BGP index: an approach to the certification of building global performance

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SUMMARY

In order to improve life quality into buildings, the present paper proposes a certification model for indoor total comfort.

The first part of the paper concerns energy certification of buildings, with attention to energy efficiency, renewable sources, heating and air-conditioning. In the second part of the paper certificate concept is extended to factors which contribute to ideal requirements into buildings: acoustics and lighting, use of water, safety and technology are studied according to standards. Finally, an overall building quality certificate is proposed, based on indexes concerning specific performances. Every index is assigned a weight to characterize different contributions to Building Global Performance (BGP) index, which expresses total indoor quality. Weights are estimated according to objective criteria. Measurements and provisional models allow to analyse and classify a private flat as a case study. A reliable approach is shown to improve indoor environments and to support comfortable and sustainable buildings.

INTRODUCTION

Human activities impose a long time stay into buildings, where high comfort must be guaranteed: such a condition comes from a combination of different elements, such as thermal, hygrometric, acoustic, lighting, safety and technological factors.

According to Directive 2002/91/EC [1] and to national or regional procedures, energy certification of buildings assumes remarkable importance in order to rationalize the use of energy sources and to reduce costs and pollution.

The improvement of indoor life quality is due to many other factors too, which contribute to global well-being. In the present paper noise protection is studied according to Italian decree DPCM 5 December 1997 [2], which concerns building systems and acoustic insulation of façades, walls and floors. Suitable artificial lighting and natural light into buildings enhance indoor comfort; at present, Italian standard UNI EN 12464-1 [3] disciplines lighting of work places, while UNI 10840 [4] defines criteria for natural light into schools. Attention must be paid also to rational use of water: the installation of specific equipments can reduce considerably domestic water consumption, thus improving building performances. As concerns electrical, gas and water systems, they must be provided with protection devices and automatic control stop in case of leaks, according to Italian law 5 March 1990, n. 46 [5] and respective decrees; safety of persons, instead, can be upgraded by means of control and alarm devices. Finally, technology optimizes functionality and well-being into buildings with automation and communication systems.

The aim of the present paper is to propose a model of certification extended to building global performance, concerning all main aspects in an independent and objective way. Experimental measurements were carried out in order to analyse a private flat as a case study, considering use of rooms, building components and consumption bills.

METHODS

Indoor global performance

Quality of buildings means an appraisal of overall indoor comfort. Assessment indicators of single contributions were proposed and a global index was defined to classify new and existing buildings, referring to total performance: the model of building global certification was then applied to a case study.

ENERGY CERTIFICATION OF BUILDINGS

Building needs energy to condition indoor climate. Requirements based on primary energy consumption allow to have a coherent evaluation of energy efficiency of adopted systems. The energy performance of a building must be estimated with a methodology based on a general framework, which was defined by Directive 2002/91/EC [1]. Construction, sale and rent of a building need a certificate of energy performance for owner and purchaser: the purposes of certification are to estimate and to compare buildings, in order to make energy performance part of the appraisal, together with dimensional and aesthetic considerations.

Therefore, as household-electrics, also buildings must be provided with a coloured label, that identifies 7 classes of energy performance, where "A" means low consumptions/high efficiency while "G" means high consumptions/low efficiency. The aim is to estimate all energy contributions (heating and cooling, hot water, ventilation, lighting systems and renewable sources) thus pursuing high quality buildings. "Building Energy" index is defined according to energy certification: each class of energy performance (from G to A, Table 1) is assigned a value from 1 to 7.

Table 1. Classification of energy performance for residential buildings.

Annual specific primary energy consumption (kWh/m^{2}year)	Energy performance class	"Building Energy"
< 50	A	**7**
50-70	B	**6**
70-90	C	**5**
90-110	D	**4**
110-130	E	**3**
130-150	F	**2**
> 150	G	**1**

Energy certification procedures

Building energy requirements can be simulated by implementing calculation codes. General and climatic data, composition of opaque structures (walls and floors), transparent elements (windows) and exposure of building must be defined. Energy performance was studied for 3 different Italian cities (Perugia, Milan and Bolzano) which defined energy certificates, in order to evaluate the energy efficiency of the same building in such different places (Table 2).

Table 2. Main differences among examined energy certification procedures.

Energy performance	Perugia	Milan	Bolzano
Building shell	Yes	Yes	Yes
Heating system	Only 75%	Yes	No
Hot water	Yes	Yes	No
Plant efficiency	Only for hot water	Both for heating and hot water	No

Acoustic insulation

Noise sources can determine uncomfortable acoustic conditions into buildings. Partitions obstacle noise transmission, due to material mass. Mass increment doesn't represent a feasible method to achieve high acoustic well-being into rooms, so it is necessary to study building acoustics. In order to assess indoor acoustic quality, "Building Acoustics" index is proposed: it is evaluated by means of 7 classes of acoustic performances for 5 acoustic requirements into buildings, according to Italian decree D.P.C.M. 5 Dicember 1997 [2]. As concerns existing residential buildings, the limits imposed by decree for each parameter are assumed as central values of the scale, that was obtained by steps of 3 dB (+ 3 dB is equivalent to doubling of sources) both in increasing and decreasing sense: each acoustic requirements is assigned a score from 1 to 7, as specified in Table 3. Regarding noise insulation indexes R'_w (partitions) and $D_{2m,nT,w}$ (façades), acoustic comfort improves for increasing values, while the very contrary is the case of acoustic pressure levels L'_{nw} (floors), $L_{AS,max}$ and L_{Aeq} (systems); "Building Acoustics" index is calculated as arithmetic mean of obtained values.

Table 3. Classification of acoustic requirements for existing residential buildings.

	1	*2*	*3*	*4*	*5*	*6*	*7*
R'_w	< 41	41-44	44-47	47-50	50-53	53-56	> 56
$D_{2m,nT,w}$	< 31	31-34	34-37	37-40	40-43	43-46	> 46
L'_{nw}	> 72	69-72	66-69	63-66	60-63	57-60	< 57
$L_{AS,max}$	> 44	44-41	41-38	38-35	35-32	32-29	< 29
L_{Aeq}	> 44	44-41	41-38	38-35	35-32	32-29	< 29

Artificial lighting and natural light

Ranges of medium illuminance *E* according to visual tasks, limits for direct dazzle of light sources and suitable chromatic features of lamps are important to have comfortable lighting conditions. Natural light into building depends on site, exposure, windows, adjacent buildings and landscape natural elements. Correct exposure to sun is necessary to use natural lighting into buildings. Day lighting medium factor FLD_m is defined according to (1):

$$FLD_m = \frac{E}{E_0}, \qquad (1)$$

where *E* is room medium illuminance and E_0 is sky medium illuminance (5000 lux).

"Building Lighting" index concerns indoor artificial lighting and natural light. The assessment of artificial lighting is carried out by identifying 7 classes, for typical rooms into residential buildings (bedroom, kitchen, bathroom, living-room/access area) based on *E* medium values according to use. Maximum and minimum values (in lux unit) recommended by technical literature and standards are assumed as extreme values and the central range is divided into equal parts (Table 4). Natural lighting, instead, is evaluated by identifying 7 classes of FLD_m, for each room. The minimum value imposed by Perugia Building Regulations (2%) is assumed as inferior limit, while, on the basis of experimental measurements and technical literature advices, superior limit is fixed equal to 22%. The scale is obtained by dividing the range between 2% and 22% in equal parts and each class is assigned a score from 1 to 7 (Table 5). "Building Lighting" index is calculated as the arithmetic mean of the indicators, concerning artificial lighting system and natural light, into each room. If rooms of the same kind are present (for example, 2 bedrooms), the lowest value is considered cautiously.

Table 4. Classification of artificial lighting performance for residential buildings.

	1	*2*	*3*	*4*	*5*	*6*	*7*
Bedroom	< 50	50-70	70-90	90-110	110-130	130-150	> 150
Kitchen	< 200	200-260	260-320	320-380	380-440	440-500	> 500
Bathroom	< 50	50-70	70-90	90-110	110-130	130-150	> 150
Access area	< 50	50-70	70-90	90-110	110-130	130-150	> 150

Table 5. Classification of natural light performance for residential buildings.

	1	*2*	*3*	*4*	*5*	*6*	*7*
Bedroom	< 2%	2-6%	6-10%	10-14%	14-18%	18-22%	> 22%
Kitchen	< 2%	2-6%	6-10%	10-14%	14-18%	18-22%	> 22%
Bathroom	< 2%	2-6%	6-10%	10-14%	14-18%	18-22%	> 22%
Access area	< 2%	2-6%	6-10%	10-14%	14-18%	18-22%	> 22%

Rational use of water

Waste of water, for washing and other uses, can be reduced by specific devices or effective options, such as systems for the recovery of rain water. "Building Water" index evaluates the rational use of water taking into account the presence of water saving equipments listed in Table 6. Index may varies from 0 to 7 and each device increases the value by 1 point, except toilet with double key or stop key flush (2 points), because it guarantees higher water savings.

Table 6. Classification of water saving performance.

Rational use of water	Presence	Value
Water saving tap	Y/N	1/0
Flow controller tap	Y/N	1/0
Flow controller shower	Y/N	1/0
Low water consumption toilet	Y/N	1/0
Double key/Stop key flush toilet	Y/N	2/0
Rainwater tanks	Y/N	1/0

Safety into buildings

Safety of systems is basic in the appraisal of indoor quality: a building can't be comfortable if first of all it is unable to protect people from the risks caused by dangerous or obsolete plants. Safety is also protection from outside, so alarm and video-surveillance systems may prevent to enter someone's property illegally and contribute to satisfy the growing need of safe buildings. "Building Safety" index estimates safety into buildings, both of systems and people; it can be equal to 0 or assume a value between 4 and 7. The safety of electrical, gas and water systems, disciplined by Italian law 5 March 1990, n. 46 [5] and respective decrees, was assumed as absolutely necessary: if minimum law prescriptions are respected, the index assumes value 4 (medium safety degree). The presence of safety devices to protect people increases index value by 1 point (Table 7).

Table 7. Classification of safety performance.

Safety parameter	Presence	Value
Properly done system (certificate) + IMQ, CEI or equivalent brand + Magnetothermal switch + Differential switch + Earthed system + Aeration hole + Gas/Steam aspiration hood	Y/N	4/0
Video screen entryphone	Y/N	1/0
Alarm system	Y/N	1/0
Signalling to Police force or private vigilance service	Y/N	1/0

Technological devices

High quality habitability and functionality of buildings depends more and more on available technological systems. Integration of services affects positively indoor well-being. “Building Technology” index estimates the technological level into rooms and can assume values from 0 to 7. Each device listed in Table 8 increases by 1 point the index minimum value.

Table 8. Classification of technological performance.

Technological devices	Presence	Value
PC/Internet/ADSL	Y/N	1/0
Sensors	Y/N	1/0
Automatic lighting/curtains	Y/N	1/0
Parabolic antenna	Y/N	1/0
Hi-Fi/Wi-Fi	Y/N	1/0
Auxiliary devices (transducers, interface circuits)	Y/N	1/0
Residential gateway	Y/N	1/0

Building Global Performance index

“Building Global Performance” (BGP) index is defined by giving each indicator a weight. In order to attribute the weight fitting every index, different criteria were examined and the one based on costs was preferred, which seems to assure the greatest objectivity; therefore weights are calculated on the basis of cost analysis. Average costs to be supported in order to equip new or existing buildings with materials and devices which can guarantee high performance, quality and comfort are estimated in about 54% of the total costs of construction works (Table 9), according to Italian market general data. The weights given to the indexes were obtained by comparing single contributions to total percentage 54% (Table 9).

Table 9. Index weights according to Building Global Performance (BGP).

Index	Contribution	Percentage on total costs	Weight
Building Energy	Thermal insulation/energy performance	20%	37%
Building Acoustics	Acoustic insulation	15%	28%
Building Lighting	Natural light/artificial lighting system	5%	9%
Building Water	Water saving equipments	7%	13%
Building Safety	Safety devices	3%	6%
Building Technology	Technological devices	4%	7%
BGP	*Total*	*54%*	*100%*

Case study

A private flat in Perugia (Umbria Region, Central Italy) was assumed as a case study and an example of global certification was given. The examined flat is sited in a residential building that was built in the early Seventies (Figure 1). The occupants are 2 students. Independent heating system is fed by a boiler, having nominal thermal power of 24 kW; fuel is natural gas. Indoor temperature can be regulated by a thermostat. The system works both for heating and production of hot water. The flat has a volume of 161,7 m^3; the area is equal to 56,7 m^2. External walls are 29 cm thick (1,5 cm external and internal plaster, 2 layers of 12 cm bricks separated by 2 cm of mortar). The walls that separate the examined flat from the adjacent ones are 15 cm thick (12 cm bricks and 1,5 cm coat of plaster). The floor thickness is 30 cm and dividing walls into the flat are 10 cm thick.

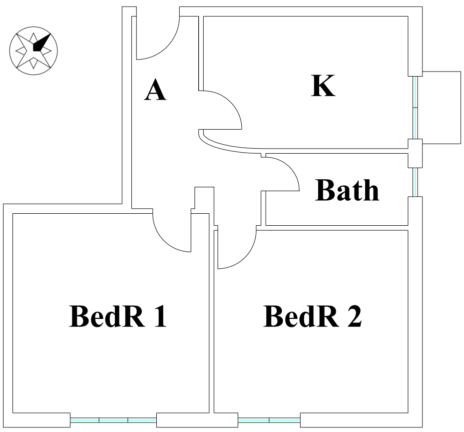

Figure 1. Plan of examined flat.

RESULTS

Building energy performance

According to calculations, the flat was assigned "E" class, with annual specific consumption of primary energy equal to 126,13 kWh/m^2year (86,90 for heating; 0,00 contribution from renewable sources; 39,23 for hot water). The examined procedures classify the flat in the same category: differences among obtained values of energy consumption, however, is due mainly to the methodology of calculation, the contributions to be considered and the climatic zones (average temperatures). In order to compare the specific energy performance of the building shell, the values to be considered are 115,87 kWh/m^2year for Perugia, 102,72 kWh/m^2year for Milan and 106,80 kWh/m^2year for Bolzano. Finally, the value obtained as simulated energy consumption of the case study has a good agreement with the study of real energy consumptions of the same flat as concerns the bills (126,75 kWh/m^2year).

Case study "Building Energy" index, defined by "E" class, obtained 3 points (Figure 2).

Building acoustic performance

Italian and international standards UNI EN ISO 140 [6] and 717 [7] were applied to carry out measurements and calculations (Table 10). According to Table 11, "Building Acoustics" index for the examined flat obtained 2,0 points (medium; Figure 2).

Table 10. Case study acoustic performance.

Acoustic parameter	Measured value	Unit
R_w	37	dB
$D_{2m,nT,w}$	33	dB
$L'_{n,w}$	74	dB
L_{ASmax}	47	dB(A)
L_{Aeq}	33	dB(A)

Table 11. Classification of case study acoustic performance.

R'_w	1						
$D_{2m,nT,w}$	1						
L'_{nw}		2					
$L_{AS,max}$	1						
L_{Aeq}					5		

Building lighting performance

According to standards UNI EN 12464-1 [3] and UNI 10840 [4], artificial lighting and natural light were measured (Tables 12 and 13). “Building Lighting” index for the case study equals 3,8 points (medium-low), as shown in Figure 2.

Table 12. Case study lighting performance.

Room	Natural light	Artificial lighting	Unit
Bedroom	1030	109	lux
Kitchen	1235	168	lux
Bathroom	783	83	lux
Access area	145	66	lux

Table 13. Classification of case study lighting performance.

Artificial lighting	Bedroom				4			
	Kitchen	1						
	Bathroom			3				
	Access area		2					
Natural light	Bedroom						6	
	Kitchen							7
	Bathroom					5		
	Access area		2					

Other building performances

The flat obtained a low value of “Building Water” index, equal to 2 (only water saving tap and flow controller tap are present). Also “Building Technology” index obtained 2 points (flat equipped with PC/Internet/ADSL and sensors/thermostat). Finally, as alarm and signalling devices are unavailable, case study has “Building Safety” index equal to 4 (Figure 2).

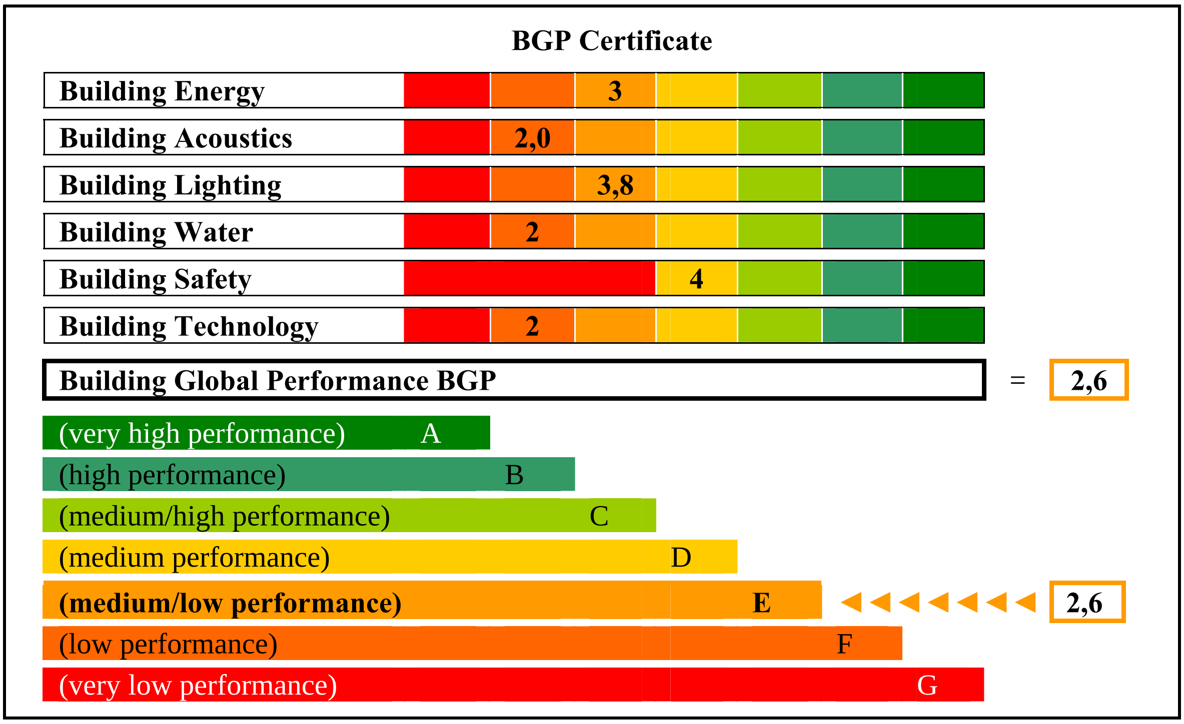

Figure 2. BGP certificate: results of application to the case study.

Building Global Performance index

All required input data were processed to calculate BGP index: the calculation gives back the values of all indicators as a certificate (Figure 2). Case study obtained BGP = 2,6 (low-medium performance), in tune with the appraisal of the occupants.

DISCUSSION

A new instrument for indoor quality certification was proposed: “Building Energy”, “Building Acoustics”, “Building Lighting”, “Building Water”, “Building Safety” and “Building Technology” indexes were defined to determine “Building Global Performance” BGP.

As a validation, the assessment of a private flat in Perugia (Umbria Region, Central Italy) was carried out. Energy certification was analysed according to different methodologies: total energy consumptions of the flat, calculated according to Perugia Building Regulations, are equal to the ones obtained by studying actual energy consumptions, thus demonstrating the reliability of such a procedure. Weights were assigned to indexes on the basis of cost analysis; actually costs were estimated with approximation, so a combination of mentioned analysis and further assessments, even subjective evaluations (such as statistical preferences of people), may improve the model. Being comfort a personal feeling, there are different perceptions, but it must be attempted to satisfy the greatest number of persons. The assessment could be integrated with other peculiar features, such as architectural quality of buildings. BGP index could be measured to test existing buildings or it could be predicted to evaluate new buildings, according to standards.

The purpose of the present paper is to put in evidence the advantages that would be obtained by pursuing building overall quality. High performances are expensive, however the increment of building cost is amortized thanks to lower consumption and optimal comfort.

Quality and saving must be pursued by builders and planners in order to guarantee high indoor habitability, functionality and efficiency and to perform sustainable buildings.

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