TECHNICAL REPORT

ISO/TR 52003-2

First edition
2017-06

Energy performance of buildings — Indicators, requirements, ratings and certificates —

Part 2: Explanation and justification of ISO 52003-1

Performance énergétique des bâtiments — Indicateurs, exigences, classification et certificats —

Partie 2: Explication et justification de l'ISO 52003-1

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built* environment, in collaboration with ISO/TC 205, *Building environment design*, and with the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 52003 series can be found on the ISO website.

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Introduction

Relation between this document and the accompanying International Standard

For proper understanding of the present document, it is necessary to read it in close conjunction, clause by clause, with ISO 52003-1. First, the corresponding clause in Part 1 needs to be read; then the complementary information in the same clause in this report can be read. Essential information provided in Part 1 is not repeated in this part. References to a clause refer to the combined content of that clause in both parts 1 and 2. Brief articles on the subject can be found in [14] and [15].

The set of EPB standards, technical reports and supporting tools

In order to facilitate the necessary overall consistency and coherence, in terminology, approach, input/output relations and formats, for the whole set of EPB-standards, the following documents and tools are available:

a) a document with basic principles to be followed in drafting EPB-standards: CEN/TS 16628:2014, Energy Performance of Buildings - Basic Principles for the set of EPB standards[6];

b) a document with detailed technical rules to be followed in drafting EPB-standards: CEN/TS 16629:2014, Energy Performance of Buildings - Detailed Technical Rules for the set of EPB-standards[7];

The detailed technical rules are the basis for the following tools:

1) a common template for each EPB standard, including specific drafting instructions for the relevant clauses;

2) a common template for each technical report that accompanies an EPB standard or a cluster of EPB standards, including specific drafting instructions for the relevant clauses;

3) a common template for the spreadsheet that accompanies each EPB (calculation) standard, to demonstrate the correctness of the EPB calculation procedures.

Each EPB standard follows the basic principles and the detailed technical rules and relates to the overarching EPB standard, ISO 52000-1[10].

One of the main purposes of the revision of the EPB standards has been to enable that laws and regulations directly refer to the EPB standards and make compliance with them compulsory. This requires that the set of EPB standards consists of a systematic, clear, comprehensive and unambiguous set of energy performance procedures. The number of options provided is kept as low as possible, taking into account national and regional differences in climate, culture and building tradition, policy and legal frameworks (subsidiarity principle). For each option, an informative default option is provided (Annex B).

Rationale behind the EPB Technical Reports

There is a risk that the purpose and limitations of the EPB standards will be misunderstood, unless the background and context to their contents – and the thinking behind them – is explained in some detail to readers of the standards. Consequently, various types of informative contents are recorded and made available for users to properly understand, apply and nationally or regionally implement the EPB standards.

If this explanation would have been attempted in the standards themselves, the result is likely to be confusing and cumbersome, especially if the standards are implemented or referenced in national or regional building codes.

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Therefore each EPB standard is accompanied by an informative technical report, like this one, where all informative content is collected, to ensure a clear separation between normative and informative contents (see CEN/TS 16629[7]):

- to avoid flooding and confusing the actual normative part with informative content;
- to reduce the page count of the actual standard; and
- to facilitate understanding of the set of EPB standards.

This was also one of the main recommendations from the European CENSE project[12] that laid the foundation for the preparation of the set of EPB standards.

This document

This document accompanies ISO 52003-1, which forms part of the set of EPB standards.

The role and the positioning of the accompanying standard in the set of EPB standards is defined in the Introduction to ISO 52003-1.

Accompanying spreadsheet(s)

Because in the accompanying document ISO 52003-1 no calculation procedures are defined, an accompanying calculation spreadsheet is not relevant.

History of this document and the accompanying International Standard

The first standard on this topic was EN 15217:2007[2]. It was developed as part of Mandate 343 of the EC to CEN to support the EPBD (2003)[3]. An upgrade of it was published as ISO 16343:2013[4]. The document has been thoroughly reworked and split in a normative International Standard (Part 1) and the present informative document (Part 2) as part of Mandate 480 of the EC to CEN[5].

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Energy performance of buildings — Indicators, requirements, ratings and certificates —

Part 2: Explanation and justification of ISO 52003-1

1 Scope

This document refers to ISO 52003-1. It contains information to support the correct understanding and use of ISO 52003-1 and does not contain any normative provisions.

NOTE The relation with other EPB standards, product standards and product policy is shown schematically in Figure 4 of Clause 6.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

More information on the use of EPB module numbers for normative references between EPB standards is given in ISO/TR 52000-2[11].

ISO 52003-1:2017, *Energy performance of buildings – Indicators, requirements, ratings and certificates – Part 1: General aspects and application to the overall energy performance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the accompanying EPB document, ISO 52003-1, apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

More information on some key EPB terms and definitions is given in ISO/TR 52000-2[11].

4 Symbols and abbreviations

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52003-1 and the following apply.

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More information on key EPB symbols is given in ISO/TR 52000-2[11].

Symbol	Name of quantity	Unit
A	area	m^2
c	constant	a)
f	factor	-
f	shape factor	-
V	volume	m^3
a) varies with the context		

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52003-1 and the following apply.

More information on key EPB subscripts is given in ISO/TR 52000-2.

c	conditioned
env	envelope
use	useful

5 Description of the document

5.1 General

Figure 1 shows in a first, simplified step and in a schematic manner, the main uses that can be made of the EPB indicators.

EPB indicators are numeric quantities that are the intermediate or final output of the EPB assessment standards (see also Figure 4 in Clause 6). They can be the result of either calculations (e.g. a thermal transmittance value) or of measurements (e.g. the air tightness value of the thermal envelope) or a combination of both (e.g. an overall energy performance value that is partly based on a measured air tightness). Ideally, all mathematical operations of a technical variable are defined in the EPB assessment standards and the value as such (and its definition) are directly ready for further use, without the need for further mathematical manipulation.

The EPB indicators can be used in several different ways by public and private actors. A first major use of EPB indicators is to impose regulatory EPB requirements on construction works of all kinds. A second major use is to rate the energetic quality of the considered EPB feature through comparison with benchmarks. The EPB requirements can serve as one of the references for the rating. There can still be other uses, such as the use of a variable as target function for design optimization, e.g. the least life cycle cost.

Selected EPB indicators, ratings, requirements and their (non)compliance (if applicable), and other information (such as recommendations for improvement of the energy performance) can be included in the EPB certificate, and its detailed report.

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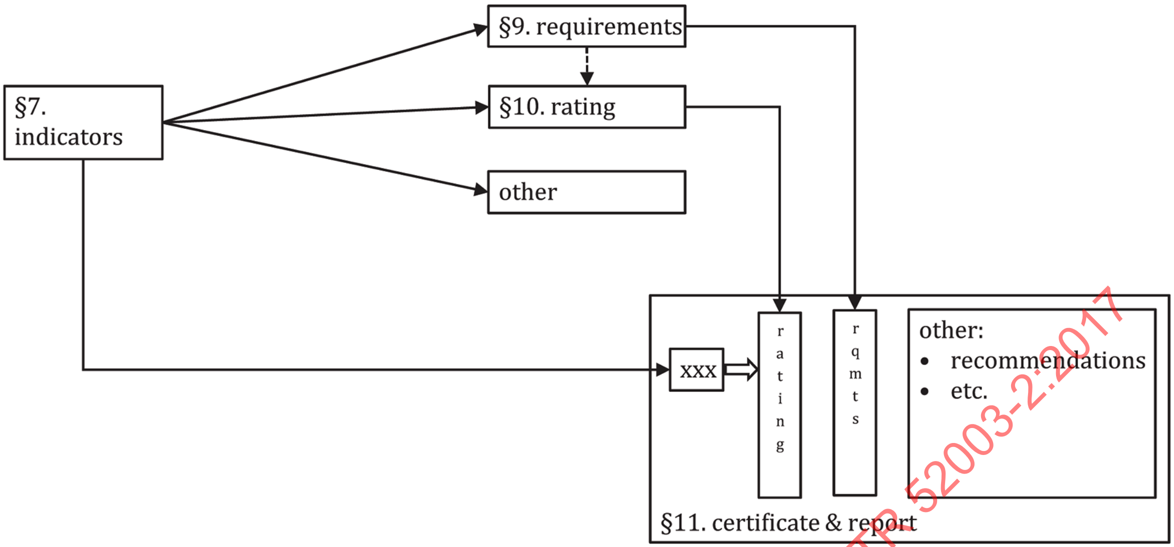

Figure 1 — Simplified schematic overview of the relations between various EPB aspects

Figure 2 illustrates in dotted lines potential additional interactions. In order to achieve equitable requirements or ratings, it can be necessary for many indicators to use in a first instance variable values as requirement or reference. Such variable values are tailored to the characteristics of each individual project. For ease of communication, the primary indicator can be converted in a second instance into a derived indicator by taking its ratio to the variable requirement or reference value. The derived, secondary indicator then again allows the requirement or rating reference to be a constant value, which can greatly facilitate communication. Generally speaking, it seems desirable that all mathematical operations are defined in the actual EPB assessment standards. But for derived indicators that are intrinsically related to the (requirement and rating) policy choices, the last few mathematical calculations inevitably can only be defined in a regulatory context.

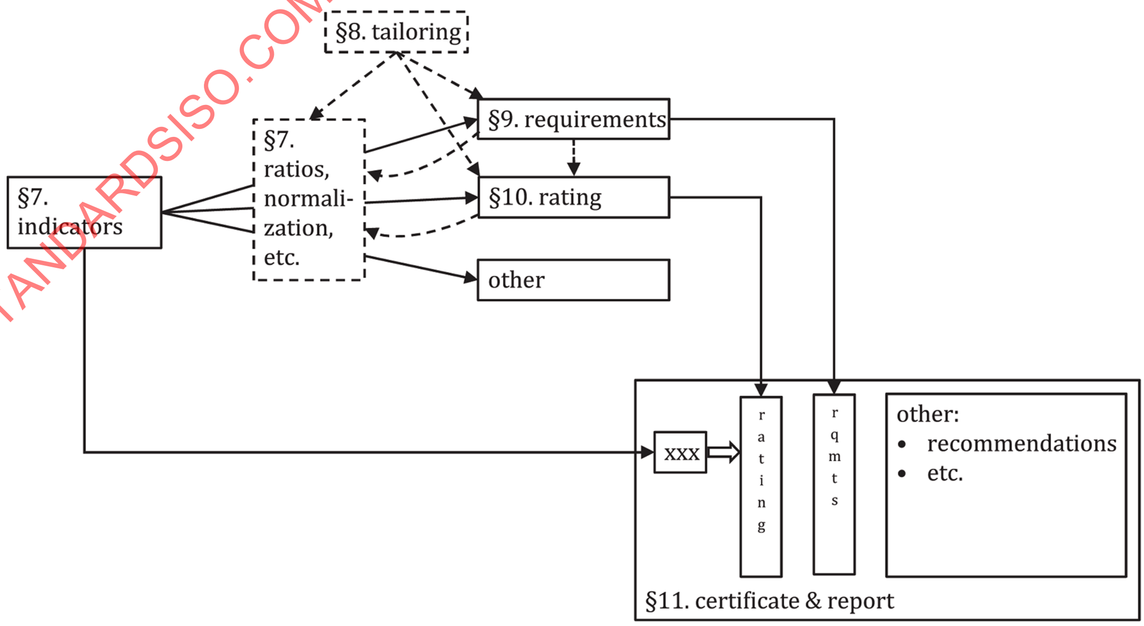

Figure 2 — Full schematic overview of the relations between various EPB aspects

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5.2 Selection criteria between possible options

No additional information beyond the accompanying document.

5.3 Input and output data

No additional information beyond the accompanying document.

6 Relation between EPB features, indicators, requirements, ratings and certificates

The conceptual table of Figure 3 is an alternative to the presentation in Figure 2. It allows a user to visualize and report the practical choices that a given (public or private) actor makes with respect to its uses of the EPB indicators.

On top of each of the columns of the table, the number of the clause in ISO 52003-1 and ISO/TR 52003-2 that deals with the particular aspect is given.

In the first column, the different EPB features can be listed. (For reasons of sizing, here these are done in an exemplary, non-exhaustive manner.) They can be grouped in 3 categories: overall energy performances, partial energy performances and the energy performances of products ("traded commodities").

NOTE 1 The product group can of course include devices that are not used in buildings (e.g. vehicles) or that are not always considered in the building energy performance assessment (for instance, the energy use of plug-in appliances such as refrigerators, televisions, computers etc., is usually not included in the calculations of the energy use of the building, but is usually part of the measured overall building energy performance).

In the second column, the possible indicators for each of the EPB features can be listed.

Clause 7	Clause 7	Clause 9		Clause 10	-
EPB feature	**indicator**	**requirements**		**rating**	**other uses**
		new	**existing**		
OVERALL ENERGY PERFORMANCES					
primary energy use		X			
non-renewable primary energy use				X	
...					
PARTIAL ENERGY PERFORMANCES					
...	...				
lighting	LENI				
	...				
fans					
	specific fan power				
	...				
systems					
	efficiency		X		
	expenditure factor				
...	...				
heating need					
	...				

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Clause 7	Clause 7	Clause 9		Clause 10	-
EPB feature	**indicator**	**requirements**		**rating**	**other uses**
		new	**existing**		
cooling need					
	...				
envelope airtight-ness					
	specific air leakage				
	...				
overall thermal insulation	mean thermal transmittance				
component ther-mal insulation					
	thermal transmittance		X		
	temperature factor				
...					
PRODUCT ENERGY PERFORMANCES					
...					
boilers					
pumps					
fans					
...					
refrigerators				X	
televisions					
...					
vehicles					
...					

Figure 3 — Tabular overview of the relation between various EPB aspects

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The third column concerns requirements. It is subdivided into 2 sub-columns, dealing with new construction on the one hand and works in existing buildings on the other hand. With a cross, the EPB indicators for which requirements are set can be indicated. These can differ between new construction (focus typically on one or more overall EPB indicators) and works in existing buildings (by their nature, focus typically on the elements and systems that are the object of the works).

In the fourth column crosses can indicate the indicators that are rated.

The empty fifth column reminds that there can be many more uses for the EPB indicators. The column can be replaced by several columns if the purpose is to illustrate/document practical instances where such other uses apply.

In Figure 4, the further relation with the assessment methods is shown. The arrows in the figure represent the transfer of data (output of 1 module is input for 1 or more other modules) towards the final use of a result (e.g. as indicator).

Product standards assess basic characteristics either by measurement or calculation, or a combination of both. Sometimes there is for a given product an alternative, free choice between measurement and calculation methods (e.g. the thermal transmittance of glazing). This choice is represented by the ellipse in Figure 4. Product calculation methods usually rely on measured features of its composing elements (e.g. coating with low thermal emissivity in glazing, or dimensions of a frame) or on production control

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schemes (e.g. noble gas filling in glazing). The product characteristics thus assessed can be used either directly as indicator (e.g. full and part load efficiencies of a boiler) or combined in a further calculation model to give a more comprehensive assessment (e.g. typical seasonal efficiency, taking into account auxiliary energy use).

On-site measurements and inspections can evaluate a building as a whole or its various elements and subsystems as they are effectively built/installed, sometimes also including the way they are used (controller settings, user behaviour, etc.). Examples are:

— measurement of the air tightness of the envelope or of the ducts;

— measurement of ventilation flow rates;

— measurement of boiler efficiency; and

— measurement of the overall energy uses, etc.

These measurement results can be used directly as indicator (or after minor further processing, e.g. conversion of delivered to primary energy) and/or they can serve as input for EPB calculations.

The EPB calculation standards are an extensive set of calculation models with multiple interactions among them. The ultimate output are overall energy performance indicators, but a very large number of intermediate results can potentially be used as partial energy performance indicators and can serve a useful purpose at some time.

NOTE 2 For this reason, it seems desirable that all (i.e. both final and intermediate) results are explicitly reported in full detail as calculation output of any EPB calculation programme. This includes each and every one of the internal variables that are defined in the EPB methods. In this manner also full transparency and traceability is created.

All the diverse input for the EPB calculations (input arrows at the bottom of the large EPB calculation triangle in Figure 4 can be grouped in some major categories:

— Annex A choices (for each of the different EPB standards):

  — in the context of regulations specified by the competent authorities;

  — in private contexts: own specifications (tailored).

— product data

— project specific features:

  — geometry (areas, layer thicknesses, orientations, et cetera.);

  — types of controls;

  — measured features (e.g. air tightness of the thermal envelope);

  — external shading, etc.

— other.

NOTE 3 The arrows at the right hand side in Figure 4 indicate the typical application range of (energy performance of building regulations and product regulations. Generally speaking, overlap of both does not seem productive.

However, in some instances, overlaps can occur in a useful manner. For instance, the product regulations can set a general requirement for a given type of product (e.g. boilers) on the market, but the building

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regulation can impose a stricter requirement when a boiler is installed in a very cold region of the jurisdiction[1].

Vice-versa, product regulations can impose requirements on the application-related aspects of products (and thus not merely the putting on the market as such of the product), e.g. that a certain type of device always be used with a minimal control, even though the control system is not necessarily integral part of the device.

NOTE 4 Generally speaking, it appears desirable that a calculation model for a given product is identical (or at least maximally parallel) when used for determining the product indicator by itself or when used as part of the overall EPB assessment (illustrated in Figure 4 for one module with the double appearance of the circled number 1). The difference would rather reside in its application. In a particular building (EPB calculation) more information can be available on the boundary conditions, which can serve as input to the model (e.g. design operating (departure and return) temperatures of the heat emission system as input for boiler calculations). For evaluating the product as such (as put on the market, independent of its ultimate application in a specific building) standard boundary conditions (e.g. considered representative of the stock-wide average) can be used as input in the same calculation model (e.g. typical design temperatures of emission systems).

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1) For instance in Europe, products are regulated on a pan-European level (through the ecodesign directive and the ecolabelling regulation), but building regulations are on a national or subnational level, which allows – among many other things – to take account of the local climate.

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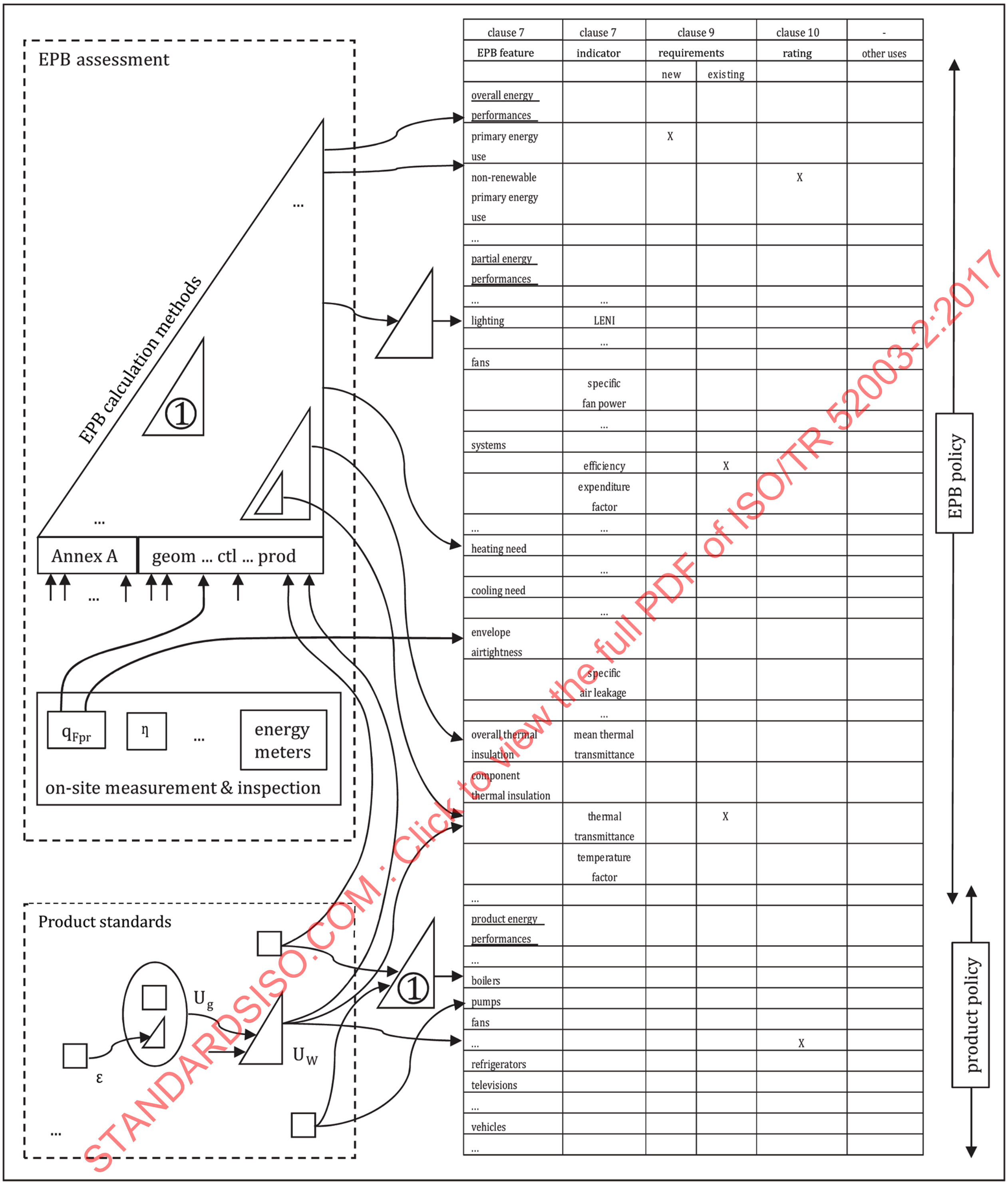

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Key

Triangle calculated assessment

Square measured assessment

Figure 4 — Relation between the assessment methods and the uses of the indicators

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7 Energy performance features and their indicators

7.1 General

No additional information beyond the accompanying document.

7.2 Normalization to building size

An overall and partial energy performance can be normalized to the building size, by relating it to one or more of the relevant metrics for the building size, such as volume or floor area.

This subject is dealt with in ISO 52000-1 and the accompanying document, ISO/TR 52000-2, but the choices can have a strong influence on the numeric value of the energy performance and of the energy performance requirements.

The reference floor area is one of the options for the reference size of the building. Some countries use another measure for the size, e.g. the space volume. These choices are facilitated in ISO 52000-1:2017, Annex A.

A factor with a strong influence is the choice which categories of spaces are included in the reference size of the building. If spaces are included in the reference size which have a relatively low energy use due to low indoor environment requirements (for instance no heating or cooling, only lighting and ventilation requirements, as can be typical for underground parking garages), then the average energy use per floor area (or per volume) will be more favourable, and vice versa. ISO/TR 52000-2 gives more detailed considerations and examples.

Some countries have indicated that they use a weighting factor for the contribution of the size of specific space categories to the reference size. In order to allow for this approach, the necessary flexibility has been incorporated into ISO 52000-1.

The type of dimension used has also a large impact on the specific value obtained after normalization. For a house of 10 m × 10 m, the indicator obtained using internal dimensions could be 20 % larger than the one obtained with external dimensions.

7.3 Energy performances and their indicators

7.3.1 Overall energy performances

No additional information beyond the accompanying document.

7.3.2 Partial energy performances

No additional information beyond the accompanying document.

7.4 Ratios of identical/similar quantities as indicators for energy performances

Some practical considerations with respect to ratios are:

— A ratio of identical quantities can be communicated succinctly by putting a letter in front of it (e.g. E from energy, for primary energy), for instance E73.

— A ratio can sometimes take negative values, e.g. when the exported energy exceeds the delivered energy (or at least the part of the delivered energy that is considered in the EPB calculations). This can for instance be the case for the renewable energy ratio (see ISO 52000-1:2017, 9.7).

— For uniformity of communication, the ratio is typically rounded to 2 significant figures. Such fine subdivision still maintains a quasi-continuous scale.

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— Without scaling factor, the ratio typically hovers in the range between 0 and 1 (or more than 1, if the denominator is quite "strict"). By using a scaling factor of e.g. 100, the figure can be rounded to the nearest integer value so that no digital separator is needed. This facilitates communication.

— Because this can differ from indicator to indicator, it is important to clearly communicate what is good and bad (e.g. the lower the value, the better, i.e. a lower value is a better performance).

— A further judgment can be communicated by setting benchmarks and references, and possibly further associating (multi-coloured, e.g. green to red) labels to the scale e.g. from A (or A+++) to G: see also Annex E.

NOTE If it is desired to have a reverse scale (e.g. the higher, the better instead of vice-versa), this can be achieved by taking the negative of the ratio and adding an appropriate constant (c). The new definition then becomes:

$$I = c - f * X / X_{ref}$$

Some advantages of a ratio are:

— Single numeric value (which is easy for communication) while differentiated: each particular building has its appropriate, tailored indicator.

— The ratio is immediately a quality indicator: lower (or higher, depending on the type of indicator) values indicate how much better a given building performs compared to the reference.

— Since standardized energy calculations usually do not exactly correspond to the real energy consumption, the dimensionless number fully focuses on the regulatory purpose, namely to differentiate among different energy efficient designs (and to impose a requirement when applicable).

A drawback of a ratio is:

— In order to maintain an adequate indicator in the future, the reference could need to change over time when the relative cost effectiveness of different technologies changes.

8 Tailoring for requirements and for ratings

8.1 Two approaches

Because the notional reference building approach and the formula approach are so different in their way of proceeding, it is often spontaneously assumed that the resulting requirements are very different too. However, despite the methodological differences this does not at all need to be the case, if the same reference set of hypotheses is taken as starting point for both approaches. This is further explained here.

Figure 5 a) and 5 b) show the information flow of both approaches in a schematic manner. The part of the figures above the dotted line is the development of the method; the part below the dotted line is its application in each specific project.

Development of the method

The (explicit or implicit) starting points are in both instances normally identical: the EPB assessment method and a reference set of technological and geometrical assumptions.

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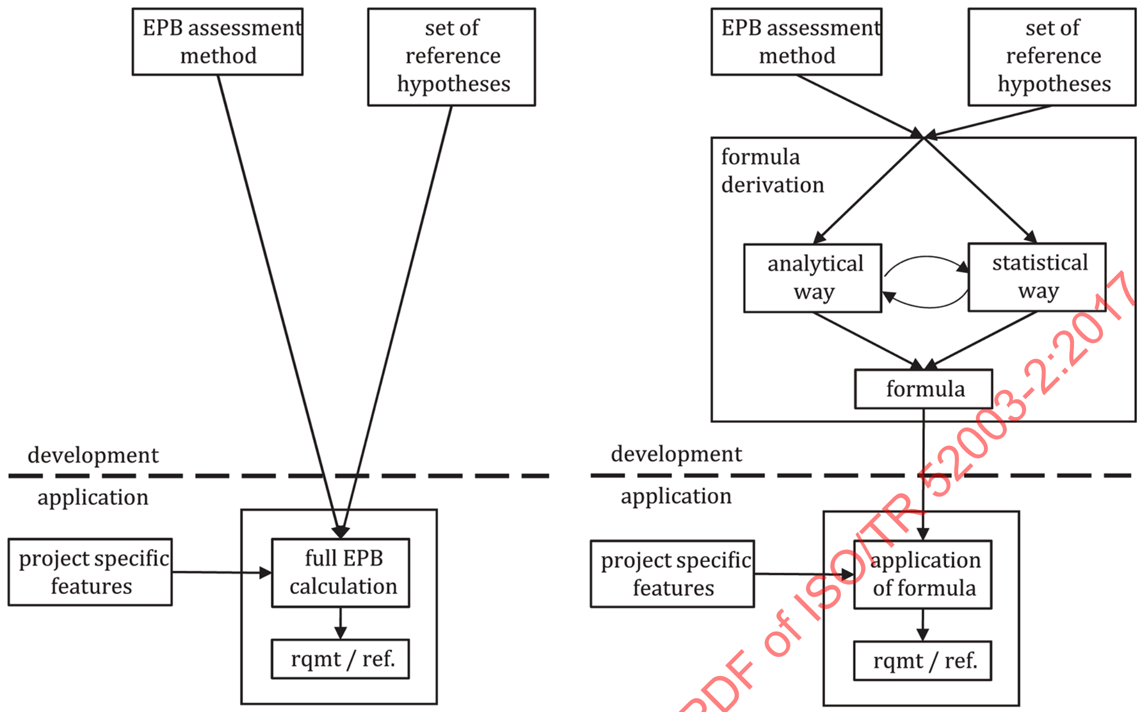

(a) Notional reference building approach **(b) Formula approach**

Figure 5 — Schematic of (a) the notional reference building and (b) formula approach

Notional reference building approach

Here, the development work is limited to the judicious choice and detailed, clear description of the set of reference hypotheses. This then needs to be correctly programmed (for all possible –possibly very diverse– projects) in the EPB calculation tool.

Formula approach

Here, the EPB assessment method and the set of reference hypotheses are used to derive a generic formula (which usually is relatively simple). In practice, 2 ways to derive the formula appear to be used (often in a combined and/or complementary manner), as shown in Figure 5 b):

— The analytical way seems most easily applied in the case of monthly or seasonal methods. Application to hourly methods can prove quite difficult. In this instance, all the hypotheses are introduced in the equations of the EPB assessment method. Only the few input values of the method related to the specific project then remain. Additionally, some approximations are made: for instance, the value of the utilization factors is determined for a typical building (or as the average calculated for many buildings, covering the application range) and is then used as a fixed value in the remainder of the equations. The final outcome is usually double-checked with full, detailed calculations (also using the reference hypotheses) on a sufficient number of building geometries.

— In the statistical way, a sufficiently large number (e.g. a few 100) of (preferably real, rather than fictitious) building geometries are considered. This collection should include extreme cases, such as very small and very large sizes, very small and very large envelope to floor area ratios, etc. For each geometry the requirement is calculated with the EPB assessment method and the set of reference hypotheses. The resulting set of outputs is used to determine the numeric parameters of a generic formula that has the specific project features as input. The general form of the formula (e.g. linear or non-linear dependence on each of the variables) needs careful consideration, and can be based on (rougher) analytical deduction as in the previous case, but this time without quantitative

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calculation. For complex formulae (as can for instance be needed in non-residential buildings) fully automated curve fitting could not lead to satisfactory results, and smarter (e.g. step by step), semi-manual curve fittings could be needed.

As indicated, in practice both ways thus are not strictly separated, but are to a greater or lesser extent combined.

Usually, the result is actually a set of different formulas, each of which applicable to a specific combination of circumstances, such as:

— for different building categories (dwelling, office, etc.);

— for certain ranges (e.g. as a function of size) within a given category (e.g. because the assessment method uses different hypotheses over different ranges); and

— for different climates.

Application of the method

The results of the development process are now combined with a few real characteristics (building size, thermal envelope area, etc.) of the specific project for which the requirement needs to be determined.

Notional reference building approach

As shown in Figure 5 a), the project characteristics are directly combined with the set of reference hypotheses in a full EPB calculation, which is rerun for every individual project, and for every input change of the project features that are used as input. The number of calculations in the programme is thus doubled: for every change of the input, both the actual energy performance and the requirement or reference are recalculated.

Formula approach

The formula that has been developed (see 8.1) is used to calculate with the specific project features as input in a very rapid manner the requirement or reference.

Discussion

In essence, the formula is a condensed form of (and replaces) the full EPB calculation. This substitution is possible because the set of reference hypotheses is fixed and freezes most of the input variables of the assessment method.

When the starting points are exactly identical (notably the full set of reference hypotheses), then the requirements/rating references that result from the notional reference building approach on the one hand and the formula approach on the other hand are normally (almost) equal (in as far as the formula developed is adequate, i.e. not too simplistic). So, although the intermediate approach is different, identical starting points lead to roughly identical final results. This is corroborated by empirical experience.

NOTE When the requirement is expressed as a ratio (see Clause 7), the result of the notional reference building or formula calculation is rather used as denominator in the ratio, and the requirement is then a fixed value, e.g. 0,7, or 1, or 100 (depending on the definition of the ratio). Such single, fixed number can facilitate communication.

8.2 Project characteristics for tailoring

No additional information beyond the accompanying document.

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9 Energy performance requirements

9.1 General

NOTE 1 Depending on the type of indicator that is chosen, EPB requirements are either a maximum (e.g. maximal overall energy performance, maximal thermal transmittance U, etc.) or a minimum value (e.g. minimal efficiency, minimal thermal resistance, etc.). As requirements are discussed in a general manner here, it has been attempted to use general, neutral wording, such as strict/lax or better/worse.

The different choices to be made with respect to the requirements are not only of a technical nature, but they also have to a greater or lesser extent a societal-political dimension. This is in particular true for the actual strictness (see 9.4), which reflects the level of policy ambition.

In principle, choices can be based on a great variety of motivations, considerations, etc., and public authorities have the full freedom to take the decisions. But it is highly recommended that these justifications are explicitly and publicly documented with a view of transparency and institutional memory.

Often, economic considerations have proven a useful way to support the decision making process, with a view of maximizing the societal benefits at the lowest cost. Precautions are of course needed to avoid negative effects on the indoor environment.

It is generally found that a comparable economic strictness for each individual construction work (whether renovation or new construction; small or large buildings; dwellings, offices or shops, etc.) leads to optimal results. Some major reasons for this are:

— a sense of “fairness” on an individual level: everybody has to do the same economical “effort”;

  — if the requirements correspond to the private cost optimum, then they are simply to the direct benefit of the building owner and users;

  — if they are stricter (corresponding to a higher energy cost scenario, reflecting more ambitious energy and environmental policy objectives), then everybody is treated in an “equal” manner;

— the achievement of an overall societal optimum:

  — too strict requirements for some projects leads to a relative “overinvestment”, with money lost on these projects;

  — too lax requirements for other projects can result in an “underinvestment”: unless the construction team opts itself on a spontaneous basis for better, cost-optimal performance, undue energy expenses will occur in the future;

  — in both instances private money is lost on a life cycle basis, and thus money is also lost on a societal level (as the sum of all private expenses);

— in the political decision making process, in the case of unequal economic strictness, the economically unprofitable cases can determine the requirements for all projects, as some practical examples of the most difficult/strict individual projects can de facto become the reference when a decision is taken on the overall strictness.

NOTE 2 Some of the possible future energy cost scenarios that can be considered for performing economic evaluations in view of setting EPB requirements are for example:

— the anticipated private market price;

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— macro-economic energy price scenarios, e.g.:

  — a higher energy cost that incorporates one or more external costs (for instance due to the impact of greenhouse gas emissions, damage to human health, environmental harm, import vulnerability of the economy, etc);

— the equivalent cost of (the most expensive large scale form of) renewable energy. Renewable energy constitutes the alternative to energy efficiency for reducing mineral (i.e. fossil and nuclear) energy resource consumption (e.g. bioenergy, photovoltaic or (on/off-shore) wind electricity production). In countries where the supplementary renewable energy costs are societally acceptable and where renewable energy is rolled out on a large scale with financial support schemes, this approach of using the total cost of renewable energy to set energy efficiency requirements allows to achieve an overall societal cost-optimal mix of renewable energy and energy efficiency.

NOTE 3 By means of energy taxes, the private energy cost can be raised to the level of one of the options of Note 2, so that the private and societal economic optima again correspond much better to each other, and private actors are stimulated by their own financial self-interest to make the societally best choices.

An aspect that is not captured by conventional economic analysis is the following. The present value of expenses more than 30 years into the future is nearly always (under common economic hypotheses, namely a higher discount rate than fuel inflation rate) almost zero. Nevertheless some aspects of the fabric, in particular the thermal insulation of opaque parts, can last the lifetime of the building, which may be ... 50 ... 100 ... years. (Nearly all buildings are left to stand after 30 years, even if the building as a whole "should have paid off".) Further increasing the insulation thickness at a later time might never pay for itself, even at higher energy prices. This is an example of a consideration that can result in other requirement decisions than what ensues from classical economic analysis.

9.2 Choice of the mix of requirements

9.2.1 General

Generally speaking, it seems most productive not to exaggerate the number of requirements, but to limit it to the number that is really useful in order to achieve the objectives that are pursued (indoor environmental quality, energy efficiency, etc., see 9.1). In this manner the regulation does not unnecessarily become overburdened and design freedom is not unduly curtailed.

9.2.2 New buildings

Most important are of course one or more overall requirements that cover at once all the various aspects of the fabric and the fixed technical building systems. In this manner, the construction team is incited to look in an integrated manner at each and every aspect that influences the overall building energy performance, while maximal design freedom is maintained. If moreover for all individual projects a requirement of adequate, tailored strictness (e.g. closely corresponding to the cost optimal value, see 9.3) is set, then it can be expected that in most projects all design choices that have a major impact on the overall energy performance will effectively be achieved in a close to cost-optimal manner, because not doing so would require very strict performances on the remaining design variables, thus entailing much higher total costs. In short, a proper (set of) overall energy performance requirement(s) will often by itself already lead to a high probability that a fairly balanced set of energy efficiency measures is implemented in most projects.

With respect to additional, partial requirements, it appears not necessary to establish separate requirements for every possible EPB feature. Only extra requirements that are needed to ensure the goals (see 9.1) seem productive. Partial EPB requirements seem certainly warranted when there are specific reasons other than energy efficiency, e.g. indoor environmental quality or material preservation. With respect to energy efficiency, they can be well justified for elements with a long lifetime for which it is practically difficult and/or expensive to upgrade their performance at a later date, i.e. notably the insulation and air tightness of the thermal envelope. More generally, it is sometimes desired to ensure that first of all the energy needs for heating and cooling get limited (as part of a broader "trias energetica" philosophy, whereby only in a second instance attention is turned to efficient technical building systems, and then thirdly the possible use of renewable energy.)

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Partial requirements related to the fabric and to the thermal energy balances are discussed in detail in ISO 52018-1[8] and ISO/TR 52018-2,[9] which includes a motivated default example for the requirement mix.

9.2.3 Existing buildings (renovations and extensions)

When works are performed on existing buildings, it is logical to set requirements specifically to those parts of the building that are the object of the works. Given that for any specific type of work there can be specific requirements, in total there can be a large number of different requirements, but usually only a few apply to a given project. In existing buildings it nearly always concerns partial EPB requirements. Only in the case of comprehensive renovations and large extensions, overall EPB requirements are frequently set.

Two types of partial energy performance requirements can be distinguished:

— Requirements on element level. The parts that are completely new (e.g. the new envelope elements in an extension) or that are fully replaced (e.g. windows) or that are modified (e.g. roofs at the time of replacement of the covering) can relatively easy be the object of elemental requirements. For elements of technical systems (and maybe certain components of the thermal envelope, e.g. windows), there can be an overlap with energy efficient product policy, which can impose requirements on any product of a certain type that is put on the market (e.g. boilers). Careful consideration is needed whether setting an additional requirement in the EPB regulations is useful or not (and whether it is not in legal conflict with the product policy). The outcome of such evaluation can vary from product to product and from country to country (e.g. depending on the climate).

— Requirements on the combination of different elements (e.g. technical subsystems or different elements of the thermal envelope considered together). Such “wider” requirements are less prescriptive and in principle allow more design freedom. However, an adequate way to express the requirement and an appropriate strictness (e.g. the full cost optimal potential) on a project by project basis can be more difficult to define, also with respect of its practical applicability.

Practical constraints, in particular when it concerns works on existing elements (e.g. insulation of an envelope elements when it is not fully replaced), are often a limiting factor to improve the energy efficiency. Imposing requirements in these circumstances thus calls for very detailed rules on the precise conditions when the requirement is applicable, when a less strict requirement applies, or when full exception is granted.

9.3 Constant or variable value requirements

9.3.1 Tailoring requirements to individual project characteristics

Unbalanced requirements can have many disadvantages. For instance, failing to capture the full potential of the regulation, if the requirements for certain projects are much laxer than the technical-economic average. And/or, if the requirements for other projects are much stricter than the technical-economic average, the erosion of public support for the regulation because the regulation is then experienced as unfair (see also 9.1).

The methods for assessing the energy performance of a building are very detailed. One of the purposes of creating such elaborate methods is to achieve a reasonably fine evaluation of the energetic quality of the building, taking into account the benefits that many different design and technological variants and improvements can offer. They thus create a stimulating context for the construction sector to invest in a comprehensive energy efficient planning and a careful execution. And the component supply industry is stimulated to ever further develop more energy efficient systems. Crudely expressed requirements can, to a large extent, annihilate this achievement.

The ways to express these requirements deserve equally extensive analysis and judicious consideration, in order to arrive at “smart” requirements that match the sophistication of the EPB assessment methods.

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As mentioned in NOTE 1 of 9.1, financial recovery of the initial investments through the energy savings can be an important consideration when deciding on the way to express each of the EPB requirements. Whenever costs are a major factor, it is important for certain EPB requirements that they are not expressed as a constant value, but as a variable value, in a tailored manner. These requirements are then a function of the actual building, with requirement values varying on an individual project by project basis. Whether there is such need for a tailored requirement should be carefully evaluated separately for each EPB indicator for which a requirement is set.

Prime examples of EPB features that could, in a given country or region (depending on outdoor climate, etc.), need tailored requirements are: the overall primary energy use, the energy needs for heating or cooling and the mean thermal transmittance of the envelope.

A practical example that illustrates the issue is given in Annex C.

The issue of the way to express the requirements is also discussed in detail for many fabric related EPB features in ISO 52018-1[8] and ISO/TR 52018-2[9]. These documents include practical examples of the energy need for heating and the mean thermal transmittance that provide a further understanding of the issue.

From economic studies, it is generally found that for a given building category (dwellings, offices, etc.) a set of “technologies”, combined with a reasonable amount of glazing, can be identified that corresponds fairly well to the lowest life cycle cost for very different building sizes and shapes. Applying this set of technologies and glazing area (called “set of reference hypotheses” in Clause 8 and hereunder) to the geometry of each individual project in order to calculate its quantitative requirement thus constitutes a good means to arrive at a comparable technical and economic strictness for all individual projects (while leaving of course the full freedom to the building team of the project to choose its own mix of preferred technological solutions, as long as it satisfies the performance requirements).

Two ways to apply this principle in practice are the notional reference building approach and the formula approach, as discussed in Clause 8.

In order to guarantee the robustness of the set of reference hypotheses, it seems very much advised to determine the set on the basis of an economic analysis of not only a few typical, “average” buildings (in terms of size, ratio of envelope to floor area, etc.), but also of some extreme cases (for instance, in the case of residential buildings, at least also a very small studio and very large –castle-type– detached dwelling). This verification over the entire range ensures that no anomalies will occur. A fully automated tool for the combined EPB and economic calculations (e.g. in the form of calculation spreadsheets) allows to make these extra analyses at little extra effort. In addition, they allow to automatically and easily analyse a very large number of possible technical combinations (e.g. more than 100 000) for each of the geometries considered so that the least life cycle cost solutions can be identified with a high degree of certainty and so that a comprehensive overview of the relative competitive position of different technologies is obtained.

In the context of the requirement setting (especially in the formula approach) the following combined variables are sometimes used (but care should be taken not to overlook other variables that can be important; see Annex C in this document and in ISO/TR 52018-2:2017[9] for some practical examples and discussion).

The building shape factor:

$$f = \frac{A_{env}}{A_{use}}$$

and/or the compactness ratio:

$$c = \frac{A_{env}}{V_c}$$

where

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A_{env} is the thermal envelope area, in m^2;

A_{use} is the useful floor area, in m^2;

V_c is the conditioned volume, in m^3.

NOTE 1 Instead of the useful floor area, the reference floor area can be used.

NOTE 2 For overall EPB requirements still other variables can play an important role, e.g. hygienic ventilation flow rate, domestic hot water needs, lighting levels, etc. (see ISO 52003-1:2017, 9.3).

9.3.2 Tightening the requirements over time

When the requirements are tightened (see also "actual strictness", 9.4) in the course of time (due to price rises of energy, or cost decreases of technologies, etc.), one of the following two situations can occur:

1) For the different building geometries the new cost optima are ALL more or less the same fraction (for the numeric indicator considered) of the optima in the previous analysis a few years earlier. This probably implies that all technologies (thermal insulation, energy efficiency of ventilation, lighting, etc.) improve their competitiveness in a very similar manner (e.g. due to an across-the-board energy price increase). The new requirement can then be expressed as a simple fraction of the previous requirement.

2) Or the new cost optima are rather different fractions of the previous requirements. This situation is probably due to a shift in the relative competitiveness of the different technologies, e.g. because of rapid cost reductions (for instance, owing to swift technological progress) of certain technologies only or because of significant changes in relative cost of different energy carriers, e.g. due to taxation or technological developments. In this situation, a new set of reference hypotheses seems the most appropriate way to express the new requirement.

It is clear that the use of a ratio as indicator (as discussed in 7.4) works very well in the first situation: the reference value of the ratio can remain unchanged over time and the tightening of the requirement is expressed as a new, stricter limit value of the ratio.

In the second situation, the denominator is redefined to correspond to the new set of reference hypotheses (but the value can be rescaled so that the average for all buildings within the category under consideration still corresponds to the previous reference). Such change of reference value in the denominator implies that for a specific individual building the numeric value of the new ratio indicator will, to a greater or lesser extent, differ from the value determined according to the preceding reference, so that both figures are not exactly comparable. However, if the average values for all buildings still correspond between both systems and, if the individual divergences remain relatively limited, the continued use of both ratios simultaneously in the market (e.g. on old and recent EPB certificates) can be acceptable and still productive, considering all the other uncertainties involved in the EPB assessment and methodological changes in the numerator (i.e. in the EPB methodology) that can occur over time.

NOTE A change in the assessment methodology can implicitly have the same distorting impact as an explicit tightening of the requirement.

9.4 Actual strictness

When the actual strictness is based on economic optimization, some possible energy cost scenarios that can be used for that purpose have been listed in 9.1 of this document. The essential societal-political choice is then the level of ambition that is set for energy efficient construction (as part of the general energy, environmental and other policies), and thus the height of the future energy costs to be taken into consideration when doing the economic evaluation.

In practice, the actual strictness can be somewhat influenced by the rigour with which the requirements are applied. When the requirements are to be very firmly adhered to (whether on a spontaneous basis or by strict enforcement), it is important to verify that all projects systematically can achieve the requirements with what is considered acceptable effort (which can, for example, be somewhat more

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costly than the general cost optimum in the case of lavish designs). When on the contrary in practical application quite some tolerance with respect to requirement compliance occurs, public authorities can be inclined to set somewhat stricter requirements as compensation, so that on the average the effectively achieved performances are still at the desired level.

9.5 Reporting template for the overall energy performance

No additional information beyond the accompanying document.

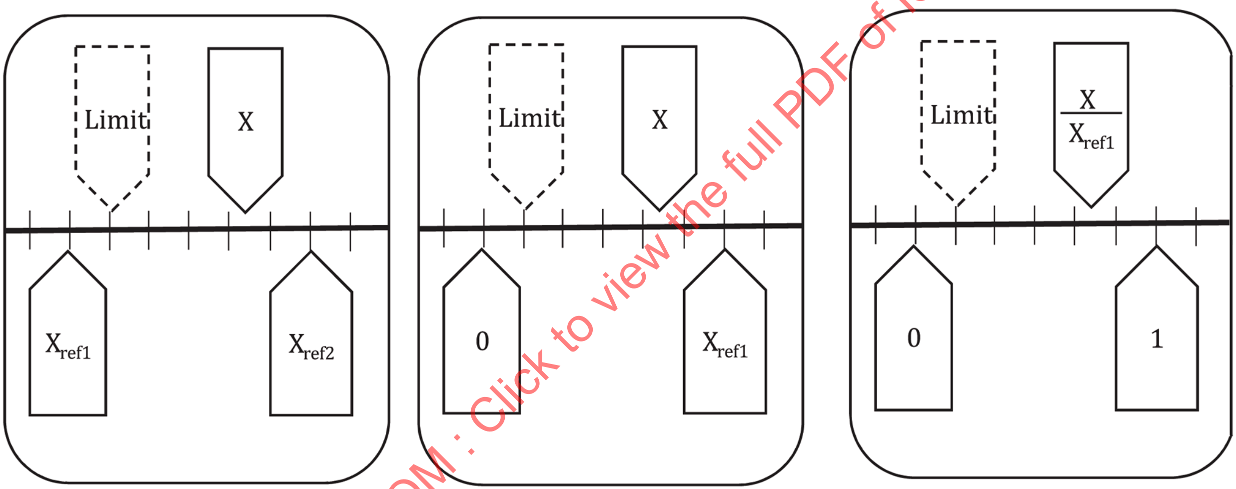
10 EPB rating

10.1 General

No additional information beyond the accompanying document.

10.2 EPB rating procedures

Figure 6 illustrates different options to express the rating.



The scales can be continuous or discrete (classes).

The references can be constant or variable (notional reference building or mathematical formula).

'Limit' stands for a required minimum level (if any); see Clause 9.

Figure 6 — Examples to illustrate different options to express the energy rating (scale against one or more references)

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Method 1 in ISO 52003-1:2017, 10.2, the default energy rating method with two reference points, is copied from the preceding documents, EN 15217 and ISO 16343.

It typically has the boundaries between the classes B & C and D & E. Annex D provides a practical suggestion for defining the boundaries of the other classes.

NOTE 1 These conventions mean that for a given country or region and a given building type, such as, in Europe, most buildings completed from 2006 onwards, should be in classes A and B, approximately 50 % of the building stock will be in classes between A and D, and approximately 50 % of the building stock will be in classes E, F, and G.

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Research into consumer understanding of energy labels for domestic appliances has shown that the use of the colours on the label has an important impact on the interpretation by the consumer: anything in the (dark-light) green range will be considered as good (with no further stimulus to go for better than the "worst green"). So, the limit of the use of the colour green will shape the market.

Method 2 in ISO 52003-1:2017, 10.2, the default energy rating method with a single reference point was proposed in a European study[13] on the Definition of an Energy Performance Scale for the "Voluntary EU certification for non-residential buildings", related to the EPBD. This method would be better suited for new buildings, while Method 1 is more focused on existing buildings (only 2 classes below minimum EP requirement).

Some background information on Method 2, based on the presentation of the results of the above mentioned study:

10.2.1 Reference point - National legal requirements for new buildings

<u>Advantages:</u>

— easy to remember and understand;

— (ratio to requirement = fulfilling or not the legal requirement of country);

— national minimum requirements are well known and available;

— buildings in national portfolio can be placed on the scale;

— EPC as a rule include reference values-minimum energy performance requirements (Art. 11 of recast EPBD[3]);

— link to incentives or high performance and possible NZEB definitions (European wide comparable definition).

<u>Disadvantages:</u>

— linked to the countries definition of the minimum energy performance level. (Low legal requirements = highest performance can more easily be reached); and

— link with article 5 of recast EPBD[3] (comparative methodology framework calculating cost-optimal level of minimum energy performance requirements) is important, in order to avoid significant discrepancies among the EU Member States.

10.2.2 Expressions of reference point of the scale

Possible definitions of minimum requirements for overall energy performance in kWh/(m^{2}a) of primary energy used in the EU Member States:

— absolute values related to the energy consumption and climatic zones;

— values taking into account building geometry in some way;

— description of the Mirror Baseline Buildings (MBB) (including the description of the recommended / required properties of the building envelope and of the technical systems (Art.4,5,8)).

All 3 possibilities can be used.

More detailed the description ⇒ more comparable the evaluation of the performance (reference point takes better into account the real possibilities of each specific building)

Most accurate approach = when the energy performance of the real building and of the reference point is determined by using the same calculation procedures.

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10.2.3 Proposal for the shape of the scale

Stepped scale with geometric series to express the upper limits of the energy classes

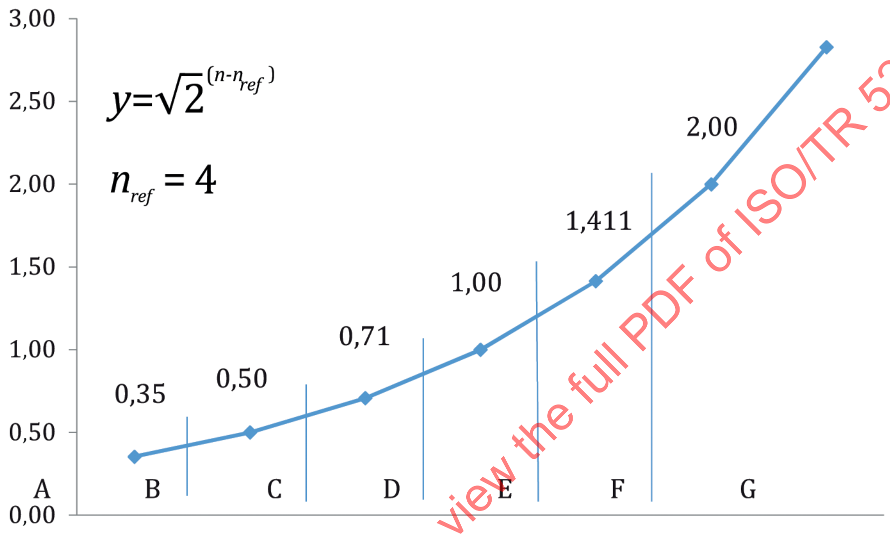
$$Y = \sqrt{2}^{(n - n_{ref})}$$

where:

n is the position of energy class on the scale;

n_{ref} is the position of the energy class for reference point on the scale.

It has been proposed to place the reference point on the limit of classes 4 and 5 ($n_{ref} = 4$), see Figure 7.



NOTE 2 EN 15217 places mandatory minimum legal requirements on the limit of classes 2 and 3.

Figure 7 — Method 2 - illustration of the class boundaries

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Advantages:

— one reference point;

— non-linear scale - better adapted to cover all buildings;

— respects efforts and costs to shift from one class on the scale to the class above.

Proposed scale with ranking and intervals of classes:

— 7 Classes + Energy positive

The same scale but possibility for different “awards” for:

— new buildings;

— renovated/existing buildings.

NOTE 3 for instance for existing buildings the same “award” could be linked to a lower class; because legal requirements for major renovation are lower than for new buildings (e.g. Germany 140 %).

Terms like high performance buildings (HPB) and nearly zero energy buildings (NZEB) will also be more understandable and European wide comparable for incentives scheme if these are directly linked to certain classes on the scale.

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10.2.4 Conclusions on Method 2

Principles of scale can also be used for mandatory schemes.

Proposed scale:

- easily understandable;
- flexible;
- comparable;
- takes into account other articles of recast EPBD:
  - the minimum energy performance requirements (art. 4, art.8);
  - the calculation of cost-optimal levels of minimum energy performance requirements (art. 5); and
  - the nearly zero-energy buildings (art. 9).

Experimental phase is needed for the fine tuning of the scale of Method 2.

10.3 Reference values

See ISO 52003-1:2017, 10.3. The text in the document is applicable to both Method 1 with two reference points and Method 2 with a single reference point. The content of Annex D was originally based on Method 1, but can be applied more widely.

11 Energy performance certificate

11.1 General

No additional information beyond the accompanying document.

11.2 Content of the procedure for a building energy certificate

No additional information beyond the accompanying document.

11.3 Content of the energy performance certificate

11.3.1 General

11.3.1.1 Suggestions for the content of the energy performance certificate:

The following administrative and technical data can be requested as content of a building energy certificate.

11.3.1.2 Administrative data

- reference to a specific procedure for a building energy certificate, including its date;
- name of person responsible for issuing the energy certificate;
- address of the certified building; and
- date when the energy certificate was issued and its limit of validity.

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11.3.1.3 Technical data

- type and subtype of EPB assessment, as specified in ISO 52003-1:2017, 11.2 under c); based on ISO 52000-1:2017, 6.2.4, (Table 3), including the explanation from that Table 3;

EXAMPLE Type of EPB assessment: "Calculated, as built": calculated energy performance based on data from the building 'as built', assuming a standard use and standard climate conditions.

- if the certificate is based on design energy rating, the requested additional content as specified in ISO 52003-1:2017, 11.2 under c);
- if the certificate is based on measured energy rating, the requested additional content as specified in ISO 52003-1:2017, 11.2 under c);
- one overall indicator representing the energy performance, as specified in ISO 52003-1:2017, 11.2 under d);
- reference values as specified in ISO 52003-1:2017, 11.2 under g);
- specific other information on the energy performance of main building and system components, as specified in ISO 52003-1:2017, 11.2 under h);
- specific additional indicators, as specified in ISO 52003-1:2017, 11.2 under i);
- recommendations for cost-effective improvements, as specified in ISO 52003-1:2017, 11.2 under j);
- energy performance rating, as specified in ISO 52003-1:2017, 11.2 under k);
- specific additional content on the certificate to identify the characteristics of the building, as specified in ISO 52003-1:2017, 11.2 under l).

Compared to the preceding standards, several paragraphs on "administrative and technical data" and reporting of types of energy performance assessment (previously called 'rating types') have been deleted because these are covered in the overarching EPB standard, ISO 52000-1.

11.3.1.4 Graphical representation of the energy rating

See ISO 52003-1:2017, 11.3.2. The default graphical model is offered as a choice.

See Annex E of this document for examples of energy label models, including different graphical representations of the energy rating.

11.3.2 Default graphical representation model

The default graphical model is consistent with the two default energy rating methods (Method 1 and Method 2) in ISO 52003-1:2017, 10.2.

11.4 Recommendations

No additional information beyond the accompanying document.

12 Quality control

Several of the reporting elements in ISO 52003-1:2017, Clause 11, would also fit in Clause 12, because these are not only applicable to procedures for building energy certificates, but also outside the context of the energy certificate (e.g. specifications for the overall energy performance indicator(s), overall energy rating and overall EPB requirements.

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13 Compliance check

No additional information beyond the accompanying document.

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Annex A
(informative)

Input and method selection data sheet — Template

A.1 General

This subclause in the accompanying document is a common subclause for all EPB standards. In ISO 52003-1 it is a normative annex. The explanation on Annex A of the accompanying standard in this Annex is informative.

More information and explanation on the concept of Annex A and Annex B for all EPB standards is given in ISO/TR 52000-2.

A.2 References

This subclause in the accompanying document is a common subclause for all EPB standards.

More information and explanation on the concept of the normative references to other EPB standards via Table A.2 (normative template) and Table B.2 (informative default choices) of the accompanying document is given in ISO/TR 52000-2.

A.3 Energy performance requirements

No additional information beyond the accompanying document.

A.4 Rating

No additional information beyond the accompanying document.

A.5 Label model

No additional information beyond the accompanying document.

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Annex B
(informative)

Input and method selection data sheet — Default choices

B.1 General

This subclause in the accompanying document (ISO 52003-1) is a common subclause for all EPB standards.

More information and explanation on the concept of Annex A and Annex B for all EPB standards is given in ISO/TR 52000-2.

B.2 References

This subclause in the accompanying document is a common subclause for all EPB standards.

The references, identified by the module code number, are given in ISO 52003-1:2017, Table B.1.

More information and explanation on the concept of the normative references to other EPB standards via Table A.1 (normative template) and Table B.1 (informative default choices) is given in ISO/TR 52000-2.

B.3 Energy performance requirements

As in all EPB standards, the template in ISO 52003-1:2017, Annex A is applicable to different applications and building types, as explained in ISO 52003-1:2017, A.1.

EXAMPLE Applications: design of a new building, certification of a new building, renovation of an existing building, certification of an existing building.

Buildings types: small or simple buildings and large or complex buildings.

A distinction in values and choices for different applications or building types can be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

In ISO 52003-1:2017, B.3, the second option is used, by introducing Table B.2a and Table B.2b. In this case the table with addition “a” is applicable to new buildings and the table with addition “b” is applicable to existing buildings.

In this way the integrity of the template of Annex A is not violated. If these Tables would have been numbered Table B.2, Table B.3, Table B.4, etc., instead of Table B.2a, Table B.2b, Table B.3, etc., the numbering would no longer be in line with the template of Annex A.

B.4 Rating

No additional information beyond the accompanying document.

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B.5 Label model

No additional information beyond the accompanying document.

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Annex C
(informative)

Illustration of the variable value of the overall primary energy use per floor area for a given set of technical measures

This Annex illustrates in a practical manner how the overall primary energy use per useful floor area can vary for a given set of technical measures. The issue is discussed in a general manner in ISO 52003-1:2017, 9.3. The concrete example is based on the Belgian EPB assessment method for dwellings (status 2013) and more than 200 real Belgian dwelling geometries (including single apartments and small studios).

NOTE 1 The Flemish Energy Agency is gratefully acknowledged for giving its kind permission to use its calculation tool with dwelling database to generate these graphs.

NOTE 2 A similar example for the energy need for heating is given in ISO/TR 52018-2[9].

In Figure C.1, the overall primary energy use per floor area is calculated for a given set of technical hypotheses, corresponding to the results of the cost optimal calculations on 4 sample dwellings (indicated as dark blue crosses + symbols).

NOTE 3 The abscissa gives the ratio of the envelope area to the useful floor area for the building unit, which is sometimes called the building shape factor (symbol f, see 9.3). Small values (i.e. to the left of the axis) are typical for deep, centrally located apartments or studios (e.g. with only 1 external facade). Large values (i.e. to the right of the axis) are typical for small, detached houses.

When considering all points (x-marks in the graph), it can be seen that the specific primary energy use corresponding to the set of technical hypotheses (and thus probably also in good approximation to the individual cost optimal value) varies greatly, depending among other things on the ratio of the envelope area to the useful floor area. There is a factor of no less than 2 difference between the highest (more than 120 kWh/m^2) and lowest (less than 60 kWh/m^2) points. Setting a constant requirement, e.g. the intermediate value of 90 kWh/m^2 (horizontal, bold, red line), for instance determined on the basis of an "average" dwelling, would mean that some dwellings (with a high envelope to floor area ratio, towards the right of the x-axis) would need to do much more effort, most likely well beyond the cost optimum, and that other dwellings (many of the those with a low envelope to floor area ratio, towards the left of the x-axis) would satisfy the requirement with easy technical measures, not at all achieving what would be cost optimal for their particular project. The example illustrates that it is recommendable to investigate the full range of building geometries, including the extreme cases, in any technical analysis of the requirements. In the economic evaluations, it also seems advisable to include a few limit cases, rather than to restrict the analysis to typical buildings, deemed representative for the "average" of the stock (as is at present common practice, as illustrated by the 4 blue + symbols in the graphs). Fully automated calculations of these technical-economic analyses can reduce the marginal effort and cost of analysing extra geometries to nearly zero.

This example illustrates that it is very important to formulate the requirements in a well-thought manner if the purpose is to arrive at economically comparable performance levels for all individual projects.

NOTE 4 Most of the individual points form a narrow cloud, but not a precise line. A number of points hovers (much) above the majority cloud, which can be explained as follows. Most of these isolated points concern small apartments and studios. In the Belgian calculation method, it is assumed that the domestic hot water need does not descend below the consumption of a single person, even if the size of the dwelling unit becomes very small. It is deemed that this represents reasonably well a real use of such units. As a logical result, the primary energy use per floor area becomes quite large for very small units, which shows up in the graph.

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