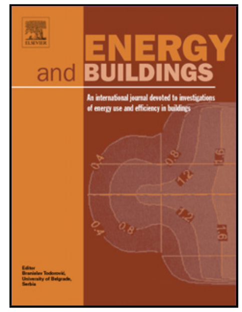
Accepted Manuscript



Title: A review of benchmarking, rating, labelling concepts within the framework of building energy certification schemes

Authors: Luis Pérez-Lombard, Jose Ortiz, Rocío González, Ismael R. Maestre

PII: S0378-7788(08)00220-X
DOI: doi:10.1016/j.enbuild.2008.10.004
Reference: ENB 2526

To appear in: *ENB*

Received date: 1-2-2008
Revised date: 10-10-2008
Accepted date: 13-10-2008

Please cite this article as: L. Pérez-Lombard, J. Ortiz, R. González, I.R. Maestre, A review of benchmarking, rating, labelling concepts within the framework of building energy certification schemes, *Energy and Buildings* (2008), doi:10.1016/j.enbuild.2008.10.004

A REVIEW OF BENCHMARKING, RATING AND LABELLING CONCEPTS WITHIN THE FRAMEWORK OF BUILDING ENERGY CERTIFICATION SCHEMES

Abstract

Energy certification schemes for buildings emerged in the early 1990s as an essential method for improving energy efficiency, minimising energy consumption and enabling greater transparency with regards to the use of energy in buildings. However, from the beginning their definition and implementation process were diffuse and, occasionally, have confused building sector stakeholders. A multiplicity of terms and concepts such as energy performance, energy efficiency, energy ratings, benchmarking, labelling, etc, have emerged with sometimes overlapping meanings. This has frequently led to misleading interpretations by regulatory bodies, energy agencies and final consumers.

This paper analyses the origin and the historic development of energy certification schemes in buildings along with the definition and scope of a building energy certificate and critical aspects of its implementation. Concepts such as benchmarking tools, energy ratings and energy labelling are clarified within the wider topic of certification schemes. Finally, a seven steps process is proposed as a guide for implementing building energy certification.

Keywords

Energy certification, energy labelling, energy rating, energy benchmarking.

1. Introduction

World energy crises, such as the 1979 oil shortage caused by the Iranian revolution or the drastic increase in the price of oil in the early 1990s due to the first Gulf War, raised governmental concerns over the supply of and access to worldwide energy resources. European nations, highly dependent on energy resources from politically unstable areas, were particularly affected. At the same time, the global contribution from the energy consumption of buildings was steadily increasing, to around 20-40% in developed countries and exceeding the other major sectors, industry and transportation [1].

It was under such circumstances that a new concept relating to energy efficiency in buildings emerged in the early 1990s as an essential method of reducing energy use and CO_2 emissions: energy certification for buildings.

An overall objective of energy policy in buildings is to save energy consumption without compromising comfort, health and productivity levels. In other words, consuming less energy while providing equal or improved building services, that is, being more energy efficient. Regulatory bodies (Government, energy agencies, local authorities, etc.) have three basic instruments available for encouraging savings and maximising energy efficiency in buildings: regulations, auditing and certification.

Building energy regulations, also referred to as building energy codes, establish minimum requirements to achieve energy efficient design in new buildings. The primary aim is saving final energy or any related parameter (primary energy, CO_2 emissions or energy costs) without compromising comfort or productivity. Europe developed early building envelope regulations in the late 1970s to reduce heat transfer through envelope elements and control vapour diffusion and air permeability. This was followed by regulations or best practice recommendations on design, calculation and maintenance of building thermal services (HVAC and DHW). Eventually, HVAC equipment was subject for the first time to minimum requirements of energy efficiency. This paper analyses energy certification in buildings and focuses on three critical issues: (1) the definition and scope of energy certification schemes, (2) building energy classification and (3) the implementation of energy certificates in buildings.

2. Definition and scope of building energy certification

From the beginning this term has been imprecisely and inconsistently used. In the European Council Directive 93/76/CEE [2] to limit carbon dioxide emissions by improving energy efficiency, energy certification is presented as one of the cornerstones for achieving energy efficiency in buildings. This certification "shall consist of a description of their energy characteristics, must provide information for prospective users concerning a building's energy efficiency" and additionally, "may also include options for the improvement of these energy characteristics".

The directive was non-mandatory and also full of ambiguities (with regards to how to provide information about building energy efficiency) that resulted in low impact implementations of its requirements across Member States. This is the case of the Spanish certification schemes for dwellings, CEV [3] and for commercial buildings, CALENER [4].

Almost ten years later, the EU acknowledged the need for a new regulatory instrument and introduced directive 2002/91/EC [5] on the energy performance of buildings. Directive 2002/91 was ambitious, although lacked sufficient detail for a clear and consistent implementation across the EU members. Among other objectives it contained the requirement for a building energy performance certificate as "a certificate recognised by the Member State... which includes the energy performance of a building calculated according to a methodology...".

This second approach to an energy certification definition perpetuated two unresolved issues: how to define and how to measure building energy efficiency. It also introduced a new term energy performance referring to building energy use. In this context, European energy performance indicators (EPI) and American energy-intensity indicators [6] or energy use intensities (EUI), are equivalent since both are ratios of energy use input to energy service output (site energy per square meter, CO_2 emissions per home, etc.).

The new European standard EN 15217 [7] is an attempt to describe methods for expressing energy efficiency and certification of buildings. Energy Performance Certificates are redefined within the development of a certification scheme (Figure 1) which must contain at least:

• An overall energy performance index (EPI) stated in terms of energy consumption, carbon dioxide emissions or energy cost, per unit of conditioned area to allow the comparison between buildings.

• An overall minimum efficiency requirement to be established by the legislation as a limit of the energy performance index (EPI_{MAX}). The standard recommends its correlation with other parameters (such as climate and building type) or a self-reference method.

• A label based in the A to G bands to achieve a suitable grading of buildings. A key issue is the definition of the scale that should make reference, at least, to the building energy regulations (R_r), the existing building stock (R_s) and the zero-energy building (R_0).

• Energy consumption by the main building components, such us building envelope and services, together with recommendations of energy efficiency measures for building owners' consideration.

The scope of the certification is therefore extended not only to the energy performance of the building but also to include a minimum requirement and a label or class that allows users to compare and assess prospective buildings. The certificate must contain, amongst other information, a classification of the building energy efficiency based on an energy label.

3. Building energy classification

The term building energy classification encompasses any procedure that allows the determination of the quality of a building (in terms of energy use) in comparison with others. Several similar terms have been used which has caused some confusion within the industry. This section attempts to clarify the concepts of benchmarking, rating and labelling in the context of building energy classification.

3.1. Benchmarking process

Originally, the word benchmark was used exclusively in topography to precisely define a reference point in terrain or geological analysis. In the 1970s, some companies developed benchmarking tools to allow comparison of key production parameters and thus to check whether improved processes enhanced their performance. In the 1990s, the term building energy benchmarking started to be used to refer to the comparison of energy use in buildings of similar characteristics.

Basically it consists of a comparison of the EPI of a building with a sample of similar buildings. A common EPI used for many building types is annual energy use per unit area but others such as energy per worker or energy per bed may also be used. Energy services companies use the EPI as a starting point in energy audits and assess saving opportunities by comparing with existing references (benchmarks) of average (typical), above average (good) and excellent (best) practice. At the design stage, energy performance indices for different designs are of great use when choosing suitable technologies, particularly if benchmarks for similar buildings are available. Last but not least, governments should consider benchmarking in the early conception, development and implementation of energy efficiency policies within the building sector.

The benchmarking process consists of four stages [8]. First, it is necessary to hold or develop a database with information on the energy performance of a significant number of buildings. This information should be categorised, at least, by building type and size. Second is gathering the relevant information for the evaluation of the EPI for the actual building. Third, a comparative analysis of the building energy performance against the samples held in the database gives a quantification of the quality of the building in terms of energy use. Finally, energy efficiency measures that are feasible from both technical and economical perspectives should be recommended (Figure 2).

The energy consumption of the actual building can be predicted via a computer-simulation-method or measured on site (Table 1). Energy simulation offers detailed information and a wide variety of outputs, however, it may require a great number of inputs, skilled users and a significant amount of time to gather and input the necessary data, all of which can make the process expensive. Measured consumptions can be obtained from energy bills or monitoring. Energy bills give easy access to energy consumption by energy source, although it is difficult to establish a split by end-uses. Energy monitoring based on sub-metering can also be expensive but offers profuse performance information of great use to auditors and building maintenance. In summary, energy use of new and existing buildings may be obtained at different levels of accuracy and cost.

In any case, there are always discrepancies between predicted and measured energy use. Some sources of error are natural uncertainties like the differences between real weather and typical simulation climate data. Others, like the use of default data for internal loads may be reduced by adjusting the building model to the existing building real conditions. The influence of occupant behaviour on energy performance is considerable. Variables like number of people and activity, thermostat setpoints, equipment usage, natural ventilation, hot water demand, etc. are strongly dependent on the occupants or owner and can result in large variations in energy use, even for the same climate and building type.

Database information availability is a different issue. Gathering energy information to populate a database with a representative sample of the building stock is not only expensive but also technically complex. It is not surprising that only a few nations have undertaken this task to date. Usually, information is collected on site from building owners, tenants, facility managers, etc. An outstanding example is the US Energy Information Administration (EIA) database and the later surveys for both the residential sector (RECS [9]) and commercial buildings (CBECS [10]).

A different approach to database generation is the application of building energy simulation to a variety of building types for a range of energy parameters (parametric benchmarking). Careful selection of building types and calculation methods is critical to the validity of the database. Another added constraint is the need to customise building envelopes and HVAC sizing for each climate and system type. An advantage is the possibility of covering a wide range of building energy consumption characteristics with a suitable selection and variation of the energy parameters. Additionally, energy simulation provides a wider range of energy outputs for future comparisons.

Finally, any benchmarking program that combines the use of measured energy consumption for actual buildings with a database based on simulation must be calibrated to ensure the comparative analysis is consistent. At the moment, most benchmarking programs are based on measured energy use of existing buildings.

The core of the benchmarking process is the comparative analysis. First, the degree of similarity between buildings to be compared must be specified. Every parameter not easily influenced by the design process and with a potential significant impact on building energy use must be similar in the comparison process. The minimum degree of similarity is two: same climate and building type. Within the building type, it is common to use subtypes to avoid the comparison of buildings with different shape or mixes of activities. For example, individual detached houses consume significantly more energy than flats in the same weather, and if compared within the same building type (e.g. dwellings) would have their energy quality artificially degraded.

A subset of comparable buildings could be obtained by filtering the database against similarity parameters. This is called the comparison scenario. Energy intensity frequency distribution curves for that scenario enables determination of a percentile ranking, percentage of buildings with better (or worse) energy performance. Programs such as Energy Star [11] score from 1 to 100, based on models and normalization methods of statistical analysis applied to the EIA database. To obtain a certificate (Energy Star Label) the building must achieve a minimum of 75 points, equivalent to belonging to the quartile of better energy efficiency. Other tools such us Cal-Arch [12] do not offer any score but represent the energy intensity frequency distribution curve and the relative position of the actual building.

At European level, the unavailability of building energy use databases has restricted the development of benchmarking tools. At a national level, within those programmes aimed at gathering building energy information, the UK's former Action Energy programme for office buildings [13] should be recognised. Recently, the European projects Euroclass [14], Europrosper [15], EPlabel [16] and ENPER-EXIST [17] have studied the complexity associated with the elaboration of a database of building energy consumptions in Europe and with identifying suitable reference levels as intermediate steps for the development of an energy performance certificate for existing buildings.

3.2. Energy rating

"Rating" is perhaps the most confusing term within this framework, especially in non English-speaking nations, as it is indistinctly used to refer to the building energy classification (the rating system), its application (the action of rating) and its final result (the rating figure).

In general, the expression energy rating system (ERS) may be used as a synonym of energy classification, that is, a method for assessing energy quality. Examples can be found in both the Home energy rating system (HERS) of the Energy Star program and the US Green Building Council LEED building rating system [18].

Authors like Stein and Meier [19] are more precise in the ERS definition ("a method for the assessment of predicted energy use under standard conditions and its potential for improvement") and usual output (energy use prediction, rating score based on a comparison with a reference building and a list of improvements). In other references

[20] the difference between energy rating systems and building energy certification disappears.

Within the framework of Directive 2002/91, energy rating means evaluation of the building energy performance. In the standard EN 15603 [21], CEN proposes two types of ratings: (1) calculated ratings, based on computer calculations to predict energy used by a building for HVAC systems, domestic hot water and lighting and (2) measured (or operational) ratings, based on real metering on-site. Calculated ratings are subdivided into standard (also called asset) and tailored ratings. The asset ratings use the calculation procedure within standard usage patterns and climatic conditions not to depend on occupant behavior, actual weather and indoor conditions, and are designed to rate the building and not the occupant. Asset ratings can be shaped to buildings during the design process (as designed), new buildings (as built) or to existing buildings. For the latter, when calculated under actual conditions (different to standard usage patterns) the rating becomes a tailored rating. In this sense, most of the American ERS are asset ratings for new or existing buildings, while benchmarking tools are normally based on measured ratings applicable only to existing buildings. Definition details for each rating are shown in table 2.

Energy efficiency certification schemes for new buildings are usually implemented by asset ratings. For existing buildings, both calculated and measured ratings are applicable, but the later is preferred to reduce energy performance discrepancies and limit consumer risks due to uneconomic retrofit investment or credibility problems if stakeholders conclude that energy rating system are less accurate than expected.

In accordance with CEN recommendations, a building energy certification scheme for existing buildings should be implemented by the use of operational ratings with reference values (benchmarks) taken from the building stock in order to establish the classification system. In like manner, for new buildings, an asset rating should be used in comparison with the references values set by the regulation, the building stock and the zero energy building [22].

3.3. Energy labelling

It was in the early 90s when the EU introduced energy labelling with a double objective: to inform consumers about the energy performance of energy consuming devices and to promote energy savings and energy efficiency. Following the success of its application to domestic appliances (Directive 92/75 [23]), energy labelling was extended to buildings a decade later (Directive 2002/91).

Building energy labelling, consisting of assigning an energy performance class or label to the building, requires the development of a scale related to a labelling index (LI). The choice of the comparison scenario is a key issue for the scale definition. If there are enough comparable buildings, statistical analysis of the EPI through the cumulative frequency distribution curve allows the use of the percentile as an indicator of the energy position. At this point, labelling is equivalent to assigning percentile intervals (bands) to energy classes. In fact, by normalizing the EPI distribution of cumulative frequencies using an average value such us the percentile of 50% (EPI_{50}) the labelling index could be defined as:

$$LI = \frac{EPI}{EPI_{50}} \quad (1)$$

The scale is defined by fixing the transition values between classes, LI_{IJ}. Figure 3 shows a possible scale of 7 bands over the labelling index distribution curve.

Informative annex B of standard EN 15217 describes a procedure to define limits between classes based on two references: building regulations and building stock. The first is the overall minimum efficiency requirement set by the regulation as a maximum limit for the energy performance index (EPI < EPI_r). The second reference corresponds to the energy performance reached by 50% of the building stock (EPI_S). If the EPI is normalized by the stock reference, the label index for the regulation reference is:

$$LI_r = \frac{EPI_r}{EPI_S} = \alpha \quad (2)$$

Regulation developers should assure a certain saving percentage (1-α) ahead building stock to improve energy efficiency. According to this methodology CEN's scale (table 3) situates the regulations reference on the boundary between B and C and the stock reference on the boundary between D and E. Obviously, CEN's scale suffers from a lack of sensitivity since every new building must comply with the regulation and would be labelled B or A depending on the saving percentage ahead regulations reference.

Alternatively, a self-reference method should be used when the comparison with other buildings is not feasible and the only valid reference is set by a reference building (RB) generated from the actual building once a set of standard rules are applied. In this case, energy performance comparison must be done on the basis of a labelling index showing the saving percentage in relation to the self-reference:

$$LI = \frac{EPI}{EPI_{RB}} \quad (3)$$

The latter approach does not require a database for the comparison, nor a statistical analysis of the building stock comparison scenario. However, bands must be adjusted for the scale to be sensitive enough to improvement measures.

Criteria to set the scale are subjective and, perhaps, closer to policy decisions than to technical analysis. Thus, there is great disparity between different scales. A key issue is the level of definition or number of classes, with examples such as the 13 bands (A to M) Danish system ELO and the Australian ABGR five stars system. Figure 4 shows a comparison of the saving percentages of four different labelling scales for classes ahead a certain reference. The CEN's scale reference is set by the regulations, while the Spanish energy certification [24] for new non-residential buildings, the BREEAM [25] for office certification and the American LEED-NC propose different self-reference buildings. The latter, rewards with up to 10 points (from a total of 69) if the running costs of the building are below the reference established in Annex G of ASHRAE 90.1 [26].

4. Implementation of energy certificates in buildings

In the development of an energy certification scheme for new buildings seven questions should arise: (1) What should be calculated in order to assess building energy efficiency? (2) How should it be calculated? (3) How should the limit for energy efficiency be set? (4) To what should the building energy efficiency be compared ? (5) How should building energy efficiency be labelled? (6) What energy efficiency improvements should be recommended? (7) What information should the energy certificate include?

Our working experience within the teams developing the Spanish and British building energy certification together with a review of the state of the art in energy certification in other countries, allow us to briefly comment on these critical issues for building energy certificate implementation.

4.1. What should be calculated in order to assess building energy efficiency?

The words "energy efficiency" are normally used to express the idea of "doing more with less" [27], in other words, consuming less energy while providing better services. So, any quantitative approach to energy efficiency should be based on a ratio of energy input to service output. Energy use may be predicted via simulation or measured on site, but assessing the quality and quantity of a given service is a complex task and the definition and measurement of energy efficiency is a real challenge for policy makers. For this reason energy intensity or energy performance indicators are used as a substitute in energy efficiency analysis. Thus, first step to take within the energy certificate implementation is the definition of energy performance indices.

Some authors [28] propose multiple indices to consider simultaneously energy use, environmental impact and indoor air quality, though energy use per unit of area and year is almost the standard EPI for buildings. Even for this simple EPI, we must decide the magnitude for energy use (delivered energy, primary energy, CO_2 emissions or energy cost) and choose energy services (lighting, hot water, HVAC, cooking, refrigeration, etc.) to be accounted for.

4.2. How should energy performance be calculated?

Basically, there are two different approaches for the prediction of energy performance of buildings: simplified and detailed simulation methods. The implementation of the methodology requires the development of a computer-based tool. When choosing the method issues such as accuracy, scope, reproducibility, complexity, sensitivity to energy parameters and user skills should be considered because they have a great impact on final users, professional associations, manufacturers, software developers, policy makers and other stakeholders. For instance, a complex simulation method would make the certificate expensive and have possible repercussions on building purchase or rental prices, on the experience and training required from professionals and manufacturers, or on the ability of the government to control and inspect the certification process. Thus, credibility and success of the certification scheme are strongly dependent on the second step of building energy certification implementation: development of an energy calculation tool.

4.3. How should the limit for energy efficiency be set?

Building regulations should answer this question setting the minimum overall requirement for the energy performance index ($EPI < EPI_r$). Again, there are two different approaches: fixed and customized limits.

Energy efficiency of different building types is not comparable in terms of the energy performance index, since they provide different services. A hospital is not less efficient than a dwelling despite having an EPI more than five times bigger on average. Thus the limit value should be discriminated at least by building type.

Climate dependence of the overall requirement causes controversy. Some authors [29] defend an unique threshold value for every climate because of heating/cooling compensation and an excessive cost for little environmental benefit, while others propose an increasing EPI limit with increasing climate severity [30]. Other parameters for achieving discrimination could be building shape, energy source and ventilation rates. Therefore, in the fixed limit option, the threshold value is dependent upon the parameters whose impact is to be reduced or neutralized:

$$EPI_r = f(\text{building type, climate,} \ldots) \tag{4}$$

A customised limit may be obtained by the self-reference (also called notional building) approach, where EPI_r is set by a reference building having at least same location, geometry and pattern of use but different envelope and systems.

The difference between the standards and calculation tool languages might be a source of problems. The rules to model the reference building must be written in the calculation tool terminology while regulations use a normative language. Thus, certification and energy code developers must have experience in both fields to assure the consistency and effectiveness of the certification scheme.

4.4. To what should the building energy efficiency be compared?

Once the EPI of the building has been calculated, a sample of buildings to be compared to must be found. Thus, the fourth step in the implementation process is the definition of the comparison scenario.

The key question is whether the EPI of a wide number of buildings is available. For the affirmative answer, the comparison is feasible and a certain degree of similarity between buildings to be compared must be set. Minimum degree of similarity would be two, climate and building type, but other parameters like energy sources or building shape may be considered. A subset of comparable buildings must be obtained by filtering the database against similarity parameters.

Alternatively, when there are no buildings to be compared to, the solution is the self-reference approach where the actual building is compared with a reference building derived from the actual building according to rules laid down in the energy code.

4.5. How should building energy efficiency be labelled?

The next step is to classify the building energy performance related to the comparison scenario by assigning an energy label.

First, a label index (LI) should be defined. If a sample for comparison is available, LI would be defined as the ratio of the EPI of the building to the EPI average value of the sample (equation 1). In the self-reference approach, label index shows the saving percentage in relation to the reference building performance (equation 3).

Second, we must set the limits between classes (definition of the scale) on the label index frequency curve if the comparison scenario is available or depending on the saving percentages ahead the reference building for the self-reference approach.

Among others, two criteria should be considered for the scale definition: scale sensitivity, the ability to improve the energy label of a given building, and scale credibility, buildings with better labels should save energy.

4.6. What energy efficiency improvements should be recommended?

Building energy certification schemes should produce a list of recommended measures to encourage building designers, owners, operators and users to improve the energy performance of their buildings.

For new buildings at design stage, engineers should work in parallel with architects to adjust design parameters to reduce energy consumption. An early stage model of the building could be enough for the evaluation of energy efficiency measures with the energy calculation tool in order to check how far and cost-effective an improved label would be. Energy analyst knowledge and experience are necessary to suggest those measures of greater impact on savings and labels. Intelligent tools capable to automatically explore different options and even to select an optimum are part of the coming future, meanwhile a results based analysis tool to guide the user in the improvement process could be of great help.

4.7. What information should the energy certificate include?

Obviously, building energy certification final report must include at least the energy label and the EPI. In order to assess what other information should be included we suggest three categories of energy information according to its final use:
(1) administrative data such as building address, date, certifier name, etc. are necessary to identify both building and certifier, (2) energy variables to be controlled and inspected (glass shading coefficient, boiler efficiency, etc.) by competent bodies and (3) information gathered by the energy agencies to populate their building database (building type, total area, conditioned area, HVAC system type, energy sources, etc.).

5. Conclusions

The implementation of the new European building energy certification scheme is a complex task facing seven critical issues: (1) definition of the energy performance index, (2) development of an energy performance calculation tool, (3) setting a threshold value for the performance index, (4) definition of the comparison scenario, (5) definition of the scale for energy labelling, (6) identification of potential energy efficiency measures and (7) gathering energy information in the certification process. Therefore, energy labelling is only one step in the implementation process.
The words energy rating should only be used for the assessment of the energy performance, both for new and existing buildings, in standard or actual conditions.
Energy benchmarking tools provide a comparative appraisal of the energy performance of an existing building within a comparison scenario. Assigning classes or labels

implies a step forward: defining a scale based on a labelling index. The definition of the scale is more a political issue than a technical one, with the overall aim of reducing the energy consumption.

The success of building energy certification schemes will almost certainly depend on: (1) the ability to obtain better labels cost-effectively, (2) the credibility achieved by real energy savings and (3) the degree of commitment to the global environmental crisis of the building sector stakeholders.

References

[1] Pérez-Lombard, L. et al. A review on buildings energy consumption information. *Energy and Buildings* 2008; 40(3):394-398.

[2] Council Directive 93/76/CEE of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency (SAVE).

[3] Calificacion Energetica de Viviendas: Fundamentos Técnicos y Manual del Usuario. Madrid. 1999.

[4] CALENER (Calificación Energética de edificios). Versión 2.02. Desarrollado por el Grupo de Termotecnia, E.S. Ingenieros de Sevilla. 2003.

[5] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.

[6] Energy Information Administration (EIA). *Measuring energy efficiency in the United States Economy: A Beginning*. DOE/EIA-0555(95)/2. Washington D.C.: Department of Energy. 1995.

[7] EN 15217. *Energy performance of buildings - Methods for expressing energy performance and for energy certification of buildings.* 2007.

[8] Matson, N.E. and Piete, M.A. Review of California and National Methods for Energy Performance Benchmarking of Commercial Buildings, Ernest Orlando Lawrence Berkeley National Laboratory, 2005.

[9] Energy Information Administration. Residential Energy Consumption Survey (RECS). U.S. Department of Energy, 2001.

[10] Energy Information Administration. Commercial Buildings Energy Consumption Survey (CBECS). U.S. Department of Energy, 2003.

[11] Environmental Protection Agency and the U.S. Department of Energy. ENERGY STAR program.

[12] California Energy Commission. CAL-ARCH (California Energy benchmarking tool).

[13] Carbon Trust/Action Energy. Energy Consumption Guide 19, Energy use in offices. 2003.

[14] Santamouris, M. et al. *Energy performance of residential buildings: a practical guide for energy rating and efficiency*. James & James Earthscan, 2005.

[15] EUROPROSPER. European Programme for occupant satisfaction, productivity and environmental rating of buildings: certification of existing building energy performance. <http://www.europrosper.org/>

[16] EPLabel. A programme to deliver energy certificates based on measured energy consumption for display in Public buildings across Europe within a harmonising framework. <http://www.eplabel.org>

[17] ENPER-EXIST. Applying the EPBD to improve the Energy Performance Requirements to Existing Buildings. Building stock knowledge. <http://www.enper-exist.org>

[18] U.S. Green Building Council. LEED-NC. Green Building rating system for new construction & major renovations. Version 2.2. 2005.

[19] Stein, J. R. and Meier, A. Accuracy of home energy rating systems, *Energy* 2000; 25(4):339-354.

[20] Míguez, J.L. et al.. Review of the energy rating of dwellings in the European Union as a mechanism for sustainable energy. *Renewable and Sustainable Energy Reviews* 2006; 10(1):24-45.

[21] EN 15603. *Energy performance of buildings – Overall energy use and definition of ratings*. 2008.

[22] Meier, A., Olofsson, T. et al. What Is an Energy Efficient Building? ENTAC 2002, National Conference of Technology in the Built Environment, Foz do Iguaçu, Brazil. 2002.

[23] Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances.

[24] Real Decreto 47/2007, de 19 de enero, por el que se aprueba el Procedimiento básico para la certificación de eficiencia energética de edificios de nueva construcción.

[25] BREEAM, BRE Environmental Assessment Method. <http://www.breeam.org/>.

[26] ANSI/ASHRAE/IESNA 90.1-2004. Energy Standard for Buildings Except Low-Rise Residential Buildings. 2004.

[27] European Commission. Directorate-General of Energy and Tranport. *Green paper on Energy efficiency. How to do more with less?* Office for Official Publications of the European Communities, 2005.

[28] Roulet, C.-A. et al. ORME: A multicriteria rating methodology for buildings. *Building and Environment* 2002; 37(6):579-586.

[29] García-Casals, X. Analysis of building energy regulation and certification in Europe: Their role, limitations and differences. *Energy and Buildings* 2005; 38(5):381-392.

[30] Sánchez, F. et al. A new methodology towards determining building performance under modified outdoor conditions. *Building and Environment* 2006; 41(9):1231-1238.

Figure 1. Scope of the new European building energy certification scheme.

Figure 2. Building energy benchmarking process.

Figure 3. Labelling scale and cumulative frequency curve of labelling index (LI).

Figure 4. Comparison of energy scales (CEN and CALENER labels and BREEAM and LEED-NC credit points) of different certifications schemes in terms of saving percentage ahead certain reference.

Table 1. Comparison of energy use estimation methods.

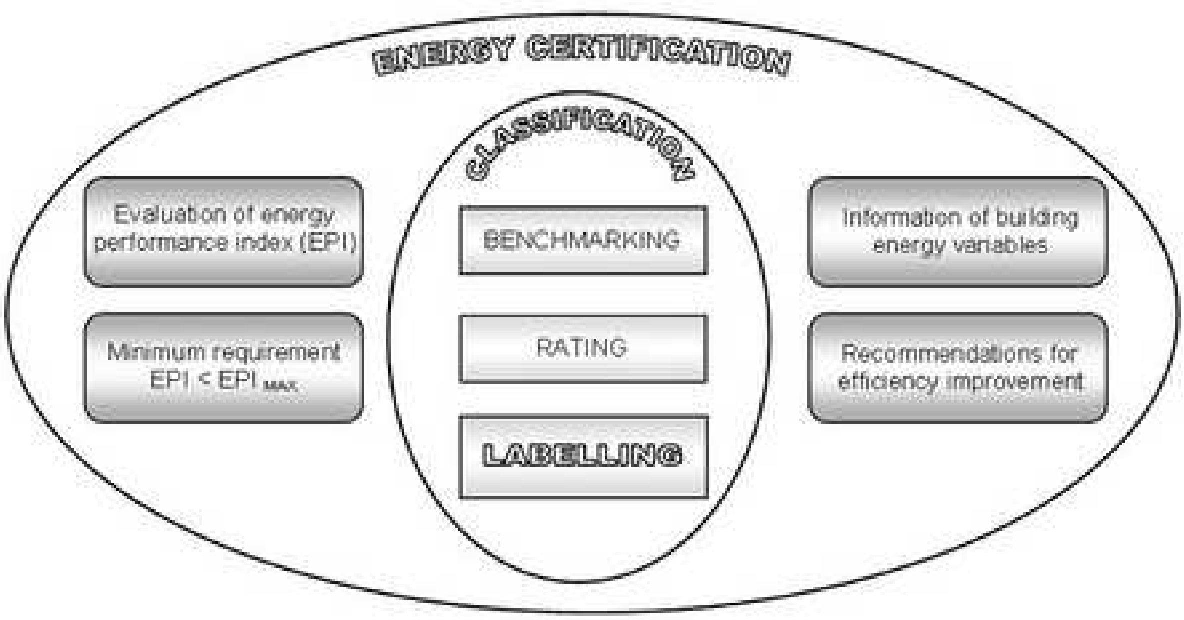
Concept	*Simulation*	*Measured on-site*
Input data	Detailed information	Energy Bills or metering
Output data	Detailed and split	Global and non-split
Weather and use	Standard	Actual
Energy use	Estimated	Measured
Scope	New and existing buildings	Existing buildings
Cost and user skill	High	Low

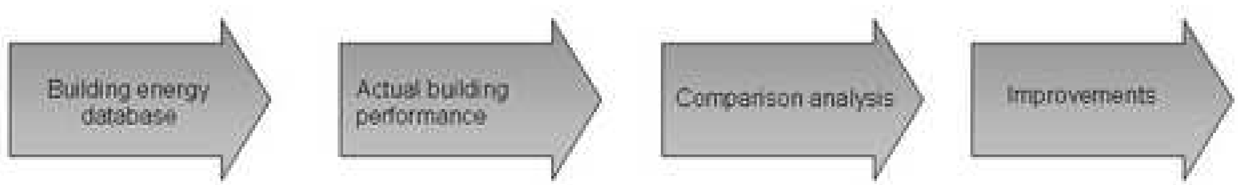
Table 2. Definition of energy ratings.

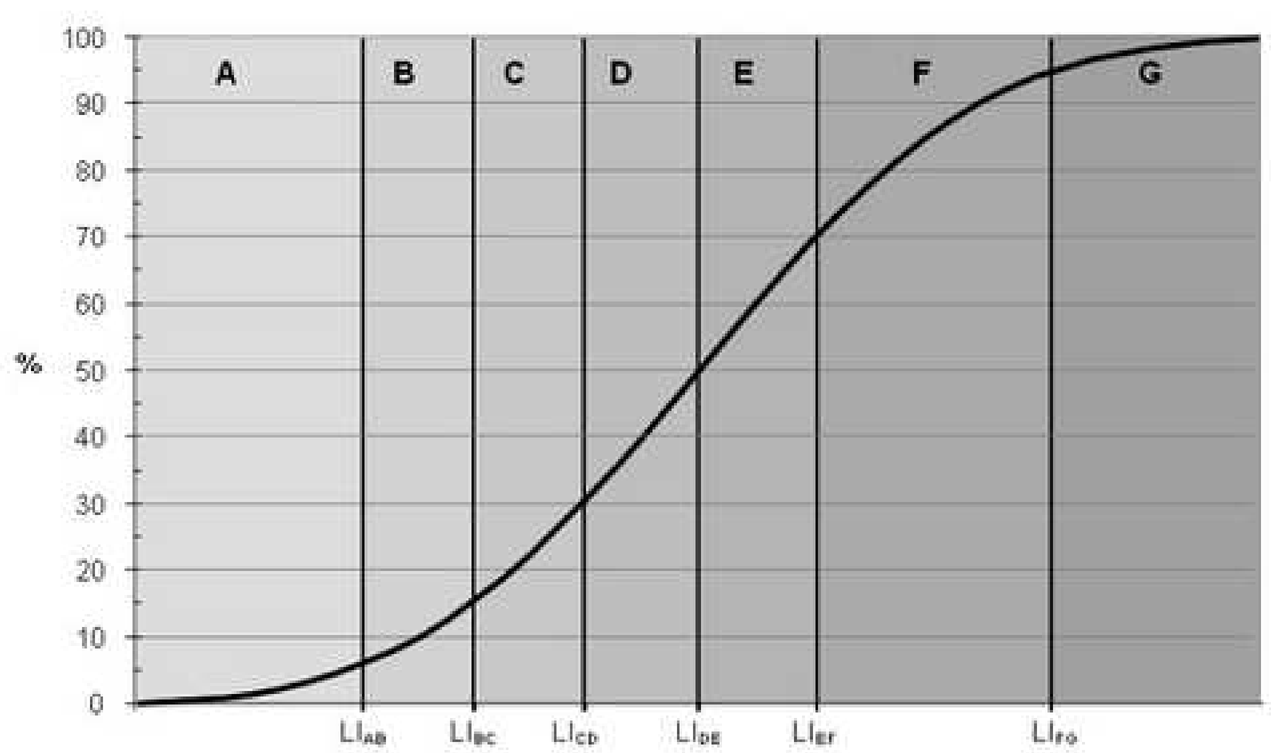
Rating type	*Rating subtype*	*Based on*	*Pattern of use*	*Project stage*
Standard or asset	Design	Calculations	Standard	Design
	As built	Calculations	Standard	Built
Tailored	-	Calculations	Non-standard	Built
Measured or operational	-	Metered amounts	Actual activity	Built

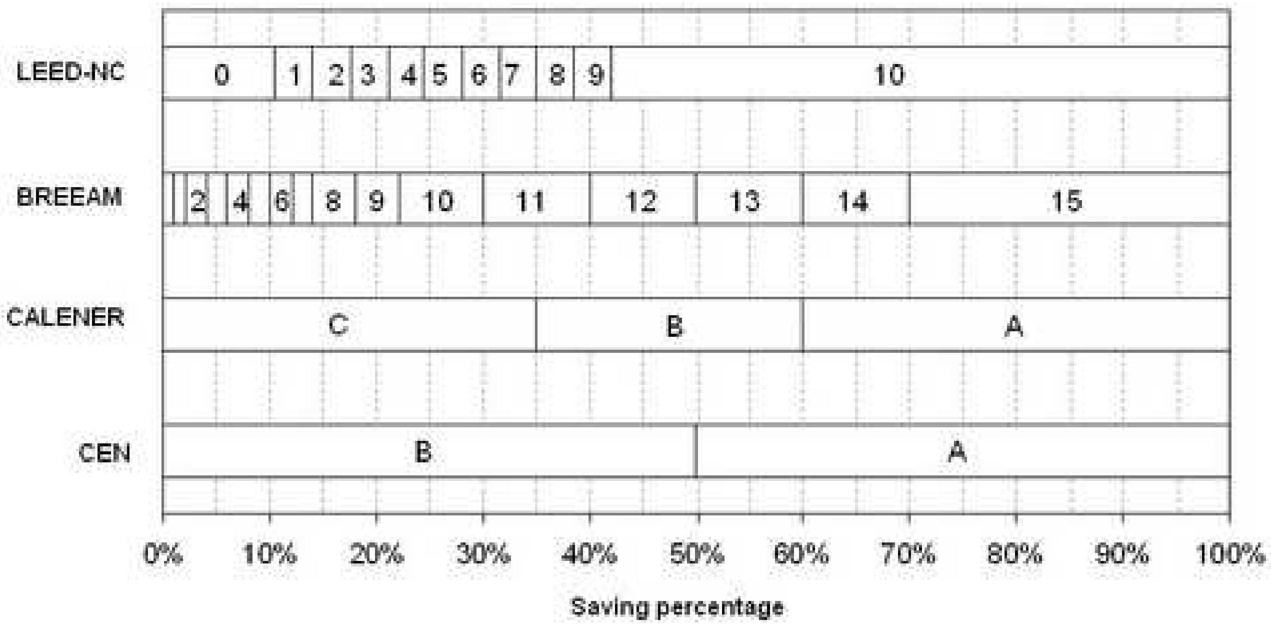
Table 3. Limits between classes for the scale proposed by CEN.

LI_{AB}	LI_{BC}	LI_{CD}	LI_{DE}	LI_{EF}	LI_{FG}
0.5 α	α	0.5 (α+1)	1	1.25	1.5


ENERGY CERTIFICATION
CLASSIFICATION
Evaluation of energy performance index (EPI)
Minimum requirement EPI < EPI MAX
BENCHMARKING
RATING
LABELLING
Information of building energy variables
Recommendations for efficiency improvement


Building energy database
Actual building performance
Comparison analysis
Improvements


100
90
80
70
60
50
40
30
20
10
0
%
A
B
C
D
E
F
G
LI_{AB}
LI_{BC}
LI_{CD}
LI_{DE}
LI_{EF}
LI_{FG}


LEED-NC
0
1
2
3
4
5
6
7
8
9
10
BREEAM
2
4
6
8
9
10
11
12
13
14
15
CALENER
C
B
A
CEN
B
A
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Saving percentage