. According to [CSTC 2010]' which evaluates the sustainability of buildings, the average water consumption per person and day is estimated to range between 110-115 litres whose breakdown is as follows: 36% WC, 33% shower and bath, 13% washing machine, 7% dishes, 4% gardening, 4% cleaning, and 3% cooking.

Only the WC and cleaning consumptions sources will be applicable to the office buildings, which represent the 40% of the overall water consumption: 44- 46 litres. If the consumption of both potable water and showers is included, then the final consumption will be higher. MS Ecolabelling schemes set current performance levels between 11 to 100 litres per person and day, while the best practice scenarios range between 5.5 to 20 l/p.d[14]. Through the application of water-saving equipments and/or the reuse of rainwater and/or grey water, it is possible to achieve remarkable annual water savings. These savings are especially remarkable if the high number of users of office buildings (between 1,430 and 24,570 l/p.a, considering 260 working days per year) is taking into account. The maximum water consumption value is chosen as a benchmark for this criterion.

Other measures to limit the consumption of water are the provision of a water monitoring system to report the overall water consumption of the building and the development of a water saving management plan which identifies saving potential.

Like the energy consumption of the office building during the use phase, water consumption in the building can be higher than that estimated. These differences are mainly due to user's behaviour.

In this sense, the better way to identify where the improvement potentials are, is the water monitoring followed by a comparison to the estimate values. The comparison of both real and

[13] http://cic.vtt.fi/superbuildings/sites/default/files/D5.1_final.pdf
[14] http://cic.vtt.fi/superbuildings/sites/default/files/D5.1_final.pdf

estimated values allows the identification of the mismatches and the inappropriate user's habits or construction problems that cause the higher water consumption.

One of the ways to save water in office buildings is to set up a water management plan. This management plan consists of applying several measures to identify where the possibilities to save water are. Some of these measures are:

- flow monitoring: water audits routinely identify undetected leaks representing (10-50%) of consumption. Rectification of these usually provides good savings at remarkable low cost.

- system pressure data can be requested from the supplier. However, expert advice may be needed, especial for high rise buildings as adequate pressures must be maintained at the upper levels. Excessive pressure is best evidenced by excessive basin spout flows for only small tap movements.

- billing and charges: data need to be collected to ensure comprehensive water consumption information is obtained.

- information to the users: a detail description of the best practice shall be communicated at least to maintenance staff with detailed information on how to inform the end users.

5.1.1.3 Determination of the criteria and benchmarks related to the materials selection (content of reuse and recycled materials)

The recycled content could be considered as an indicator for the selection of the materials. However, this indicator seems not to be appropriate for materials that are already extensively recycled via well-established, highly efficient and economically sound markets, as indicated in one of the stakeholder's comments received. Into the case of metals, their intrinsic economic value is the main driver for their sound collection and recycling. As well as reduced emissions, energy savings between 60-95% that may be achieved when compared with primary productions. This assists companies to reduce their costs.

However, recycled content is a sector related concept that looks at how much recycled material is used in the production of a new product. Recycled content is focused on the manufacturing stage of a product and it has non sense in products such as metals with services life of several decades and with open loop recycling schemes. There may be a gap between current demand and the availability of scrap metal. This could lead to a situation where the actual recycled content of a product falls below the level that is technically feasible and virgin material has to be introduced into the loop to meet the rising demand. Therefore, it is suggested that instead of recycled content, recyclability should be used as a key criterion for metals, glass and other highly recycled materials, as commented previously.

On one hand, it was suggested that closed loops for recycling can not possible be practiced with demolition waste due to pollution by other materials and where technical specifications of decades old products are no longer available. In addition, it was pointed out that the production processes might not tolerate all kind of quality for recycling and that the use of recycled materials may lead to less durable materials.

As commented, due to the large amount of D&C waste to be reused or recycled regarding the current and forthcoming European legislation and the large amounts of recycled and reuse construction materials that should be already incorporated in the construction materials, this criterion seems to be recommendable.

However, structure materials are left out of this criterion. A structure material consists mainly in metals and allows and at present they are already produced within a large amount of reuse and recycled material content. For this reason, and due to the low environmental benefits gained while developing new EU Ecolabel criteria for this kind of materials, they are left out of this benchmark.

Finally, in order to avoid that the use of recycled and reused materials lead to less durable building products (and, consequently, in higher life-cycle environmental impacts), it should be ensured that materials meet the corresponding quality and technical requirements.

5.1.1.4 Criteria and benchmarks related to the materials selection (low environmental impact materials)

Evaluations of the life cycle environmental impacts of the construction products show, that generally some construction products bring more environmental impacts that others. This is, because the production of some building materials needs more energy and nature resources than others. For the selection of low environmental impact construction products a set of construction product labels were developed.

a) Ecolabelled construction products according to ISO 14024.

According to ISO classification, there are three types of eco-labelling schemes, outlined below:

- *type I labels*: this group labels products based on life-cycle environmental impacts, the criteria are set by an independent body and monitored through a certification or auditing process. Transparency and credibility is ensured by the third-arty certification. Most of the existing official national and multinational ecolabel schemes in Europe belong to this category

- *type II labels* is an informative environmental self-declaration claims. These are environmental claims made about goods by their manufactures, importers and distributors. They are not independently verified, do not use pre-determined and accepted criteria for reference, and are arguably the least informative of the three type of environmental labels

- *type III labels* don't make any judgment on the environmental quality of the product, but simply inform the consumer of its environmental impacts. A "score" is given for the product for certain environmental impacts, based on LCA methods. This environmental score is compiled by a third party certification agency based on a number of performance indicators (EPI), e.g. energy use, air emissions, water emissions, etc. this provides designers an opportunity to compare the scores of different products and select those with the best score, but does not provide any guidance of what good performance is[15].

Type I Ecolabels (according to ISO classification), such as the European Ecolabel, should take into account the entire life cycle of products (including use phase and end-of-life) when setting the criteria for its obtaining. Then, aspects like energy and water consumption during the manufacturing and use phases of the product, its recycled content or its recycling potential have been considered in the process of defining the Ecolabelling criteria. As these criteria are based on scientific evidences, products awarded with this kind of Ecolabel are considered to be environmentally friendlier than others from a life cycle perspective.

In this sense, this type of Ecolabels takes into account the energy used for the production of the construction material, as well as the energy used during the construction and demolition phases attributable to the construction materials. The sum of the energy used during the lifecycles of a construction material, but that attributable from the use phase of the building is usually referred as embodied energy of the materials.

According to some stakeholder's opinions the embodied energy can definitely be used as an environmental criterion as it reflects the amount of energy used to produce a certain building product or component. The comparison among the construction materials should be made in the basis of a suitable functional unit.

In this line another environmental indicator proposed regarding the energy used for the production of the building components is the carbon storage in products. This indicator is focused on the energy used and consequently is used in studies related to the climate change debate. The use of this indicator usually recommends the substitution of energy intensive materials by others with lower energy consumption during the production processes.

[15] Information on EPDs, together with a searchable database of EPDs and product-specific requirements, is available at the website of the Global Type III Environmental Product Declaration Network (GENNet) www.environdec.com/gednet

The embodied energy of the building materials and its use as environmental indicator has been largely commented by the stakeholders of this project without consensus. On one hand, it is considered as a non-meaningful criterion for several reasons:

- A perfect knowledge of the functional unit to ensure a fair comparison between the products is needed
- The energy embodied of the construction materials is generally speaking directly related to its weight or thickness but inversely proportional to its performance
- A higher embodied energy could mean lower durability resulting in conflicting assessments with other criteria. The embodied energy of the materials is usually decreased as far as the recycled content is increased. In this sense, the recycled content could be considered as an indicator for the selection of the materials better than the embodied energy, as commented below.

However, other comments showed their agreement with using the embodied energy of the construction materials as indicator for the selection of the best environmental performing materials. These comments pointed out that the embodied energy is an indicator of the energy involved until the building components are used and as long as the functional unit is properly chose (same performance during the use-phase) it is an indication of lower environmental impacts during other life cycle phases (production and end-of-life).

The selection of the Ecolabel Type I or Type III as an indicator for the selection of materials is based on the different aspects evaluated in this kind of labels and the facility of the assessment. As commented, Type I and Type III labels provide information about not only the energy consumed by the construction material but also about other environmental impacts (water consumption, recycled content, recycling potential, etc). In addition, this kind of labels is widely recognized and therefore the assessment and verification of these materials is easier and more reliable than a comparison based on other kinds of parameters without standardization.

On the other hand, comments about the use of the Environmental Product Declarations (EPD) or ecolabels type III as an indicator have been received. Stakeholders considered that although EPD are not Ecolabels, they are based on commonly accepted and scientifically based approach to communicate the environmental impact in both B2B and B2C scenarios. In addition, and although EPDs need further development as hey are just beginning to become widespread, the requirement of EPDs will stimulate the creation and availability of a wider construction material database from an environmental point of view that can be used in the coming projects. In this sense, in the medium to long term for every product put on the market the global environmental impact over its life cycle should be known. Correct and trustworthy information will make easier the selection of the proper construction materials.

The request to provide EPDs that are according to CEN350 is also an alternative to harmonize the various criteria on material selection. CEN/TC 350 are supposed to be the way ahead when assessing the environmental performance of buildings and providing it in a harmonized way.

Because of the above commented advantages, the EPD or type III Ecolabels according to ISO 14025, ISO 21930 and EN15804 are proposed to be used for the selection of the construction materials. We agree that they do not proof that the awarded product is environmentally friendlier, but gives highly valuable information both to its manufacturer and potential buyers. Manufacturers may use this information to improve their products, whereas buyers gain the opportunity to make scientifically based comparisons between different building solutions.

In addition, it is need-to-know that EPDs should not be considered a proof of a better environmental performance of a construction product. However, for the time being, the development of an EPD helps the producers to environmentally improve the processes of production and thus, most of the products that award an EPD, products that award an EPD may show a better environmental performance than product without being labelled[16].

Finally, it is considered that adopting this criterion within the EU Ecolabel of office building will foster the use of type I and type III Ecolabel amongst manufacturers of construction products stimulating the enlargement of LCA database of construction materials that can be used in coming projects.

b) LCA assessment of the building materials

When the previous option is not possible, a LCA assessment of the construction product shall be performed. At present, there is a lack of universally valid LCA construction work. A number of sophisticated tools now exist which are aimed at calculating the full environmental impact of the materials used in construction using LCA (Life-cycle analysis). Most of these tools are applicable only at national or regional levels, and also often require a fair amount of technical expertise to apply. All in all, the LCA assessment of the building materials is the proper way to evaluate its environmental performance. Some of the LCA tools for building materials are[17]: BEAT, Ecoeffect, Ecoinstall, Ecopro, Eco-quantum, Ecosoft, Ecotech, Envest, Equer, GEQ, LEGEP, etc. Most of these software are designed for performing environmental assessment of product building elements and buildings, consisting of a database containing data for energy sources, means of transport, products, building elements and building; a user interface which allows the user to add, edict and delete data in the database and an inventory tool, which allows the user to perform calculations for products, building elements and buildings.

[16] Information provided by ESCI-GIGA

[17] www.dbur.dk, www.ecoeffect.tk, cic.vtt.fi/eco/e_ecopro.htm, www.ibo.at, www.ecotech.cc, www.cebox.at, www.legep.de, www.ecobilan.com

5.1.1.5 Criteria and benchmarks related to end-of-life phase

The concepts of recycled content in the construction materials and the recycling potential of these construction materials have been commented repeatedly by the stakeholders of this project.

First of all, it was pointed out the differences between the recycled content and the recyclability. While specifications of a recycled content may be appropriated for some materials, it is not appropriate for materials that are already extensively recycled via well-established, highly efficient and economically sound markets. Into the case of metals, their intrinsic economic value is the main driver for the sound collection and recycling. As well as reduced emissions, energy savings of between 60-95% may be achieved when compared with primary production. This assists companies to reduce their costs. Resource conservation is another beneficial aspect for an environmental perspective.

However, according to other stakeholder’s comments, the recyclability potential of the construction materials is considered no significant. The experts suggest that products used for decades are hardly recognizable after 20-50 years of use and their technical specifications are no longer available. Moreover, possible disassemblies are not always a matter of material selection but of construction habits and the choice of the designer. For these reasons, a criterion related to the separation of the materials has been left out.

However, we consider that although the end-of-life phase is difficult to be assessed when the building is constructed, criteria on the recycling potential of the construction materials are important. The main reasons are:

- recycling and reuse potential of the building materials is desirable according to the Waste framework directive. The recycling and reuse of these materials will avoid the need of larger landfills and the environmental impacts due to this end-of-life scenario.

- the recycling rate measurement is a requirement to complete any measure on the recycled content in the building materials and therefore, to be able to evolve into a circular economy. In this sense, the recycling building potential should be expressed and evaluated in the recycling rates. These rates should not be hypothetical but have a proven track record based on existing technologies, economic viability and applicable industry standards.

5.1.1.6 Determination of the criteria and benchmarks related to waste management

Waste is generated during all the phases of the office building although the type of waste generated is significantly different among the office building life cycle phases. For example, during the construction phase the waste generated consists in building materials which are concrete, metals, gypsum, packaging, paints, etc. On the other hand, during the use phase of an office building the waste generated will depend on the type of activity occurring in the building, but consisting mainly in paper and carton, plastic, metal (aluminium cans), glasses, etc. Finally, the end-of-life stage generates huge amounts of waste including building materials, equipments, etc.

The recovery processes and the waste management differ notably depending on the type of waste to be treated and therefore each of the proposed criteria addresses one of the office building life-cycle phases.

a) Criteria and benchmanks related to the waste during the use-phase

Waste is generated during all the phases of the office building although the type of waste generated is significantly different. Waste generated in the office buildings during its use phase will depend on the activities which are carried out inside. As shown in Figure 28 most of the waste can be classified into paper, plastic, glass and metal cans which can be recycled.

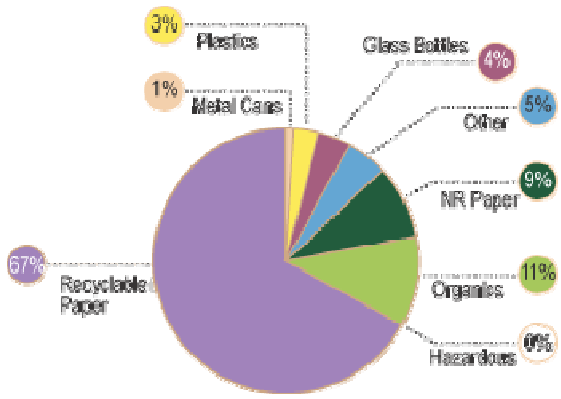

Figure 28: Office Building Waste Composition.

Source: http://www.tpsgc-pwgsc.gc.ca/biens-property/gd-env-cnstrctn/page-10-eng.html

Buildings certifications such as HQE and BREEAM recommend the definition and applications of waste management activities during the construction (HQE) and even to limit the construction waste quantity generated depending on the internal floor area and to dedicate storage space to cater for recycle materials generated during the use phase (BREEAM).

Concerning the waste generation during the use phase, the use of dedicated storage space to cater for recyclable materials is considered as an ecolabel criterion together with the development and implementation of a waste management plan. This waste management plan should focus on the reduction, reuse and recycling of the waste generated and monitoring and communication of the best practice to the end- users. Regarding the waste collection area, the different containers should be clearly labelled for recycling and adequately dimensioned according to the building operation

b) Criteria and benchmanks related to the construction and demolition waste

The phases of construction and demolition produce waste that is generally brought to landfill sites. In average, as much as 33% of solid waste of municipal waste streams is generated by these activities. Most of the construction and demolition (C&D) waste is landfilled, covering their capacity and sometimes it is illegally dumped or burned, causing land, air and water pollution.

Although according to LCA results the environmental impacts caused by the C&D waste generation and management do not significantly contribute to the overall environmental damage (see Annex 6 and the rationale of the criteria for "the selection of building materials"), it illustrates a phase within the building's lifecycle in which the reduction, diversion, reuse and recycling play an important role. For this reason, some criteria were proposed.

The purpose of the waste management plan is to ensure firstly a reduction of the C&D waste generation and secondly a proper treatment of the unavoidable C&D waste generated to ensure that it causes the lowest environmental impact.

First of all, it is considered of high importance the minimization of the C&D waste generation. It can be achieved by means of:

- the training of all employees

- the avoidance of designing and procurement (over- , under- or mis-shipment) mistakes generally as a consequence of the miscommunication among the involved parties

- the avoidance of mishandling of materials (materials damaged during fabrication, packaging, loading or delivery)

- the avoidance of operational mistakes related to the operations necessary to build the structures which are closely related to generate waste.

Once the C&D waste is generated a proper management and treatment should be ensured. Among the different alternatives, the reuse of the waste has been identified as one of the most environmentally friendly. However, this technique is constrained to tight time schedule, transport cost, operational cost, etc. Another recovery technique of the C&D waste proposed as environmentally friendly is the recycling, whose environmental advantages are summarized in Annex 6. Taking these techniques into account the waste management plan should include:

- analysis of the project with the analysis of the type, amount and timing of the construction waste

- plan for the project: statement of the objectives of the waste management plan which contains the strategies and methods for disposing the waste of the construction projects. It is the statement of the intent of the contractor prior to start the project. The actual waste management plan is a custom prepared document for the use of the contractor and to submit to the developer/owner, municipality and the regulatory agency. The plan should be a job related, easy to be understood. The clear and understandable definition of the goals and objectives of the waste management plan are very important. One of the goals is waste minimization. An officer should be appointed to implement and monitor the plan.

- implementation plan and track record system: as the construction or the demolition phases progress, the plan needs to be implemented, monitored and shortcomings are to be identified. Likely any plan, this plan needs to be flexible, recognizing changes and emerging technologies and methods. The contractor should be encouraged to explore and use new technologies. Some of the important issues to be recorded are the description of the materials, disposal alternatives, landfill, recycling, amount of waste, date removed of the job site, tipping fees, mileage, etc

- cost tracking/control: as the plan is implemented, continual cost monitoring and control should be applied to waste management activities as for any construction activity

- post project evaluation: compilation of the data from the project is helpful in establishing the plan for the next project. The owner and the municipality may want a final report indicating if the goals were met with the project

5.2 Determination of the criteria and benchmarks related to the non-LCA-environmental impacts

5.2.1 Determination of the criteria and benchmarks related to hazardous substances and materials

Although the selection of building components and construction materials criteria should be formulated at building level rather than at building component level, the avoidance of hazardous substances in the construction materials should be regarded as a priority criterion.

The use of hazardous substances for producing the construction components, not only those that are in the building products but also those that are used during the manufacture processes, are of key importance for the overall environmental impact of production and use phases. The avoidance of hazardous substances decreases the total environmental impact of both phases.

Moreover, the use of hazardous materials in the building components selected influences the environmental impact because they can be released causing health and environmental damages and increasing the overall environmental impact of use phase of the office building.

Eventually, this selection influences the environmental impact caused during the end-of-life phase of the building. The environmental impact caused during the end-of-life of the office buildings can be decreased if the construction materials chosen do not content hazardous substances that should be treated with care.

Establishing criteria for substitution of dangerous substances within a building ecolabel is a very challenging report, due to the large amount of products present in a building, the large number of potentially hazardous substances present in the products, and the not well developed measurement methods to relate substance content and its emission to the indoor environment. The CEN/TC 351 *'Construction Products - Assessment of release of dangerous substance'* intend to publish Technical Specifications in June 2013, with fully validated EN test methods becoming available in December 2016 at the earliest.

5.2.2. Determination of the criteria and benchmarks related to indoor air quality

High quality of indoor air is an essential condition for the protection of health, both in the living and working environment. Progresses were made and today there are restrictions and bans of some particularly toxic substances in building materials, such as asbestos and pentachlorophenol. However, in the last years there have been increasing complaints about harmful effects on well-being caused by the largely unregulated use of potentially toxic substances in building materials and furniture. Moreover, saving energy by making office buildings more airtight has the effect of more effectively trapping gases released.

Indoor air may contain over 900 different chemicals, particles and biological materials with potential health effects. Among the sources for indoor air pollutant, building materials are of particular importance, however those construction materials considered as structural ones and based on concrete, metals, allows, etc are generally speaking stable without releasing indoor air pollutants.

This means that chemical requirements for building materials could be developed by two different approaches:

- ban of hazardous substances (ban of classes of substances (CMR PBT)), what was already addressed in the environmental criteria area "Selection of materials and avoidance of hazardous substances"

- limits for emission to indoor air.

Regarding the second approach, we realized that the assessment of the IAQ, however, is not homogeneous across Europe and depends on several factors such as the pollutants, exposure, sources and policies. Among the pollutants that are usually considered to assess the IAQ of a building are bioaerosols from outdoor air, building dampness, VOCs and fine particles, randon and CO. These pollutants are coming from several sources: ambient outdoor air quality, building materials, fixed heating and combustion equipments, water systems, leaks and condensation, furnishings, decoration materials and electric appliances, cleaning agents and other household products and underlying soil (incl. the building characteristics which influence the randon entry from the soil)

Exposure is another factor that should be taken into consideration since people spend more and more time of their life indoors. Having clean air indoors is very important for the health of the population as a whole and it becomes particularly important for vulnerable groups like babies, children and the elderly or people already suffering from e.g. respiratory or allergic diseases. Nevertheless, in this work it will be supposed that population belongs to none of the above mentioned groups.

Finally, policy and the way it is regulated influence the IAQ of an office building. These regulations are usually based on scientific works and general assumptions. For example, some MS assume that the attributable impact is linearly proportional to the exposure all way to zero exposure form the source. This assumption is realistic and testable for some sources, such as tobacco smoke and indoor combustion equipment, but unrealistic and non-testable for some others, e.g. bio-aerosols of fine PM originating from outdoor air.

Improving IAQ is a specific goal although at present, there are undoubtedly difficulties to do it. The lack of information regarding the exposure to, the high number of chemical and biological compounds that accumulate indoors under the environmental climatic conditions of modern office buildings, the cost of the assessments and the lack of solid policies on IAQ, both generally and specifically in offices, which are related simultaneously to ventilation, energy and health are the causes that justify those difficulties.

According to the literature[18], the building products relevant for IAQ are

- building chemicals applied to the room covering
- building materials which are applied inside of the rooms

18 http://www.cranfield.ac.uk/health/researchareas/environmenthealth/ieh/doc6.14finallowemittingmaterials[1].pdf

Examples of these products are the wood panels, timber structures (glued laminated timber), resilient, textile and laminated floor coverings, wood flooring, flooring adhesives, decorative paints and varnishes, wall-coverings, adhesives, sealing and bitumen coatings and adhesives.

As observed, most of them are not considered as construction products (but considered as decorative products) and they remain out of the scope of this Ecolabel as they are mainly decided by the end users. Taking this point into consideration, the construction/structural materials do not seem to contribute significantly to the IAQ. Moreover, the amount of these structural materials is much higher than the others and therefore the two following approaches are suggested.

a) Harmonization of the existing IAQ schemes of the European Member States

One reason for the diversity of the labelling schemes is the different approaches to the topic. Due to the lack of harmonised standards for sampling, emission measurement and analytical procedures in the past, various developers (from industrial groups to authorities) created their own labelling systems. However, although schemes follow different approaches, they all aim at showing that the products have been produced in an environmentally friendly way without any harmful substances and have been tested on their relevance to IAQ.

But there are still some differences between the different schemes. Despite the common European market areas, many of these labelling systems still have a national preference, due to the fact that they were developed for a national market. Moreover, there is no harmonised system for material emission available in Europe and therefore consumer protection measures have in some cases created a new kind of barrier to trade and promoting of national industry. All labelling systems are open for applicants from other countries, but testing and applying for several different emission labels all over Europe is time and costs consuming for the industry. Among the existing schemes, the well-known systems established in Germany are now applied in several countries. These schemes are mainly applied to define the state of the art for the respective product category and are used as a basic requirement by many architects and consumers. Due to the private status, these product labels do not have any legal relevance in terms of basic requirements. In addition, these labels are focused on the building components and not on the building as a whole.

The AgBB[19] scheme is similar to emission tests in other countries such as France and Finland, and to testing protocols for AFSSET[20], EMICODE[21], GUT[22] or Natureplus[23] Ecolabels. For this

[19] http://www.umweltbundesamt.de/produkte-e/bauprodukte/agbb.htm
[20] http://www.eurofins.com/product-testing-services/topics/Ecolabels,-quality-labels/afsset-guideline.aspx
[21] http://www.emicode.com/index.php?id=1&L=1
[22] http://www.pro-dis.info/about_gut.html

reason, and due to the high potential of harmonization between these schemes, the IAQ criteria of the EU Ecolabel can be based on the existing IAQ schemes of the member states, especially AgBB, CESAT and M1. The strictest benchmark for each IAQ pollutant considered under these schemes has been chosen to take part in the EU Ecolabel. In this way, we ensure that the EU Ecolabel is harmonized within the three schemes. Some of the methodologies and benchmarks proposed for the EU Ecolabel criteria are summerized in the Table of criterion 8. The following tables summarize the benchmarks of some of the existing Ecolabels as well as the benchmarks and methods proposed for the EU Ecolabel.

Table 32. Testing procedures and standards

	AgBB	CESAT	M1
Sampling & test specimen	Based on EN 13419-3	EN 13419-3	Similar to EN 13419-3
Chamber operation	EN 13419-1	EN 13419-1/2	EN 13419-1/2
Chamber type	EN 13419-1/2	EN 13419-1/2	EN 13419-1/2
Analysis VOC	Similar to ISO 16000-6	ISO 16000-6	ISO 16000-6
Analysis aldehydes	ISO 16000-3	ISO 16000-3	ISO 16000-3 or ENV 717-1
1 testing	3 days	24h carcinogenous	28 days
2 testing	28 days	3 days	N/A
3 testing	N/A	28 days	N/A
Odour test	No, but intended later	CLIMPAQ intensity	CLIMPAQ 28 days, acceptance >0

Table 33. Emission evaluation

		AgBB	CESAT	M1
TVOC definition		Based on ISO 16000-6	ISO 16000-6	ISO 16000-6
TVOC	3 days	10mg/m3	5000 µg/m3	--
	28 days	1mg/m3	200 µg/m3	200 µg/m3
SVOC (28 days)		100 µg/m3	no	no
Aldehydes, (28 days) additional requirements		120 µg/m3	Formaldehyde 10 µg/m3	Formaldehyde 50 µg/m2h
List with target compounds		NIK, updated yearly, and R value	LCI as of 1997 and R value	no
Restricted emission of other emitted compounds		100 µg/m3	As considered in ECA report18	no
Restriction of carcinogenic VOC	3 days	C1+C2: 10 µg/m3	As considered in ECA report18	--
	28 days	C1+C2: 1 µg/m3		C1: 5 µg/m2h

Note:
ISO 16000-6: sum of all signals between n-hexane and n-hexadecane (C6 –C16), calculated as toluene equivalent
ECA rep 18: sum of all signals (C6 –C16), as many of these as possible calculated with their respective response factors, but non-identified VOC calculated as toluene equivalent
AgBB –TVOC: sum of all signals > 5 µg/m3 (C6-C16), all VOC with NIK value calculated with their respective factors, all other VOC as toluene equivalent
AgBB –TSVOC: sum of all signals > 5 µg/m3 (>C16-C22), calculated as toluene equivalent
R value: Sum of (concentration /LCI) expressions
LCI: lowest concentration of interest

Several comments about the control of the IAQ have been pointed out by the stakeholders. This point has a close relation to the energy consumption of the building and the need of heating and cooling. For this reason, the following comments addressed some issues related to the energy consumption too.

The control of the IAQ can be carried out by two different approaches:

[23] http://www.natureplus.org/nc/en/press/news/seite/38/news/indoor-air-2008/?tx_ttnews%5BbackPid%5D=3

- controlling the emission of the IAQ pollutants

- controlling the ventilation flows to avoid a concentration of IAQ pollutants. The ventilation can be mechanical or natural.

Regarding the assessment methods of the IAQ pollutants, some comments suggested that:

- IAQ criteria could refer to IDA levels and that the verification of VOC is unusual and does not add very much in comparison of using CO_2 levels as a marker

- the methods to translate release rates of specific materials into IAQ pollution is patchy but there is work in progress

- that the starting point of the Ecolabel could use the German AgBB and the French AFFSET schemes, is one repeating proposal

- that the building products used should comply with ISO 16000-6 and -9, or either compliance with AgBB or with class A of French compulsory labelling of VOC emission class

However some other possibilities were also suggested, for example that

- the requirement of low emission products can be assessed by the COX emission classes for CE making and select out these classes for requiring low emission products.

- require compliance with German AgBB and with French VOC emission class A

- require compliance with any of the voluntary low VOC emissions specifications in Europe, such as EMICODE, Blue Angle, GUT, M1, IA Comfort Gold, AgBB, AFSSET on top of the previous option

- follow LEED 2012 that comes with a reasonable approach for calculating required % of compliance with the requirement (LEED 2012 still in draft)

- VOCs and aldehydes standard test methods are currently under validation by CEN TC 351.

- EnVIE developed a new robust tool to evaluate the quantitative relationships between IAQ and related diseases and symptoms, indoor relevant exposure agents causing these diseases, indoor and outdoor sources of these indoor exposures and the impacts of policies to control these sources. The building materials are among these sources of exposure taken into account.

Regarding the other comments, stakeholder brought into consideration the importance of adequate ventilation and the energy efficiency. In this sense, some stakeholders suggested that the mechanical ventilation is the type of ventilation to be applied and the way to control the

IAQ. The mechanical ventilation is, according to this author, more energy efficient and if maintained healthier (due to the air filtration possibilities) than passive ventilation.

Taking into account the comments received, the harmonization of the AgBB, French scheme and M1 was considered to develop the first option. The setting up of the strictest benchmarks for the EU Ecolabel IAQ criterion tries to harmonize these existing schemes and benchmarks.

b) Evaluate the influence of the building components on the IAQ of the office buildings

The relative importance of the building components on the IAQ of the office buildings is considered to be not significant from an environmental point of view (no environmental impacts are identified from this environmental aspect in the LCA analyses). In addition, and according to some estimates, the building components contribute up to 0.2% to the IAQ of the office[24]. This little contribution is due to the high amount of pollutant released from the office equipment, pieces of furniture and floor and wall coverings. All these components are out of the scope of this EU Ecolabel.

Keeping this fact in mind a second optional criterion suggests leaving out the IAQ related criteria of this EU Ecolabel. Moreover, the lack of consensus in identifying the IAQ pollutants and the methodologies to measure them make this option to be considered.

Finally the perception of IAQ depends on cultural and behaviour aspects. Therefore, it is dramatically different from one region to another one and strongly depends on the user's behaviour, what remains out of the scope of this EU Ecolabel too.

5.2.3 Determination of the criteria and benchmarks of the visual comfort

The planned use of natural light in non-residential buildings, office in this case, has become an important strategy to improve energy efficiency by minimizing lighting, heating and cooling loads. The introduction of daylighting strategies can considerably reduce a building's electricity consumption and also significantly improve the quality of light in an indoor environment.

Evidence that daylight is desirable can be found in research as well as in observations of human behaviour and the arrangement of office space. Windows that admit daylight in building are important for the view and connection they provide with the outdoors. Daylight is also important for its quality, spectral composition and variability. Moreover, a review of people reaction suggests that working long-term in electric lighting is believed to be deleterious to health while working by daylighting is believed to result in less stress and discomfort.

[24] Information provided by EXIBA as a stakeholder's comment to the 1 AHWG meeting

Performance parameters characterise a daylighting system with in the context of a specific building application and can be used to determine whether a system should be used to achieve the design objectives. Parameters include visual performance and comfort, building energy use, economy and systems integration. Conventional window and skylight solutions meet some of these needs, being the main functions to

-provide usable daylight at greater depths from window wall than is possible with conventional designs

-increase usable daylight for climates with predominantly overcast skies

- increase usable daylight for very sunny climates where control of direct sun is required

- increase usable daylight for windows that are blocked by exterior obstructions and therefore have a restricted view of the sky and

- transport usable daylight to windowless spaces

Some parameters that are important to consider when evaluating the best daylighting system are:

- Visual comfort and performance: the visual function parameters are used to determine whether if given lighting conditions permit sight or visibility and are directly related to the physiology of the eye. Generally, good visibility is defined by and adequate quantity of light for the expected visual task, uniform distribution of illuminance and luminance, sufficient directionality to model three dimensional objects and surfaces (direction of incident light from the side or form above), the absence of glare, and sufficient spectral content to render colours accurately when required.

- Visual amenity encompasses the human responses to the lit environment that go beyond pure visibility criteria, including psychological elements. Light affects people's behaviour and their impressions of an environment. Some of the parameters included in this group are the outside view, the apparent brightness, the appearance or the colour, privacy, social behaviour and health. Windows are highly valued for their views of the natural environment and for their connection to the outdoors. The brightness impression of an interior is an important psychological aspect of daylighting, i.e. whether the interior appears to be dark or bright can be independent of the physical value of illuminance or luminance. Gradients of luminance may affect perception of brightness, too. Finally the true colour rendition is important for tasks that involve colour matching, quality control and accurate colour perception. Generally, the less a daylighting system changes colours from their true state, the better the system or strategy.

- Thermal comfort is one important parameter. Daylighting system can affect thermal comfort in a variety of ways. A cold window surface can increase thermal discomfort caused by longwave radioactive exchange between the window and the occupant in the winter, and a hot window surface can do the same during the summer. Convective downdrafts caused by cold window surfaces and infiltration can also contribute to discomfort. In some cases, direct sun can contribute to greater thermal comfort during the winter

The control of the thermal comfort (insulation of the windows) is usually taking into account in the overall energy consumption of the building and therefore this aspect is already covered by the first and second criteria of this Ecolabel.

In this section, the influence of the daylighting in the office building will be considered from a well-being point of view, regardless the energy savings that its optimization can cause. In this sense the goal of this criterion is to achieve visual comfort by balanced illumination with a proper distribution, enough quantity, non-glaring, view out, etc.

Keeping this goal in mind, and considering that the minimum luminance of an office is already set up in the legislation, the following parameters should be complying to obtain the Ecolabel: availability of enough and proper daylight on the workplaces, view out and management of a proper daylight system for the location.

5.2.4 Determination of the importance of a separate room for imaging and office equipment

Imaging equipment has been identified as a product group with significant environmental impacts, as stated in the working papers for the development of Ecolabels for imaging equipment[25]. Among the different environmental aspects identified in this product group the release of volatile organic compounds (VOC), persistent organic compounds (POP), heavy metals (in air and water), polycyclic aromatic hydrocarbons (PAH) and particulate matter (PM) are not only important from the environmental point of view but also from the healthy one. In addition, the office and imaging equipment is characterized by being noisy equipment. The provision of a room devoted to this kind of equipment will isolate the employees from this noise.

The provision of a separate room for this kind of equipment will avoid the release of these pollutants in the office rooms where the employees spend most of their time. Moreover, these rooms prepared for the location of the imaging equipments may allow higher ventilation rates without causing a significant effect in the overall energy consumption of the whole building.

[25] http://susproc.jrc.ec.europa.eu/imaging-equipment/docs/Imaging_Equipment_Ecolabel_Criteria_WorkingDoc.pdf

5.2.5 Determination of the. criteria and benchmarks related to facilities

According to the Department for transport of the UK Government[26], nearly a quarter of all car trips are made by people getting to and from work and many of these are relatively short journeys of less than five miles (8 km), that could easily be cycled. Around 1 kg of CO_2 (as well as other pollutants) will not be emitted per each 5-mile car trip avoided. Considering the number of workers and daily trips, the shift from car to bikes could have a remarkable effect in the prevention of urban contamination.

Bicycling is a highly efficient mode of transportation providing a wide range of benefits including energy conservation, improved air quality, reduction in costs and improved personal health. Depending on the case, the amount of energy use for the transportation of workers may be higher than the energy used inside the building. A new office building built according to modern energy codes such as ASHRAE 90.1-2004[27] contemplates that the energy use in transportation is nearly 2.4 times greater than the direct energy use of the building.

The energy consumption that is spent in commuting the workers is not account into the LCA boundaries as it is not related to the building itself but the user's behaviour. However, and due to the importance of this energy consumption in comparison to the overall energy consumption during the use phase, it is worth to develop Ecolabel criteria in this area.

Several factors influence the commuting of workers, among them, all the issues related to safety, security, and accessibility are of great importance. Regarding the accessibility of the building, the access to public transportation, the walk ability of communities and the access to safe pathways for walking and biking promotes this kind of commuting. Moreover, support of bicycle use secure parking (opportunity for locking wheels or frame and the accessories of a bicycle to a fixed rack or structure) protected against vandalism and weather conditions and located close to the entrance of the building is needed to encourage the greatest amount of use. In addition, showers and lockers at the work-place are absolute necessary for regular bicycle commuting. Lockers should be installed adjacent to the showers in a safe and secure area.

5.2.6 Determination of the criteria and benchmarks related to user's information

a) User's information

Due to the fact that the key factor in the area of sustainable office buildings is the end-user behaviour, appropriate information to the employees is of high importance. Thus, beside information of the technologies installed in the office building (ventilation system, heating and

[26] http://www.dft.gov.uk/topics/sustainable/cycling/cycling-to-work-guarantee/
[27] http://www.energycodes.gov/training/pdfs/ashrae_90_1_2004.pdf

cooling systems, lighting controls, etc), information concerning rational energy and water use and recommendations concerning potential savings in general and with regard to the building use shall be attached to it. This information shall also contain reference to the potential reduction of the environmental impacts due to the waste generation and the explanation how these environmental impacts can be reduced due to the reduction, reuse and/or recycling of the waste generated.

Further, importance of refurbishment and preventing heat losses and dripping water from sanitary tapware and toilets shall be emphasized as this contributes to increase the needs of electricity and fossil fuels and to high losses of completely unused water which can however easily be avoided.

Information concerning the advantage of using a more sustainable community means shall be provided and the consequences of using the private car shall be pointed out. Updated public transportation timetables and the location of the nearest stations is recommended to be shown close to the office building.

b) Information of the ecolabel

The Ecolabel placed on the building shall contain clear message indicating the advantages related to purchase and use of Ecolabelled buildings/products. It shall constitute an incentive to choose the product due to it preferable environmental performance in comparison with other buildings/products. The information which appears on the Ecolabel shall refer to improved energy and water efficiency and lower CO_2 emissions due to considering technologies in the building design. Further, high quality and longevity might be mentioned. Depending on the final stakeholder's decision concerning the inclusion of criteria on materials and community facilities, respective information about building components for refurbishment and environmentally preferable community means might be added.

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Annex 1: List and characteristics of the assessed base cases

Nº	LOCATION	AGE	% glazing	U Wall (W/m²K)	U Windows (W/m²K)	Lighting control	Solar thermal area (m²)	PV area (m²)	CODE
1	London	Existing	30	0.45	3.157	no	0	0	B1-E-01
2	London	Existing	50	0.45	3.157	no	0	0	B1-E-02
3	London	Existing	30	0.45	3.157	no	10	0	B1-E-03
4	London	Existing	30	0.45	3.157	no	20	0	B1-E-04
5	London	Existing	30	0.45	3.157	no	30	0	B1-E-05
6	London	Existing	30	0.45	3.157	no	40	0	B1-E-06
7	London	Existing	30	0.45	3.157	no	50	0	B1-E-07
8	London	Existing	30	0.45	3.157	no	60	0	B1-E-08
9	London	Existing	30	0.45	3.157	no	0	20	B1-E-09
10	London	Existing	30	0.45	3.157	no	0	40	B1-E-10
11	London	Existing	30	0.45	3.157	no	0	60	B1-E-11
12	London	Existing	30	0.45	3.157	no	0	80	B1-E-12
13	London	Existing	30	0.45	3.157	no	0	100	B1-E-13
14	London	Existing	30	0.45	3.157	no	0	120	B1-E-14
15	London	Existing	30	0.45	3.157	no	10	20	B1-E-15
16	London	Existing	30	0.45	3.157	no	20	40	B1-E-16
17	London	Existing	30	0.45	3.157	no	30	60	B1-E-17
18	London	Existing	30	0.45	3.157	no	40	80	B1-E-18
19	London	Existing	30	0.45	3.157	no	50	100	B1-E-19
20	London	Existing	30	0.45	3.157	no	60	120	B1-E-20
21	London	New	30	0.3	3.157	no	0	0	B1-N-01
22	London	New	30	0.18	3.157	no	0	0	B1-N-02
23	London	New	30	0.12	3.157	no	0	0	B1-N-03
24	London	New	50	0.3	3.157	no	0	0	B1-N-04
25	London	New	50	0.18	3.157	no	0	0	B1-N-05
26	London	New	50	0.12	3.157	no	0	0	B1-N-06
27	London	New	30	0.3	3.157	yes (50%)	0	0	B1-N-07
28	London	New	30	0.18	3.157	yes (50%)	0	0	B1-N-08
29	London	New	30	0.12	3.157	yes (50%)	0	0	B1-N-09
30	London	New	50	0.3	3.157	yes (50%)	0	0	B1-N-10
31	London	New	50	0.18	3.157	yes (50%)	0	0	B1-N-11
32	London	New	50	0.12	3.157	yes (50%)	0	0	B1-N-12
33	London	New	30	0.3	3.157	yes (100%)	0	0	B1-N-13
34	London	New	30	0.18	3.157	yes (100%)	0	0	B1-N-14
35	London	New	30	0.12	3.157	yes (100%)	0	0	B1-N-15
36	London	New	50	0.3	3.157	yes (100%)	0	0	B1-N-16
37	London	New	50	0.18	3.157	yes (100%)	0	0	B1-N-17
38	London	New	50	0.12	3.157	yes (100%)	0	0	B1-N-18
39	London	New	30	0.3	3.157	no	10	0	B1-N-19
40	London	New	30	0.3	3.157	no	20	0	B1-N-20
41	London	New	30	0.3	3.157	no	30	0	B1-N-21

42	London	New	30	0.3	3.157	no	40	0	B1-N-22
43	London	New	30	0.3	3.157	no	50	0	B1-N-23
44	London	New	30	0.3	3.157	no	60	0	B1-N-24
45	London	New	30	0.3	3.157	no	0	20	B1-N-25
46	London	New	30	0.3	3.157	no	0	40	B1-N-26
47	London	New	30	0.3	3.157	no	0	60	B1-N-27
48	London	New	30	0.3	3.157	no	0	80	B1-N-28
49	London	New	30	0.3	3.157	no	0	100	B1-N-29
50	London	New	30	0.3	3.157	no	0	120	B1-N-30
51	London	New	30	0.3	3.157	no	10	20	B1-N-31
52	London	New	30	0.3	3.157	no	20	40	B1-N-32
53	London	New	30	0.3	3.157	no	30	60	B1-N-33
54	London	New	30	0.3	3.157	no	40	80	B1-N-34
55	London	New	30	0.3	3.157	no	50	100	B1-N-35
56	London	New	30	0.3	3.157	no	60	120	B1-N-36
57	London	New	30	0.3	1.776	no	0	0	B1-N-37
58	London	New	30	0.18	1.776	no	0	0	B1-N-38
59	London	New	30	0.12	1.776	no	0	0	B1-N-39
60	London	New	50	0.3	1.776	no	0	0	B1-N-40
61	London	New	50	0.18	1.776	no	0	0	B1-N-41
62	London	New	50	0.12	1.776	no	0	0	B1-N-42
63	London	New	30	0.12	1.776	yes	0	120	B1-N-43
64	Madrid	Existing	30	0.8	3.157	no	0	0	C2-E-01
65	Madrid	Existing	50	0.8	3.157	no	0	0	C2-E-02
66	Madrid	Existing	30	0.8	3.157	no	10	0	C2-E-03
67	Madrid	Existing	30	0.8	3.157	no	20	0	C2-E-04
68	Madrid	Existing	30	0.8	3.157	no	30	0	C2-E-05
69	Madrid	Existing	30	0.8	3.157	no	40	0	C2-E-06
70	Madrid	Existing	30	0.8	3.157	no	50	0	C2-E-07
71	Madrid	Existing	30	0.8	3.157	no	60	0	C2-E-08
72	Madrid	Existing	30	0.8	3.157	no	0	20	C2-E-09
73	Madrid	Existing	30	0.8	3.157	no	0	40	C2-E-10
74	Madrid	Existing	30	0.8	3.157	no	0	60	C2-E-11
75	Madrid	Existing	30	0.8	3.157	no	0	80	C2-E-12
76	Madrid	Existing	30	0.8	3.157	no	0	100	C2-E-13
77	Madrid	Existing	30	0.8	3.157	no	0	120	C2-E-14
78	Madrid	Existing	30	0.8	3.157	no	10	20	C2-E-15
79	Madrid	Existing	30	0.8	3.157	no	20	40	C2-E-16
80	Madrid	Existing	30	0.8	3.157	no	30	60	C2-E-17
81	Madrid	Existing	30	0.8	3.157	no	40	80	C2-E-18
82	Madrid	Existing	30	0.8	3.157	no	50	100	C2-E-19
83	Madrid	Existing	30	0.8	3.157	no	60	120	C2-E-20
84	Madrid	New	30	0.66	3.157	no	0	0	C2-N-01
85	Madrid	New	30	0.29	3.157	no	0	0	C2-N-02
86	Madrid	New	30	0.15	3.157	no	0	0	C2-N-03
87	Madrid	New	50	0.66	3.157	no	0	0	C2-N-04
88	Madrid	New	50	0.29	3.157	no	0	0	C2-N-05

89	Madrid	New	50	0.15	3.157	no	0	0	C2-N-06
90	Madrid	New	30	0.66	3.157	yes (50%)	0	0	C2-N-07
91	Madrid	New	30	0.29	3.157	yes (50%)	0	0	C2-N-08
92	Madrid	New	30	0.15	3.157	yes (50%)	0	0	C2-N-09
93	Madrid	New	50	0.66	3.157	yes (50%)	0	0	C2-N-10
94	Madrid	New	50	0.29	3.157	yes (50%)	0	0	C2-N-11
95	Madrid	New	50	0.15	3.157	yes (50%)	0	0	C2-N-12
96	Madrid	New	30	0.66	3.157	yes (100%)	0	0	C2-N-13
97	Madrid	New	30	0.29	3.157	yes (100%)	0	0	C2-N-14
98	Madrid	New	30	0.15	3.157	yes (100%)	0	0	C2-N-15
99	Madrid	New	50	0.66	3.157	yes (100%)	0	0	C2-N-16
100	Madrid	New	50	0.29	3.157	yes (100%)	0	0	C2-N-17
101	Madrid	New	50	0.15	3.157	yes (100%)	0	0	C2-N-18
102	Madrid	New	30	0.66	3.157	no	10	0	C2-N-19
103	Madrid	New	30	0.66	3.157	no	20	0	C2-N-20
104	Madrid	New	30	0.66	3.157	no	30	0	C2-N-21
105	Madrid	New	30	0.66	3.157	no	40	0	C2-N-22
106	Madrid	New	30	0.66	3.157	no	50	0	C2-N-23
107	Madrid	New	30	0.66	3.157	no	60	0	C2-N-24
108	Madrid	New	30	0.66	3.157	no	0	20	C2-N-25
109	Madrid	New	30	0.66	3.157	no	0	40	C2-N-26
110	Madrid	New	30	0.66	3.157	no	0	60	C2-N-27
111	Madrid	New	30	0.66	3.157	no	0	80	C2-N-28
112	Madrid	New	30	0.66	3.157	no	0	100	C2-N-29
113	Madrid	New	30	0.66	3.157	no	0	120	C2-N-30
114	Madrid	New	30	0.66	3.157	no	10	20	C2-N-31
115	Madrid	New	30	0.66	3.157	no	20	40	C2-N-32
116	Madrid	New	30	0.66	3.157	no	30	60	C2-N-33
117	Madrid	New	30	0.66	3.157	no	40	80	C2-N-34
118	Madrid	New	30	0.66	3.157	no	50	100	C2-N-35
119	Madrid	New	30	0.66	3.157	no	60	120	C2-N-36
120	Madrid	New	30	0.66	1.776	no	0	0	C2-N-37
121	Madrid	New	30	0.29	1.776	no	0	0	C2-N-38
122	Madrid	New	30	0.15	1.776	no	0	0	C2-N-39
123	Madrid	New	50	0.66	1.776	no	0	0	C2-N-40
124	Madrid	New	50	0.29	1.776	no	0	0	C2-N-41
125	Madrid	New	50	0.15	1.776	no	0	0	C2-N-42
126	Madrid	New	30	0.15	1.776	yes (100%)	0	120	C2-N-43
127	Tallinn	Existing	30	0.25	3.157	no	0	0	A1-E-01
128	Tallinn	Existing	50	0.25	3.157	no	0	0	A1-E-02
129	Tallinn	Existing	30	0.25	3.157	no	10	0	A1-E-03
130	Tallinn	Existing	30	0.25	3.157	no	20	0	A1-E-04
131	Tallinn	Existing	30	0.25	3.157	no	30	0	A1-E-05
132	Tallinn	Existing	30	0.25	3.157	no	40	0	A1-E-06
133	Tallinn	Existing	30	0.25	3.157	no	50	0	A1-E-07
134	Tallinn	Existing	30	0.25	3.157	no	60	0	A1-E-08
135	Tallinn	Existing	30	0.25	3.157	no	0	20	A1-E-09

136	Tallinn	Existing	30	0.25	3.157	no	0	40	A1-E-10
137	Tallinn	Existing	30	0.25	3.157	no	0	60	A1-E-11
138	Tallinn	Existing	30	0.25	3.157	no	0	80	A1-E-12
139	Tallinn	Existing	30	0.25	3.157	no	0	100	A1-E-13
140	Tallinn	Existing	30	0.25	3.157	no	0	120	A1-E-14
141	Tallinn	Existing	30	0.25	3.157	no	10	20	A1-E-15
142	Tallinn	Existing	30	0.25	3.157	no	20	40	A1-E-16
143	Tallinn	Existing	30	0.25	3.157	no	30	60	A1-E-17
144	Tallinn	Existing	30	0.25	3.157	no	40	80	A1-E-18
145	Tallinn	Existing	30	0.25	3.157	no	50	100	A1-E-19
146	Tallinn	Existing	30	0.25	3.157	no	60	120	A1-E-20
147	Tallinn	New	30	0.2	3.157	no	0	0	A1-N-01
148	Tallinn	New	30	0.14	3.157	no	0	0	A1-N-02
149	Tallinn	New	30	0.10	3.157	no	0	0	A1-N-03
150	Tallinn	New	50	0.2	3.157	no	0	0	A1-N-04
151	Tallinn	New	50	0.14	3.157	no	0	0	A1-N-05
152	Tallinn	New	50	0.10	3.157	no	0	0	A1-N-06
153	Tallinn	New	30	0.2	3.157	yes	0	0	A1-N-07
154	Tallinn	New	30	0.14	3.157	yes	0	0	A1-N-08
155	Tallinn	New	30	0.10	3.157	yes	0	0	A1-N-09
156	Tallinn	New	50	0.2	3.157	yes	0	0	A1-N-10
157	Tallinn	New	50	0.14	3.157	yes	0	0	A1-N-11
158	Tallinn	New	50	0.10	3.157	yes	0	0	A1-N-12
159	Tallinn	New	30	0.2	3.157	yes	0	0	A1-N-13
160	Tallinn	New	30	0.14	3.157	yes	0	0	A1-N-14
161	Tallinn	New	30	0.10	3.157	yes	0	0	A1-N-15
162	Tallinn	New	50	0.2	3.157	yes	0	0	A1-N-16
163	Tallinn	New	50	0.14	3.157	yes	0	0	A1-N-17
164	Tallinn	New	50	0.10	3.157	yes	0	0	A1-N-18
165	Tallinn	New	30	0.2	3.157	no	10	0	A1-N-19
166	Tallinn	New	30	0.2	3.157	no	20	0	A1-N-20
167	Tallinn	New	30	0.2	3.157	no	30	0	A1-N-21
168	Tallinn	New	30	0.2	3.157	no	40	0	A1-N-22
169	Tallinn	New	30	0.2	3.157	no	50	0	A1-N-23
170	Tallinn	New	30	0.2	3.157	no	60	0	A1-N-24
171	Tallinn	New	30	0.2	3.157	no	0	20	A1-N-25
172	Tallinn	New	30	0.2	3.157	no	0	40	A1-N-26
173	Tallinn	New	30	0.2	3.157	no	0	60	A1-N-27
174	Tallinn	New	30	0.2	3.157	no	0	80	A1-N-28
175	Tallinn	New	30	0.2	3.157	no	0	100	A1-N-29
176	Tallinn	New	30	0.2	3.157	no	0	120	A1-N-30
177	Tallinn	New	30	0.2	3.157	no	10	20	A1-N-31
178	Tallinn	New	30	0.2	3.157	no	20	40	A1-N-32
179	Tallinn	New	30	0.2	3.157	no	30	60	A1-N-33
180	Tallinn	New	30	0.2	3.157	no	40	80	A1-N-34
181	Tallinn	New	30	0.2	3.157	no	50	100	A1-N-35
182	Tallinn	New	30	0.2	3.157	no	60	120	A1-N-36

183	Tallinn	New	30	0.2	1.776	no	0	0	A1-N-37
184	Tallinn	New	30	0.14	1.776	no	0	0	A1-N-38
185	Tallinn	New	30	0.10	1.776	no	0	0	A1-N-39
186	Tallinn	New	50	0.2	1.776	no	0	0	A1-N-40
187	Tallinn	New	50	0.14	1.776	no	0	0	A1-N-41
188	Tallinn	New	50	0.10	1.776	no	0	0	A1-N-42
189	Tallinn	New	30	0.10	1.776	yes	0	120	A1-N-43

Annex 2: Simulation of the energy consumption during the building's use phase

About EnergyPlus

EnergyPlus is an energy analysis and thermal load simulation program. Based on a user's description of a building from the perspective of the building's physical make-up and associated mechanical and other systems, EnergyPlus calculates heating and cooling loads necessary to maintain thermal control setpoints, conditions throughout a secondary HVAC system and coil loads, and the energy consumption of primary plant equipment. Simultaneous integration of these—and many other—details verify that the EnergyPlus simulation performs as would the real building.

EnergyPlus Key Capabilities

The following is a representative list of EnergyPlus capabilities:

- **Integrated, simultaneous solution** where the building response and the primary and secondary systems are tightly coupled (iteration performed when necessary)
- **Sub-hourly, user-definable time steps** for the interaction between the thermal zones and the environment; variable time steps for interactions between the thermal zones and the HVAC systems (automatically varied to ensure solution stability)
- **ASCII text based weather, input, and output files** that include hourly or sub-hourly environmental conditions, and standard and user definable reports, respectively
- **Heat balance based solution** technique for building thermal loads that allows for simultaneous calculation of radiant and convective effects at both in the interior and exterior surface during each time step
- **Transient heat conduction** through building elements such as walls, roofs, floors, etc. using conduction transfer functions
- **Improved ground heat transfer modelling** through links to three-dimensional finite difference ground models and simplified analytical techniques
- **Combined heat and mass transfer** model that accounts for moisture adsorption/desorption either as a layer-by-layer integration into the conduction transfer functions or as an effective moisture penetration depth model (EMPD)
- **Thermal comfort models** based on activity, inside dry bulb, humidity, etc.
- **Anisotropic sky model** for improved calculation of diffuse solar on tilted surfaces
- **Advanced fenestration calculations** including controllable window blinds, electrochromic glazing, layer-by-layer heat balances that allow proper assignment of solar energy absorbed by window panes, and a performance library for numerous commercially available windows
- **Daylighting controls** including interior luminance calculations, glare simulation and control, luminaries controls, and the effect of reduced artificial lighting on heating and cooling

- **Atmospheric pollution calculations** that predict CO2, SOx, NOx, CO, particulate matter, and hydrocarbon production for both on site and remote energy conversion

Testing and Validation

Three major types of tests are currently conducted:

a) Analytical tests:
  - HVAC tests, based on ASHRAE Research Project 865
  - Building fabric tests, based on ASHRAE Research Project 1052

b) Comparative tests:
  - ANSI/ASHRAE Standard 140-2007
  - International Energy Agency Solar Heating and Cooling Programme (IEA SHC) BESTest (Building Energy Simulation Test) methods not yet in Standard 140
  - EnergyPlus HVAC Component Comparative tests
  - EnergyPlus Global Heat Balance tests

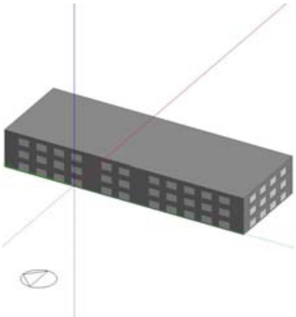
c) Release and executable tests. The BESTest suites compare the results of multiple simulation programs for a series of load-related attributes. EnergyPlus testing reports are available for many of these test suites.

References

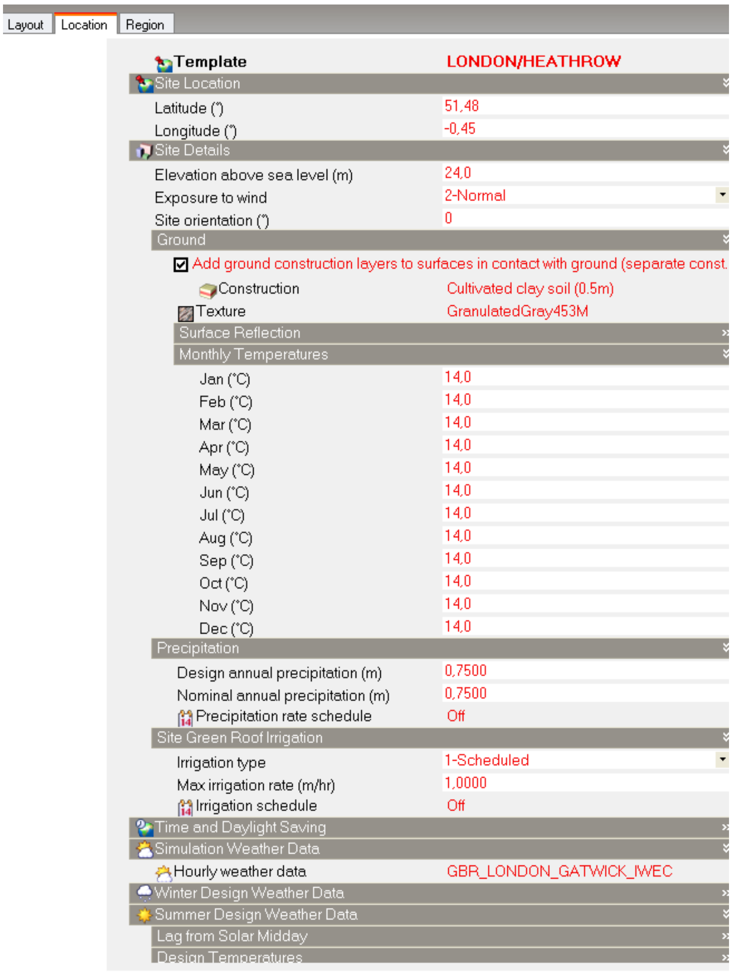
- EnergyPlus Building Energy Simulation Software. Available from: http://apps1.eere.energy.gov/buildings/energyplus/
- EnergyPlus Building Energy Simulation Software. Testing and validation available from: http://apps1.eere.energy.gov/buildings/energyplus/energyplus_testing.cfm
- EnergyPlus Building Energy Simulation Software. Available from: http://apps1.eere.energy.gov/buildings/energyplus/
- ASHRAE., International Weather for Energy Calculations (IWEC Weather Files) Users Manual and CD-ROM, Atlanta: ASHRAE. 2001.

Example of a base case simulation (B1-N-01)

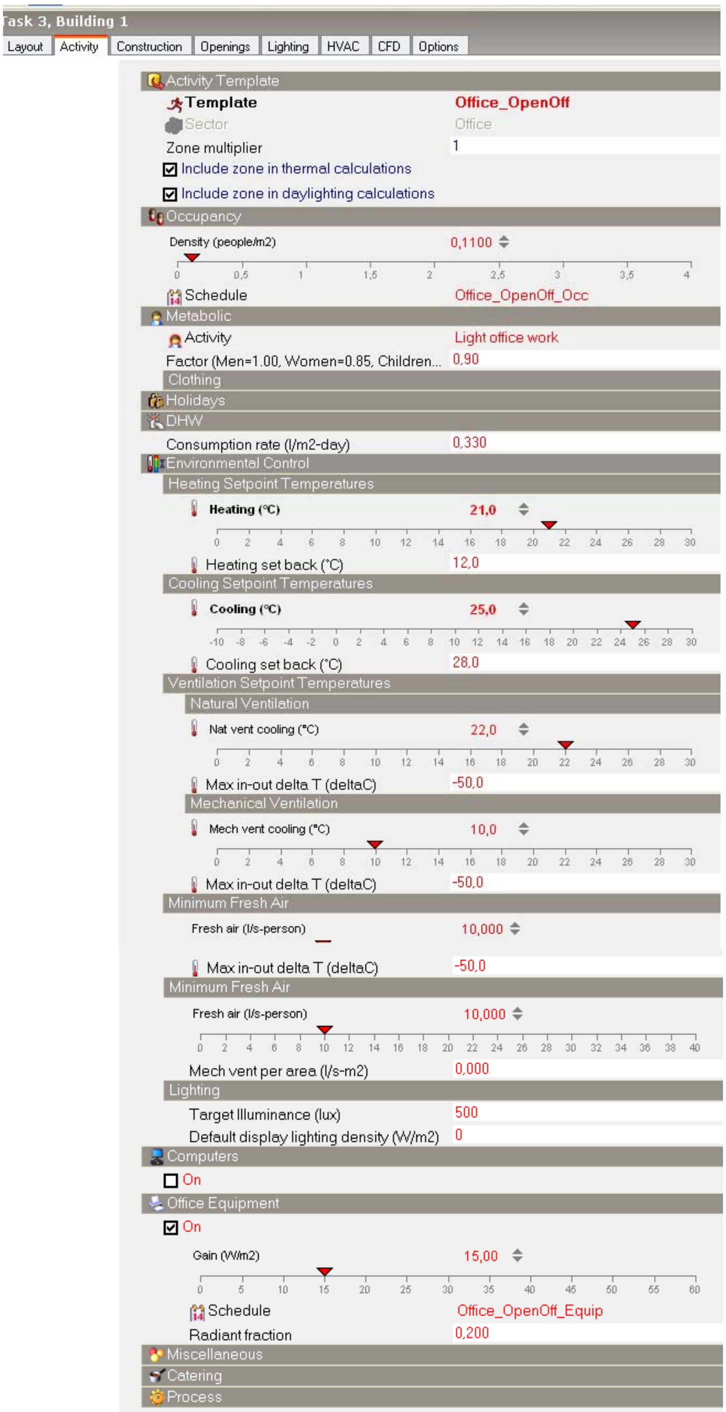
- **Definition of the layout:**



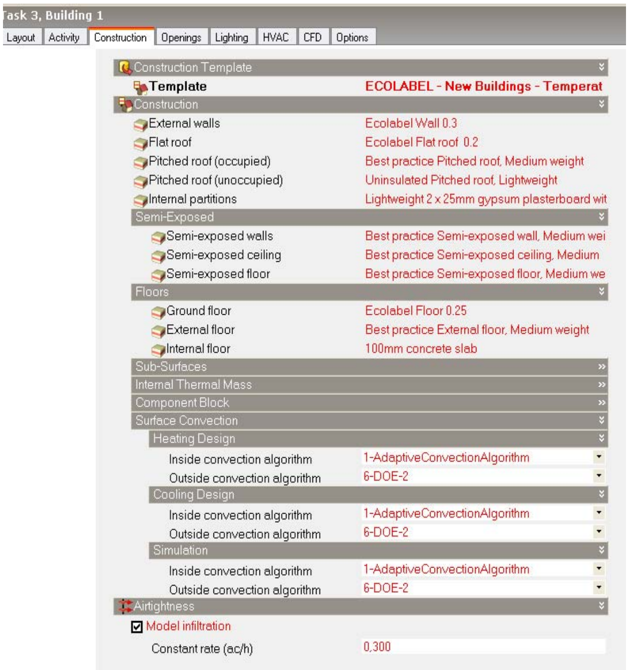
- **Selection of the building location:**



- **Definition of the building activity during its use phase:**

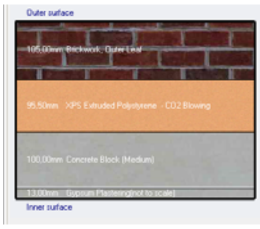


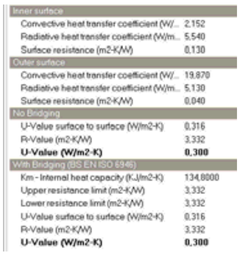
- **Selections of the construction systems:**



ask 3, Building 1	
Layout / Activity / Construction / Openings / Lighting / HVAC / CFD / Options	
Construction Template	
Template	**ECOLABEL - New Buildings - Temperat**
Construction	
External walls	Ecolabel Wall 0.3
Flat roof	Ecolabel Flat roof 0.2
Pitched roof (occupied)	Best practice Pitched roof, Medium weight
Pitched roof (unoccupied)	Uninsulated Pitched roof, Lightweight
Internal partitions	Lightweight 2 x 25mm gypsum plasterboard wit
Semi-Exposed	
Semi-exposed walls	Best practice Semi-exposed wall, Medium wei
Semi-exposed ceiling	Best practice Semi-exposed ceiling, Medium
Semi-exposed floor	Best practice Semi-exposed floor, Medium we
Floors	
Ground floor	Ecolabel Floor 0.25
External floor	Best practice External floor, Medium weight
Internal floor	100mm concrete slab
Sub-Surfaces	
Internal Thermal Mass	
Component Block	
Surface Convection	
Heating Design	
Inside convection algorithm	1-AdaptiveConvectionAlgorithm
Outside convection algorithm	6-DOE-2
Cooling Design	
Inside convection algorithm	1-AdaptiveConvectionAlgorithm
Outside convection algorithm	6-DOE-2
Simulation	
Inside convection algorithm	1-AdaptiveConvectionAlgorithm
Outside convection algorithm	6-DOE-2
Airtightness	
Model infiltration	
Constant rate (ac/h)	0,300

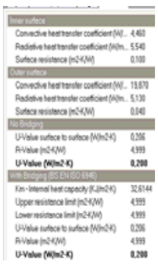
- Wall details





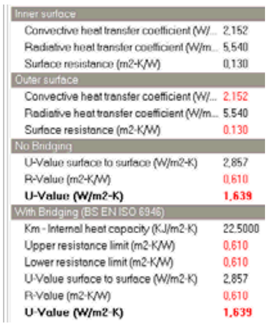
Inner surface	
Convective heat transfer coefficient (W/...	2,152
Radiative heat transfer coefficient (W/m...	5,540
Surface resistance (m2-K/W)	0,130
Outer surface	
Convective heat transfer coefficient (W/...	19,870
Radiative heat transfer coefficient (W/m...	5,130
Surface resistance (m2-K/W)	0,040
No Bridging	
U-Value surface to surface (W/m2-K)	0,316
R-Value (m2-K/W)	3,332
U-Value (W/m2-K)	**0,300**
With Bridging (BS EN ISO 6946)	
Km - Internal heat capacity (KJ/m2-K)	134,8000
Upper resistance limit (m2-K/W)	3,332
Lower resistance limit (m2-K/W)	3,332
U-Value surface to surface (W/m2-K)	0,316
R-Value (m2-K/W)	3,332
U-Value (W/m2-K)	**0,300**

- Flat Roof details



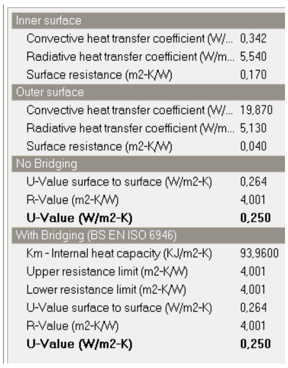
Inner surface	
Convective heat transfer coefficient (W/...	4,460
Radiative heat transfer coefficient (W/m...	5,540
Surface resistance (m2-K/W)	0,100
Outer surface	
Convective heat transfer coefficient (W/...	19,870
Radiative heat transfer coefficient (W/m...	5,130
Surface resistance (m2-K/W)	0,040
No Bridging	
U-Value surface to surface (W/m2-K)	0,206
R-Value (m2-K/W)	4,999
U-Value (W/m2-K)	**0,200**
With Bridging (BS EN ISO 6946)	
Km - Internal heat capacity (KJ/m2-K)	32,6144
Upper resistance limit (m2-K/W)	4,999
Lower resistance limit (m2-K/W)	4,999
U-Value surface to surface (W/m2-K)	0,206
R-Value (m2-K/W)	4,999
U-Value (W/m2-K)	**0,200**

- Internal partitions details:



Inner surface	
Convective heat transfer coefficient (W/...	2,152
Radiative heat transfer coefficient (W/m...	5,540
Surface resistance (m2-K/W)	0,130
Outer surface	
Convective heat transfer coefficient (W/...	2,152
Radiative heat transfer coefficient (W/m...	5,540
Surface resistance (m2-K/W)	0,130
No Bridging	
U-Value surface to surface (W/m2-K)	2,857
R-Value (m2-K/W)	0,610
U-Value (W/m2-K)	**1,639**
With Bridging (BS EN ISO 6946)	
Km - Internal heat capacity (KJ/m2-K)	22,5000
Upper resistance limit (m2-K/W)	0,610
Lower resistance limit (m2-K/W)	0,610
U-Value surface to surface (W/m2-K)	2,857
R-Value (m2-K/W)	0,610
U-Value (W/m2-K)	**1,639**

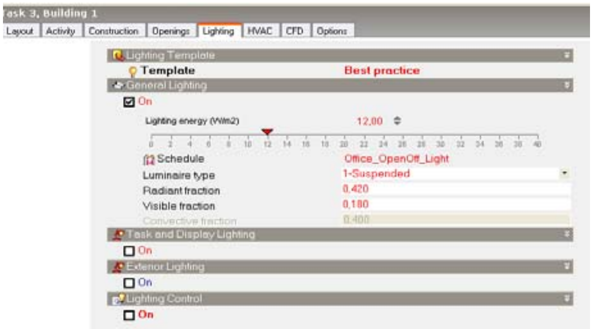
- Floor details:



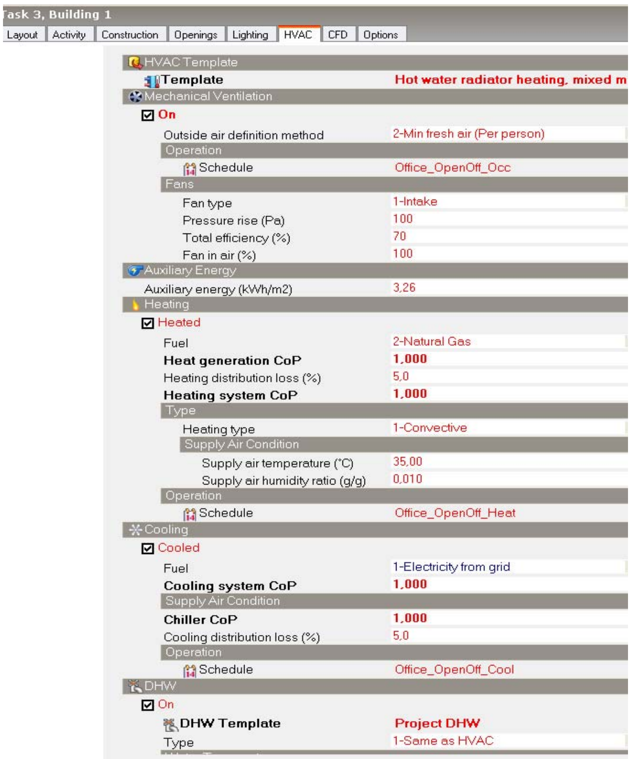
Inner surface	
Convective heat transfer coefficient (W/...	0,342
Radiative heat transfer coefficient (W/m...	5,540
Surface resistance (m2-K/W)	0,170
Outer surface	
Convective heat transfer coefficient (W/...	19,870
Radiative heat transfer coefficient (W/m...	5,130
Surface resistance (m2-K/W)	0,040
No Bridging	
U-Value surface to surface (W/m2-K)	0,264
R-Value (m2-K/W)	4,001
U-Value (W/m2-K)	**0,250**
With Bridging (BS EN ISO 6946)	
Km - Internal heat capacity (KJ/m2-K)	93,9600
Upper resistance limit (m2-K/W)	4,001
Lower resistance limit (m2-K/W)	4,001
U-Value surface to surface (W/m2-K)	0,264
R-Value (m2-K/W)	4,001
U-Value (W/m2-K)	**0,250**

- **Glazing details:**

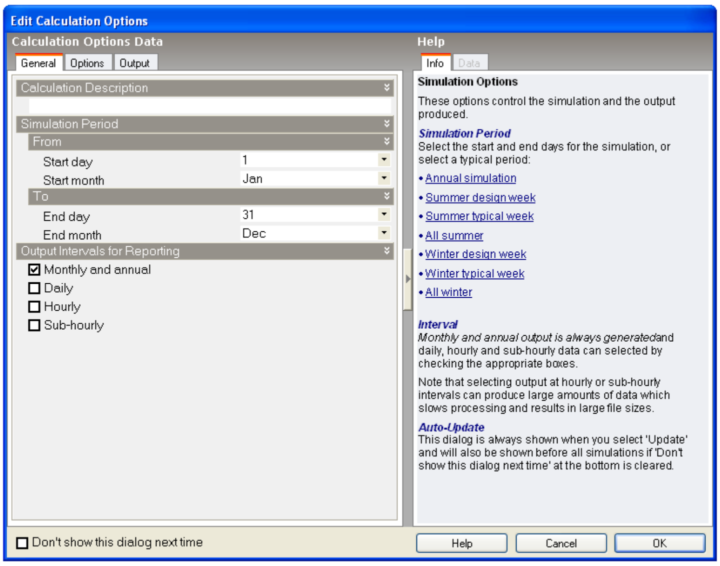
- **Lighting characteristics:**

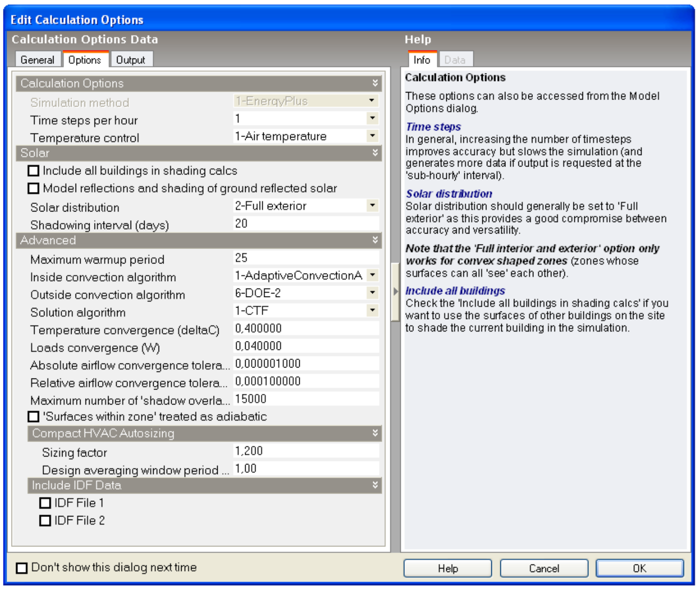


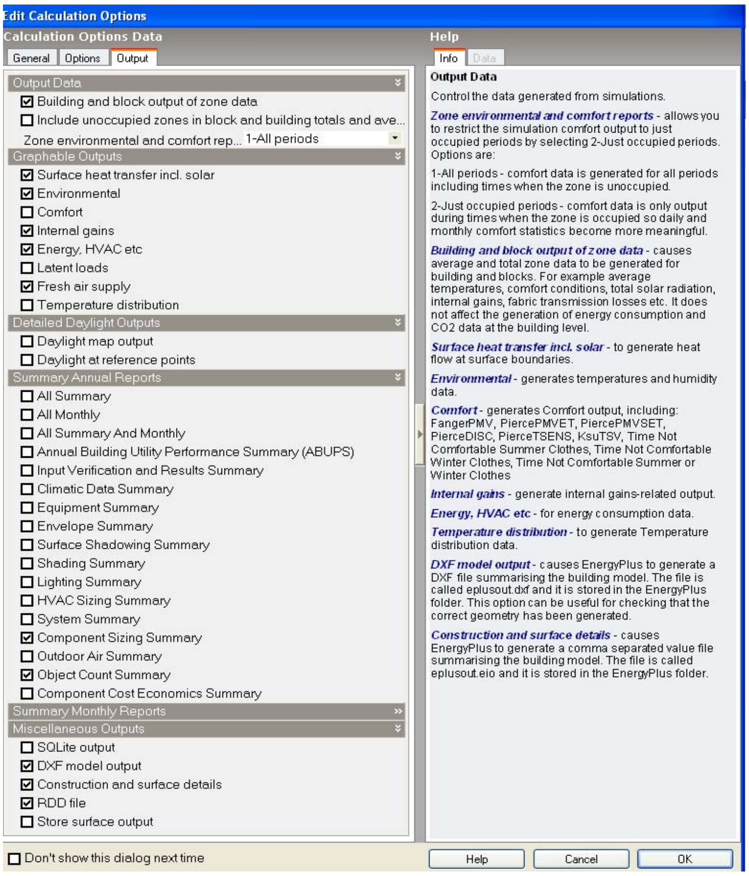
- **HVAC characteristics:**



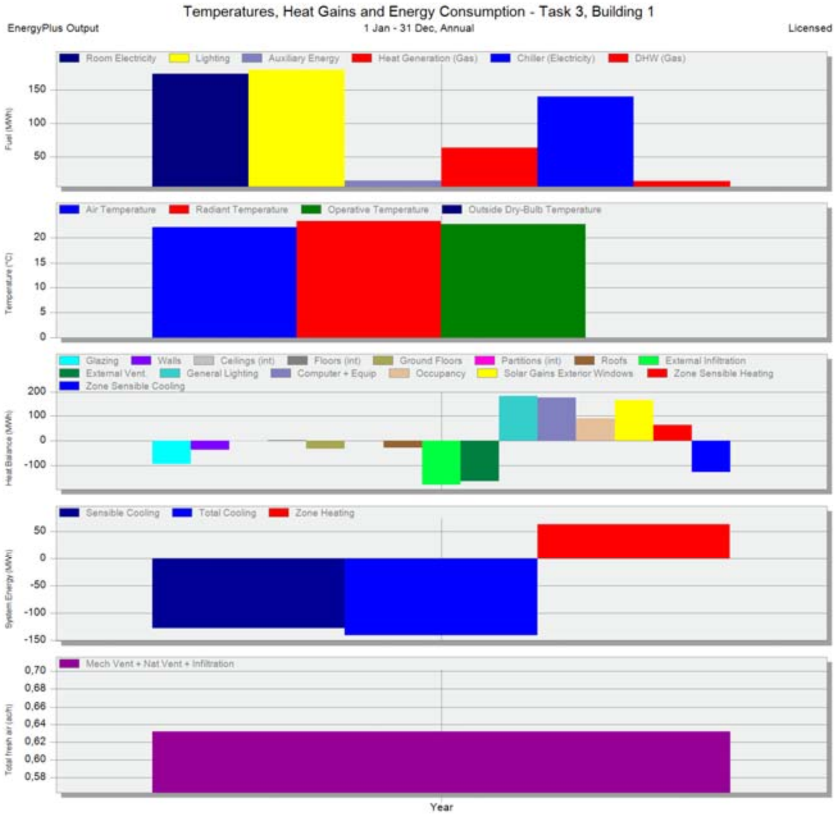
- **Definition of the calculation options:**



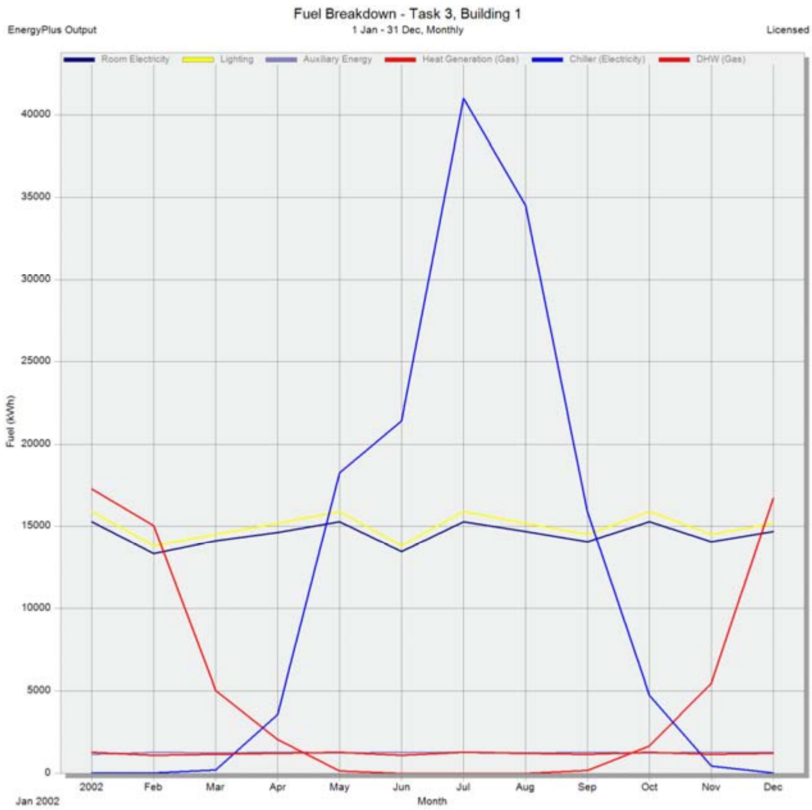

Edit Calculation Options
Calculation Options Data
General
Options
Output
Calculation Options
Simulation method
1-EnergyPlus
Time steps per hour
1
Temperature control
1-Air temperature
Solar
Include all buildings in shading calcs
Model reflections and shading of ground reflected solar
Solar distribution
2-Full exterior
Shadowing interval (days)
20
Advanced
Maximum warmup period
25
Inside convection algorithm
1-AdaptiveConvectionA
Outside convection algorithm
6-DOE-2
Solution algorithm
1-CTF
Temperature convergence (deltaC)
0,400000
Loads convergence (W)
0,040000
Absolute airflow convergence tolera...
0,000001000
Relative airflow convergence tolera...
0,000100000
Maximum number of 'shadow overla...
15000
'Surfaces within zone' treated as adiabatic
Compact HVAC Autosizing
Sizing factor
1,200
Design averaging window period ...
1,00
Include IDF Data
IDF File 1
IDF File 2
Help
Info
Data
Calculation Options
These options can also be accessed from the Model Options dialog.
Time steps
In general, increasing the number of timesteps improves accuracy but slows the simulation (and generates more data if output is requested at the 'sub-hourly' interval).
Solar distribution
Solar distribution should generally be set to 'Full exterior' as this provides a good compromise between accuracy and versatility.
Note that the 'Full interior and exterior' option only works for convex shaped zones (zones whose surfaces can all 'see' each other).
Include all buildings
Check the 'Include all buildings in shading calcs' if you want to use the surfaces of other buildings on the site to shade the current building in the simulation.
Don't show this dialog next time
Help
Cancel
OK


Edit Calculation Options
Calculation Options Data
General
Options
Output
Output Data
Building and block output of zone data
Include unoccupied zones in block and building totals and ave...
Zone environmental and comfort rep...
1-All periods
Graphable Outputs
Surface heat transfer incl. solar
Environmental
Comfort
Internal gains
Energy, HVAC etc
Latent loads
Fresh air supply
Temperature distribution
Detailed Daylight Outputs
Daylight map output
Daylight at reference points
Summary Annual Reports
All Summary
All Monthly
All Summary And Monthly
Annual Building Utility Performance Summary (ABUPS)
Input Verification and Results Summary
Climatic Data Summary
Equipment Summary
Envelope Summary
Surface Shadowing Summary
Shading Summary
Lighting Summary
HVAC Sizing Summary
System Summary
Component Sizing Summary
Outdoor Air Summary
Object Count Summary
Component Cost Economics Summary
Summary Monthly Reports
Miscellaneous Outputs
SQLite output
DXF model output
Construction and surface details
RDD file
Store surface output
Help
Info
Data
Output Data
Control the data generated from simulations.
Zone environmental and comfort reports - allows you to restrict the simulation comfort output to just occupied periods by selecting 2-Just occupied periods. Options are:
1-All periods - comfort data is generated for all periods including times when the zone is unoccupied.
2-Just occupied periods - comfort data is only output during times when the zone is occupied so daily and monthly comfort statistics become more meaningful.
Building and block output of zone data - causes average and total zone data to be generated for building and blocks. For example average temperatures, comfort conditions, total solar radiation, internal gains, fabric transmission losses etc. It does not affect the generation of energy consumption and CO2 data at the building level.
Surface heat transfer incl. solar - to generate heat flow at surface boundaries.
Environmental - generates temperatures and humidity data.
Comfort - generates Comfort output, including: FangerPMV, PiercePMVET, PiercePMVSET, PierceDISC, PierceTSENS, KsuTSV, Time Not Comfortable Summer Clothes, Time Not Comfortable Winter Clothes, Time Not Comfortable Summer or Winter Clothes
Internal gains - generate internal gains-related output.
Energy, HVAC etc - for energy consumption data.
Temperature distribution - to generate Temperature distribution data.
DXF model output - causes EnergyPlus to generate a DXF file summarising the building model. The file is called eplusout.dxf and it is stored in the EnergyPlus folder. This option can be useful for checking that the correct geometry has been generated.
Construction and surface details - causes EnergyPlus to generate a comma separated value file summarising the building model. The file is called eplusout.eio and it is stored in the EnergyPlus folder.
Don't show this dialog next time
Help
Cancel
OK

- **Simulation annual results:**



Simulation monthly results:



Annex 3. Limitation of substances in particular building products. Extracted from ISO 16814

[ISO 16814, 2008] Building environment design -- Indoor air quality -- Methods of expressing the quality of indoor air for human occupancy.

Table D.1 — European labelling schemes for low-emission flooring products

<table>
<tr><th>Labelling schemes</th><th colspan="4">Classification requirements/Description</th></tr>
<tr><td>Danish voluntary labelling scheme</td><td colspan="4">Requires evaluation of the VOC emission rates and odour and irritation thresholds of the flooring materials in an environmental chamber or cell, with results scaled to a 17 m^3 modelled room.</td></tr>
<tr><td>Finnish M1 label for finishing materials
http://www.rts.fi/</td><td colspan="4">Requires measurements of TVOC (< 200 $\mu g \cdot m^{-2} \cdot h^{-1}$), carcinogens (< 5 $\mu g \cdot m^{-2} \cdot h^{-1}$), formaldehyde (< 50 $\mu g \cdot m^{-2} \cdot h^{-1}$), ammonia (< 30 $\mu g \cdot m^{-2} \cdot h^{-1}$) and odour dissatisfaction (15 %) after 28 days of exposure in an environmental chamber.</td></tr>
<tr><td>GuT, Environmental Quality Mark for Carpets
http://www.gut-ev.org/</td><td colspan="4">Regulates emissions of CFCs, pesticides, carcinogens (recognized, proven or suspected, e.g. benzene, butadiene, vinylchloride, vinylacetate and formaldehyde), which shall not be detected in product; and limits emission of toluene (50 $\mu g \cdot m^{-3}$), styrene (5 $\mu g \cdot m^{-3}$), 4-vinylcyclohexene (2 $\mu g \cdot m^{-3}$), 4-phenylcyclohexene (20 $\mu g \cdot m^{-3}$), TVOC (30 $\mu g \cdot m^{-3}$), total aromatic hydrocarbons (150 $\mu g \cdot m^{-3}$), and odours, tested in a standard environmental chamber. Dyes or auxiliary substances shall not contain heavy metals, such as lead, cadmium, mercury or chromium(VI).</td></tr>
<tr><td rowspan="6">GEV EMICODE Labelling System for adhesives, primers and smoothing compounds
http://www.emicode.com/</td><td colspan="4">The product is analysed for carcinogenic compounds after 24 h of exposure in an environmental chamber. The substances are classified as a recognized (C1), a proven (C2) or a suspected (C3) carcinogen according to European Directives or German legislation.

The following carcinogenic compounds are currently restricted:
C1: acrylamide, acrylonitrile, benzene, 1,4-dioxane;
C2: acetaldehyde and formaldehyde;
C3: vinylacetate.

EMICODE sets the following limits:
C1 substances: < 2 $\mu g \cdot m^{-3}$,
C2 substances: < 10 $\mu g \cdot m^{-3}$;
C3 substances: < 50 $\mu g \cdot m^{-3}$.

TVOC and the principal VOCs (above 20 $\mu g \cdot m^{-3}$) are also quantified, after 10 days of exposure. The following three categories of product are used, based on TVOC emission rates.</td></tr>
<tr><th rowspan="2">Product</th><th colspan="3">TVOC emission rates by product category
$\mu g \cdot m^{-3}$</th></tr>
<tr><th>EC 1</th><th>EC 2</th><th>EC 3</th></tr>
<tr><td>Primers</td><td>< 100</td><td>100 to 300</td><td>> 300</td></tr>
<tr><td>Levelling compounds</td><td>< 200</td><td>200 to 600</td><td>> 600</td></tr>
<tr><td>Flooring adhesives</td><td>< 500</td><td>500 to 1 500</td><td>> 1 500</td></tr>
</table>

Table D.1 (*continued*)

Labelling schemes	Classification requirements/Description
Swedish standard for floorings GBR/SP Trade standards GBR 1992.	Requires measurement and declaration of TVOC emission rates after 4 weeks and 26 weeks of exposure of the flooring materials in an emission cell, and the 10 principal individual VOCs.
Nordic Swan Ecolabelling Programme	The scheme prohibits the presence in the product of carcinogens, halogenated VOCs, organic tin compounds, phthalates, polybrominated diphenyl ethers and also substances that are mutagenic or harmful to the human reproductive system. Heavy metals are also not allowed. Emission of formaldehyde from the finished product shall be less than 0,1 $mg \cdot m^{-3}$ in the chamber air. The procedures used in the Danish and Finnish schemes also apply in the Nordic Swan Ecolabelling Programme. Both the environmental chamber and emission cell tests can be used.
German Blue Angel Ecolabelling Scheme RAL-UZ 38 RAL-UZ 76 RAL-UZ 430	This labelling scheme covers flooring materials, furniture and wall panels. Auxiliary materials, such as adhesives and coating materials, are also included in the scheme. The scheme provides labelling to cover the whole life-cycle of the products. The scheme controls emissions of formaldehyde, TVOC, halogenated organic compounds and toxic substances that are carcinogenic, mutagenic and/or teratogenic. Standard environmental chamber tests are required for the certification of VOC emissions from the products. The following are the emission requirements for large surface products used in building.

Compound	Emission requirements $\mu g \cdot m^{-3}$	
	1 day	28 day
Formaldehyde	—	62
TVOC (50 °C to 250 °C)	—	300
Total VOCs (> 250 °C)	—	100
Toxic substances	< 1	1

Table D.2 — European labelling schemes for control of VOC emissions from coatings

Labelling schemes	Requirements/Description
Danish voluntary labelling scheme	See Table D.1 for requirements.
Finnish M1 label for finishing materials http://www.rts.fi/	See Table D.1 for requirements.
EU Ecolabel Scheme http://www.ecosite.co.uk/ B & Q and British Coating Federation Scheme	Provides criteria for paints, varnishes and cleaning products for indoor uses. The quantity of VOCs and volatile aromatic hydrocarbons (VAHs) are included in restrictions. The limits for Class I and Class II paints and varnishes are similar to those required by B & Q and the British Coatings Federation schemes. The "Ecolabel" criteria limit the use of paints and varnishes that contain toxic, highly toxic, carcinogenic, mutagenic or teratogenic substances classified under the European Directives 79/831/EEC and 83/4367/EEC, and also substances that are mandated a warning label by Directives 88/379/EEC. The VOCs included in this restriction are benzene, methanol, acetonitrile, 1,1,1-trichloroethane, xylenes, toluene, turpentine, ethylbenzene, butanol, 2-ethoxyethylacetate and formaldehyde. a) Paint category 1 (for walls and ceiling): — The VOC content shall not be greater than 30 $g \cdot l^{-1}$ (and in warm and dry climate $\leqslant$ 60 $g \cdot l^{-1}$). — The VAHs shall not be greater than 0,5 % of the product mass. b) Paint category 1 (for use on other surfaces): — The VOC content shall be less than or equal to 250 $g \cdot l^{-1}$. — The VAHs shall be less than or equal to 5 % of the product mass.
German Federal Environment Agency, Blue Angel Scheme	This scheme requires that the paints and varnishes not contain mutagenic or carcinogenic substances. The maximum allowed levels are as follows: — VOC content 10 % by mass for water-soluble paints and 15 % by mass for oil-based paints; — toxic VOC content $\leqslant$ 0,5 % by mass for water-soluble paints and $\leqslant$ 5 % by mass for oil-based paints. The product should not contain any heavy metals, such as lead, cadmium or chromium. Chamber tests of low-emission paints that had qualified for the Blue Angel Label showed that, after 48 h of paint application, the emission of the solvent VOCs was reduced to below the detection range of the analysis. The scheme also has restrictions on the production and uses of dyes that contain more than 1 % 2-naphthylamine, 1 % 4-nitrodiphenyl and $\leqslant$ 1 % chlorinated solvents, such as carbon tetrachloride, tetrachloroethanes and pentachloroethanes.
The Danish Technological Institute "Paint favourable to IAQ"	The factors included for consideration are IAQ and working environment, paint application characteristics, and coating performance. Emission rates of VOCs and odour are the properties to be assessed as well as drying time, adhesion and paint mass application. Three categories of paints are provided. This classification scheme is supported by a Nordic group of industries and institutes. Products are characterized as follows: — "Amongst the very best paints": paints that produce a VOC concentration less than 5 $\mu g \cdot m^{-3}$ within 2 weeks to 4 weeks after paint application; — "Acceptable": paints that do not emit any substances that are carcinogenic or have a toxic effect or cause mucous membrane irritation to the eye or the respiratory system; — "Poor-quality paints": paints that do not meet the criteria for acceptable paints.

Annex 4. Extract from EN 15251

[EN 15251, 2007] Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

Example on how to define low and very low polluting buildings

The building is **low polluting** if the majority of the materials are low polluting. Low polluting materials are natural traditional materials, such as stone and glass, which are known to be safe with respect to emissions, and materials which fulfil the following requirements:

- Emission of total volatile organic compounds (TVOC) is below 0,2 mg/m²h.
- Emission of formaldehyde is below 0,05 mg/m²h.

- Emission of ammonia is below 0,03 mg/m²h.
- Emission of carcinogenic compounds (IARC) is below 0,005 mg/m²h.
- Material is not odorous (dissatisfaction with the odour is below 15 %).

The building is **very low polluting** if all of the materials are very low polluting and smoking has never occurred and is not allowed. Very low polluting materials are natural traditional materials, such as stone, glass and metals, which are known to be safe with respect to emissions, and materials which fulfil the following requirements:

- Emission of total volatile organic compounds (TVOC) is below 0,1 mg/m²h.
- Emission of formaldehyde is below 0,02 mg/m²h.
- Emission of ammonia is below 0,01 mg/m²h.
- Emission of carcinogenic compounds (IARC) is below 0,002 mg/m²h.
- Material is not odorous (dissatisfaction with the odour is below 10 %).

Annex 5. Examples of WHO recommendations.

Extracted from Bluyssen (2010). "Indoor sources and health effects: background information and ways to go", Product Policy and Indoor Air Quality, September 23 & 24, 2010 in Brussels. Background Document, June 2010. TNO Built Environment and Geosciences.

WHO guideline values for individual substances based on effects other than cancer or odour/annoyance (WHO, 2000)

Substance	*Time-weighted average ($\mu g\ m^{-3}$)*	*Averaging time*
Carbon disulfide	100	24 hours
Carbon monoxide	100,000 60,000 30,000 10,000	15 minutes 30 minutes 1 hours 8 hours
1,2-dichloroethane	700	24 hours
Dichloromethane	3000 450	24 hours 1 week
Formaldehyde	100	30 minutes
Hydrogen sulfide	150	24 hours
Nitrogen dioxide	200 40	1 hour annual
Ozone	120	8 hours
Styrene	260	1 week
Sulfur dioxide	500 125 50	10 minutes 24 hours annual
Tetrachloroethylene	250	annual
Toluene	260	1 week

WHO guideline values based on sensory effects or annoyance reactions, using an averaging time of 30 minutes (WHO 2000)

Substance	*Detection Threshold ($\mu g\ m^{-3}$)*	*Recognitions Threshold ($\mu g\ m^{-3}$)*	*Guideline Value ($\mu g\ m^{-3}$)*
Carbon disulphide	200	—	20
Hydrogen sulfide	0.2-20	0.6-6.0	7
Formaldehyde	30-60	—	100
Styrene	70	210-280	70
Tetrachloroethylene	8,000	2,400-3,200	8,000
Toluene	1,000	10,000	1,000

Update to WHO Air Quality Guideline values (WHO 20006)

Substance	Annual mean ($\mu g\ m^{-3}$)	24-hour mean ($\mu g\ m^{-3}$)
$PM_{2.5}$	10	25
PM_{10}	20	50
		1-hour mean ($\mu g\ m^{-3}$)
NO_2	40	200
	24-hour mean ($\mu g\ m^{-3}$)	10-minute mean ($\mu g\ m^{-3}$)
SO_2	20	500
	Daily maximum 8-hour mean ($\mu g\ m^{-3}$)	

WHO (2000), Air Quality guidelines for Europe, Second Edition, World Health Organisation Regional Publications, European Series, No. 91, Copenhagen, 2000.
WHO (2006a) *Air quality guidelines, global update 2005*, Particulate matter, ozone, nitrogen dioxide and sulphur dioxide. ISBN 92 890 2192 6; WHO Regional office for Europe; Denmark.
WHO (2006b) Development of WHO guidelines for indoor air quality, report on a working group meeting. Bonn; Germany; 23-24 October 2006; Copenhagen; WHO regional office for Europe.