TECHNICAL REPORT

ISO/TR 52016-2

First edition
2017-06

Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads —

Part 2: Explanation and justification of ISO 52016-1 and ISO 52017-1

Performance énergétiques des bâtiments — Besoins d'énergie pour le chauffage et le refroidissement, les températures intérieures et les chaleurs sensible et latentes —

Partie 2: Explication et justification pout ISO 52016-1 et ISO 52017-1

Reference number
ISO/TR 52016-2:2017(E)

Contents

Page

Foreword vi
Introduction vii
1 Scope 1
2 Normative references 1
3 Terms and definitions 1
4 Symbols, subscripts and abbreviations 2
4.1 Symbols 2
4.2 Subscripts 2
4.3 Abbreviations 3
5 Brief description of the method(s) and routing 3
5.1 Output of the method 3
5.1.1 Reference hourly method in ISO 52017-1 3
5.1.2 Hourly method in ISO 52016-1 3
5.1.3 Monthly method in ISO 52016-1 3
5.1.4 Overall and partial energy performance 4
5.2 General description of the methods in ISO 52016-1 and ISO 52017-1 4
5.2.1 Hourly calculation procedures in ISO 52016-1 and ISO 52017-1 4
5.2.2 The hourly method in ISO 52017-1 4
5.2.3 The hourly method in ISO 52016-1 5
5.2.4 Monthly calculation procedures in ISO 52016-1 7
5.2.5 Other differences between ISO 52016-1 and ISO 13790:2008 which it supersedes 7
5.2.6 Input data and assumptions for hourly and monthly method in ISO 52016-1 8
5.2.7 Choices between methods in ISO 52016-1 8
6 Calculation method in ISO 52016-1 8
6.1 Output data 8
6.1.1 General data on the assessed object and application 8
6.1.2 Calculated data 9
6.2 Calculation time intervals and calculation period 9
6.3 Input data 9
6.3.1 Source of data - General 9
6.3.2 Deviating subscripts 9
6.3.3 General data on the assessed object and application 9
6.3.4 Geometrical characteristics 10
6.3.5 Thermophysical parameters of the building and building elements 10
6.3.6 Loops between input and output variables 11
6.3.7 Operating and boundary conditions 11
6.3.8 Constants and physical data 12
6.3.9 Input data from Annex A (Annex B) 12
6.4 Zoning of the assessed object 12
6.4.1 General 12
6.4.2 Thermal zoning procedures 12
6.4.3 Size of the thermal zones 13
6.4.4 Heat exchange between thermal zones and service areas 13
6.4.5 Adjacent thermally unconditioned zones 14
6.4.6 Residential buildings or building units, adjustment for spatial average temperature 15
6.4.7 Thermally coupled or uncoupled zones 18
6.5 Hourly calculation procedures 19
6.5.1 Principle 19
6.5.2 Applicable time interval and calculation period 19
6.5.3 Assumptions and specific conditions 19

6.5.4 Calculation procedure 19
6.5.5 Calculation of (sensible) heating and cooling loads and temperatures 20
6.5.6 Overall energy balance of a thermal zone 21
6.5.7 Type of construction dependent properties of the nodes 25
6.5.8 Thermal transmission properties 25
6.5.9 Temperature of adjacent thermally unconditioned zone 28
6.5.10 Ventilation heat transfer coefficient, supply temperature and moisture content 28
6.5.11 Thermal capacity of the internal environment of the thermal zone 29
6.5.12 Internal heat gains 29
6.5.13 Solar gains 29
6.5.14 Moisture content and latent heat load 29
6.5.15 Calculation of key monthly data from hourly output 30
6.6 Monthly calculation procedures 30
6.6.1 Principle 30
6.6.2 Applicable time interval and calculation period 30
6.6.3 Assumptions 31
6.6.4 Energy need for space heating and cooling 31
6.6.5 Heat transfer by transmission 32
6.6.6 Heat transfer by ventilation 35
6.6.7 Internal heat gains 35
6.6.8 Solar heat gains 35
6.6.9 Internal effective heat capacity of a zone 35
6.6.10 Utilization factors 36
6.6.11 Calculation temperature and intermittency modes 37
6.6.12 Corrections for intermittency 38
6.6.13 Overheating indicator 46
6.6.14 Length of the heating and cooling season for operation of season-length-dependent provisions 47
6.6.15 Humidification and dehumidification 47

7 Quality control in ISO 52016-1 48
7.1 Calculation report 48
7.2 Hourly method: verification cases 48
7.2.1 Choice for BESTEST cases 48
7.2.2 Description of the verification test cases 49
7.2.3 Results of the verification test cases 49
7.2.4 Comparison with available BESTEST results of other programs 49
7.2.5 Limited scope 49
7.2.6 Specific deviations allowed 49
7.2.7 Availability of the data file with hourly values 50
7.2.8 More details on description of the verification test cases 50
7.2.9 Results of comparison with “reference” programs 50
7.2.10 Peak hourly loads 51
7.3 Hourly method: validation in case of specific alternative calculation procedures 52
7.4 Specific validation cases 52
7.4.1 Heat transfer through ground floor 52
7.4.2 Solar shading 52

8 Compliance check in ISO 52016-1 52

9 Worked out examples on ISO 52016-1 53
9.1 Example 1 53
9.1.1 Description 53
9.1.2 Description of construction elements of envelope 53
9.1.3 Calculation details 59
9.1.4 Remarks and comments 59
9.2 Example 2 59
9.2.1 Description 59
9.2.2 Description of construction elements of envelope 60
9.2.3 Other data 62

9.2.4 Calculation details ... 62
9.2.5 Remarks and comments ... 62

10 Validation of the calculation procedures ... 62

Annex A (informative) **ISO 52016-1: Input and method selection data sheet — Template ... 63**

Annex B (informative) **ISO 52016-1: Input and method selection data sheet — Default choices ... 64**

Annex C (informative) **ISO 52016-1: Regional references in line with ISO Global relevance policy ... 67**

Annex D (informative) **ISO 52016-1: Multi-zone calculation with thermal coupling between zones ... 68**

Annex E (informative) **ISO 52016-1: Heat transfer and solar heat gains of windows and special elements ... 69**

Annex F (informative) **ISO 52016-1: Calculation of solar shading reduction factors ... 78**

Annex G (informative) **ISO 52016-1: Dynamic transparent building elements ... 89**

Annex H (informative) **Rationale behind reorganization of suite of standards ... 90**

Annex I (informative) **Discussion on the hourly versus the monthly calculation methods in ISO 52016-1 ... 95**

Annex J (informative) **Accuracy of the methods in ISO 52016-1 ... 104**

Annex K (informative) **Explanation and derivation of monthly utilization factors ... 110**

Annex L (informative) **Calculation examples ... 120**

Bibliography ... 126

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 the 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*, Subcommittee SC 2, *Calculation methods*, in cooperation 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 52016 series can be found on the ISO website.

Introduction

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* [1];

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* [2].

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 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 [3].

One of the main purposes of the revision of the EPB-standards is 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.

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 [2]):

— 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 [34] that laid the foundation for the preparation of the set of EPB standards.

This document

This document accompanies ISO 52016-1 and ISO 52017-1, which form part of a set of standards related to the evaluation of the energy performance of buildings (EPB).

The role and the positioning of the accompanying standards in the set of EPB standards is defined in the Introduction to the standards.

Brief articles on the subject can be found in [50] to [51].

Accompanying spreadsheets

An extensive spreadsheet was produced on ISO 52016-1, covering both the hourly and the monthly calculation method. Examples of the calculation sheet can be found in this document. This spreadsheet (including possible updated version) is available at www.epb.center.

No spreadsheet was produced on ISO 52017-1, because this EPB standard (with reference hourly thermal balance calculation procedures) is not directly used for calculations.

History of this Technical Report and the accompanying standards

The first series of standards on thermal and hygrothermal properties of building components and elements were prepared by ISO Technical Committee 163 in the 1980s, as a result of growing global concern on future fuel shortages and inadequate health and comfort levels in buildings. During the following decades these first standards were revised and new standards were added, to cope with new developments and additional needs. From the 1990s on, many of these standards were developed in close collaboration with CEN (see further on).

As part of the Mandate 343 of the EC to CEN to support the EPBD (2003)[26], the series of standards were scrutinized to see which changes would be needed for the purpose of supporting the EPBD [25]. This resulted in new versions of a number of standards, most of them published in 2007. The standards were further revised in the 2010s as part of Mandate 480 of the EC to CEN [28], to support the EPBD recast [29].

More extensive background information and history of the set of EPB standards is given in the Introduction to ISO/TR 52000-2[4], the Technical Report accompanying the overarching EPB standard and in recent ISO papers ([47],[48],[49]).

Application area of ISO 52016-1**:**

ISO 52016-1 presents a coherent set of calculation methods at different levels of detail, for the (sensible) energy needs for the space heating and cooling and (latent) energy needs (de-)humidification of a building and/or internal temperatures and heating and/or cooling loads.

The effect of specific system properties can also be taken into account, such as the maximum heating or cooling power, and the impact of specific system control provisions. This leads to **system-specific energy loads and needs**, in addition to the **basic energy loads and needs**.

ISO 52016-1 contains both hourly and monthly calculation procedures. These are closely linked: they use as much as possible the same input data and assumptions. And the hourly method produces as additional output the key monthly quantities needed to generate parameters for the monthly calculation method. This means that a number of (nationally) representative cases can be run with the hourly method and from the key monthly quantities the monthly correlation factors can be derived

ISO 52016-1 has been developed for buildings that are, or are assumed to be, heated and/or cooled for the thermal comfort of people, but can be used for other types of building or other types of use (e.g. industrial, agricultural, swimming pool), as long as appropriate input data are chosen and the impact of special physical conditions on the accuracy is taken into consideration.

NOTE 1 For instance, it can be used when a special model is needed but is missing.

Depending on the purpose of the calculation, it can be decided nationally to provide specific calculation rules for thermal zones that are dominated by process heat (e.g. indoor swimming pool, computer/server room or kitchen in a restaurant).

NOTE 2 For instance, in the case of a building energy certificate and/or building permit, e.g. by ignoring the process heat or using default process heat for certain processes (e.g. shops: freezers, lighting in shop window).

Design heating and cooling load

Upon request of CEN/TC 156, the method to calculate the design heating and cooling and latent heat load from prEN 16798-11:2015[21], prepared by CEN/TC 156, has been integrated in ISO 52016-1.

ISO 52016-1 includes specification of the method and the boundary conditions for the calculation of the design heating and cooling load, including latent load, as a basis for the dimensioning of equipment on zone level and on central level for cooling and dehumidification. It specifies also the methods and conditions for the calculation of the humidification load.

The method given for the design heat load is intended especially for the cases where the cooling load calculation needs to be done (for instance when cooling is necessary) and/or an hourly calculation is used for the energy needs calculation. The principle idea is that there is only one method needed for load and energy calculations for heating and cooling in case of an hourly calculation interval.

A simplified steady state calculation method for the design heat load is given in EN 12831-1[22].

Link between the two standards, ISO 52017-1 and ISO 52016-1

In short, ISO 52017-1 contains a generic (reference) hourly calculation method for building (zone). This method is based on and replaces that in ISO 13791. This document contains no specific assumptions, boundary conditions, specific simplifications or input data that are not needed to apply the generic calculation method. Compared with ISO 13791, the heat flows describing the energy needs for heating and cooling are added to increase the application range. This document does not include validation cases (unlike ISO 13791). For validation, specific assumptions and input data would need to be given that only apply to the validation cases. To keep a clear distinction between the generic method and a specific application, verification and validation cases are adopted in ISO 52016-1.

ISO 52016-1 replaces the information in ISO 13790:2008[5]. It contains a (new) hourly calculation method and a monthly calculation method. The hourly calculation method is a specific application of the generic method provided in ISO 52017-1. ISO 52016-1 further contains specific boundary conditions, specific simplifications and input data for the application: calculation of energy needs for heating and cooling. Amended simplifications and input data are provided for the application to calculate the design heating and design cooling load and (e.g. summer) internal temperatures.

In this way the generic calculation method (ISO 52017-1) is clearly separated from the specific application with all specific assumptions, simplifications and specific input data (ISO 52016-1). Due to these changes, ISO 52016-1 together with ISO 52017-1 also replace ISO 13792.

The hourly method in ISO 52016-1 produces as additional output the key parameters needed to generate parameters for the monthly calculation method. This means that a number of (nationally) representative cases can be run with the hourly method and from the output, the key monthly parameters for the different cases, the monthly correlation factors can be derived.

See flowchart in Figure 1.

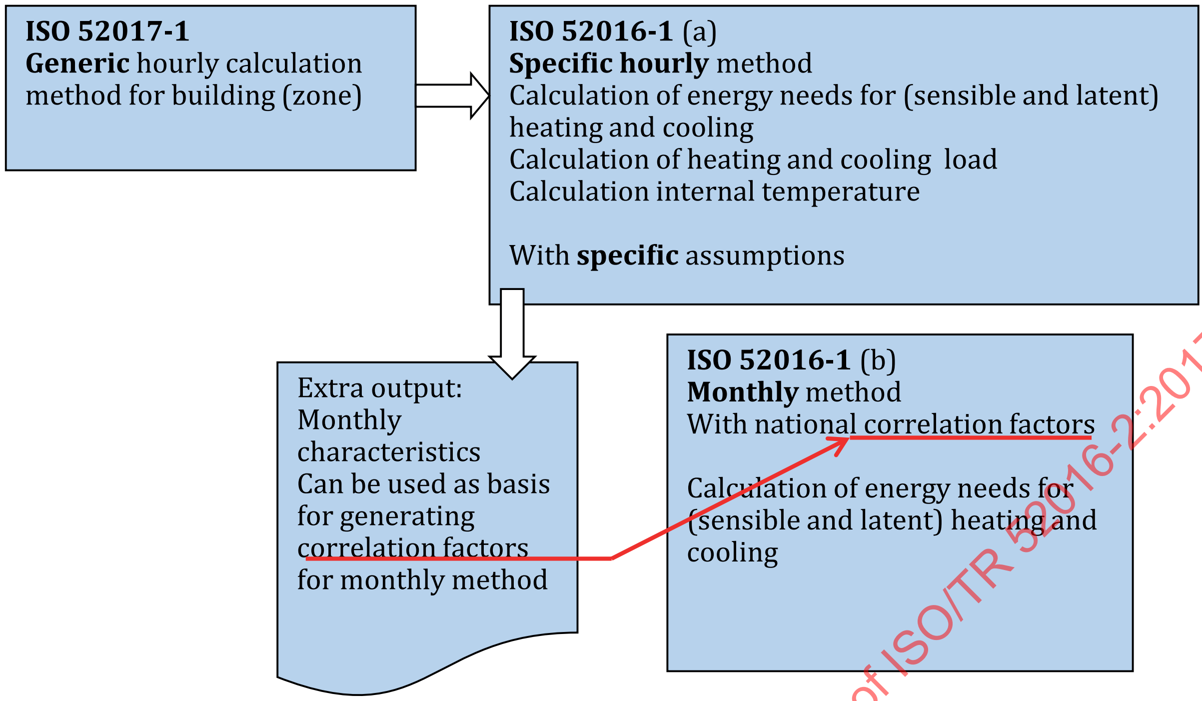


Figure 1 — Relationship between ISO 52016-1 and ISO 52017-1

Input-output relations between the two standards and other standards of the set of EPB standards

As explained above, ISO 52017-1 plays a role as a reference calculation method. For instance as reference method for ISO 52016-1.

For the input-output relations with the other EN and ISO standards in the set of EPB standards, only ISO 52016-1 is relevant.

There are many inputs from and many interactions with many other EPB standards. More details are given in the core of this document.

See flowchart in Figure 2.

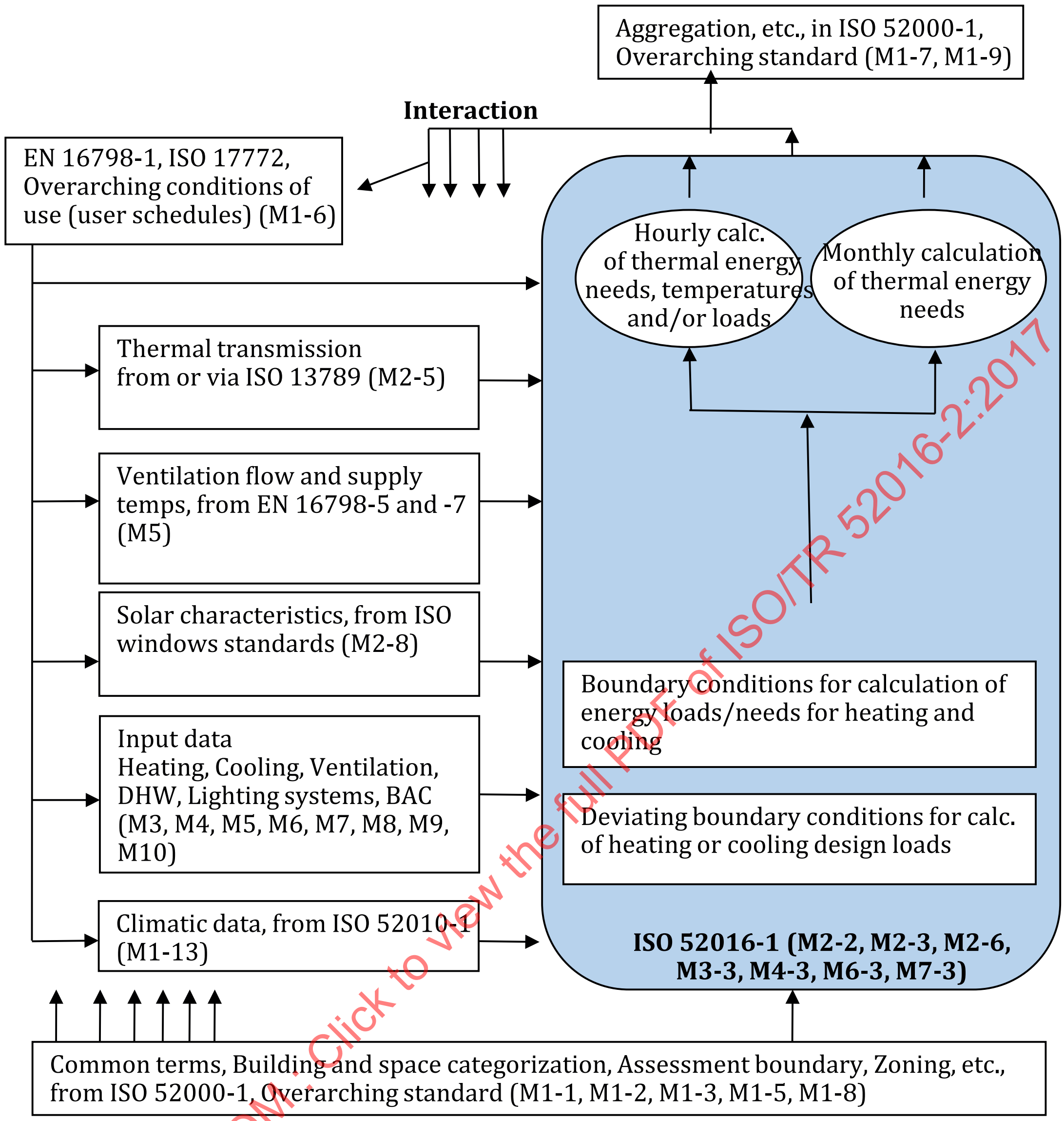


Figure 2 — Relationship between ISO 52016-1 and other EPB standards

NOTE 3 The list of referenced standards can be found in ISO 52016-1:2017, Table B.1.

Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads —

Part 2: Explanation and justification of ISO 52016-1 and ISO 52017-1

1 Scope

This document contains information to support the correct understanding and use of ISO 52016-1 and ISO 52017-1.

These documents give calculation methods for the assessment of:

— the (sensible and latent) energy load and need for heating and cooling, based on hourly calculations;

— the (sensible and latent) energy need for heating and cooling, based on monthly calculations (ISO 52016-1);

— the internal temperature, based on hourly calculations; and

— the design (sensible and latent) heating and cooling load, based on hourly calculations.

This document does not contain any normative provisions.

NOTE A description of the rationale behind the reorganization of the cluster of strongly related and partly overlapping ISO and CEN standards is given in Annex H.

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, in all EPB standards, for normative references to other EPB standards is given in ISO/TR 52000-2[4].

ISO 52016-1:2017, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures*

ISO 52017-1, *Energy performance of buildings — Sensible and latent heat loads and internal temperatures — Part 1: Generic calculation procedures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 52016-1 and ISO 52017-1 apply.

This clause provides an explanation of some of the terms and definitions given in ISO 52016-1:2017, Clause 3 and ISO 52017-1: 2017, Clause 3.

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

NOTE 1 Explanations on the terms and definitions that are copied from ISO 52000-1 are given in ISO/TR 52000-2. For instance on the difference between useful floor area and reference floor area. But also, more general explanations, on the difference between a definition of a term (given in Clause 3) and a specification of a term (procedure to assess the term).

NOTE 2 For terms that are sensitive to national or regional policy, building tradition or legal context, the EPB standards contain a definition, but leave the specification to be provided at national or regional level, if possible using Annex A (normative template) and Annex B (informative default choice).

NOTE 3 The term “load” is used in (sensible) heating or cooling load, latent heating or cooling load and humidification or dehumidification moisture load. It is defined, for hourly calculations, as the hourly mean value of the heat or mass flow rate supplied to or extracted from the internal environment to maintain the intended space temperature or moisture conditions. The unit is Watt (J/s, for heat) or kg (for moisture; sometimes more specifically called kg_{H2O}/s). See 6.5.14 for an explanation of the calculation of the moisture load versus latent heat load for (de-)humidification in the application of ISO 52016-1. The load under design conditions, conditions that are assumed for the design (sizing) of the system, is called “design load”.

NOTE 4 The term “power” is used for the heat flow rate that is available from the system to cover the load. If the power is insufficient to cover the load, the system is called “undersized” and the operative temperature or air moisture level in the internal environment exceeds the limit of the set-point in question.

NOTE 5 The term “need” is used for the heat to be delivered to, or extracted from the internal environment to maintain the intended space temperature or moisture conditions during a given period of time. This period is typically a month or a year. The unit is kWh (for heat) or kg_{H2O} (for moisture). See also 6.5.3 on the distinction between “basic need” versus “system specific need” calculations.

4 Symbols, subscripts and abbreviations

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52016-1 and ISO 52017-1 and the following apply.

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

Symbol	Quantity	Unit
ω	ratio of the total solar radiation	-

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52016-1 and ISO 52017-1 and the following apply.

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

Subscript	Term	Subscript	Term
al	air layer	sw	solar wall
hem	hemispherical	t	transparent element
ref	reflected	te	external thermal transmittance

NOTE ISO 52016-1 needs input data from many technology fields. In the exceptional cases that subscripts in ISO 52016-1 are different from subscripts in other EPB standards that produce output needed as input to ISO 52016-1, these differences are reported in a special column in the tables with the overview of input data in 6.3. This can occur when the source documents use subscripts that are crucial for that specific technology field, but conflict with subscripts that are crucial for another specific technology field.

EXAMPLE Subscript g for glazing and for ground.

4.3 Abbreviations

For the purposes of this document, the abbreviations given in ISO 52016-1 and ISO 52017-1 apply.

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

5 Brief description of the method(s) and routing

5.1 Output of the method

5.1.1 Reference hourly method in ISO 52017-1

ISO 52017-1 is a generic reference hourly calculation method to calculate the thermal balance in a building or building zone. The main output quantities are the indoor air and indoor mean radiant temperature and (derived from these two) the operative temperature. The energy need for heating or cooling can also be produced as output, at given heating and/or cooling set points for the operative temperature. However, the actual conditions and temperature control specifications depend on the application. ISO 52016-1 contains such a specific hourly calculation method.

ISO 52017-1 also contains a moisture balance formula to calculate the moisture balance in a building or building zone. The main output quantities are the moisture content of the internal air, the moisture load and the latent energy load and need. Again in a generic way, because the actual moisture and latent heat load depends on the specific application. This is covered in ISO 52016-1.

5.1.2 Hourly method in ISO 52016-1

ISO 52016-1 contains a specific hourly method to calculate the energy loads and needs for heating and cooling and the hourly indoor temperature (air, mean radiant and operative). It also contains a specific hourly method to calculate the moisture and latent energy loads and needs for humidification and dehumidification and the hourly indoor air moisture content (humidity). The assumptions and simplifications have been chosen in such a way that sufficient accuracy is obtained (e.g. in relation to the reliability of input data and boundary conditions), with a minimum of required input data. The input data to be gathered by the user of the calculation procedures is equal or equivalent to the input data for the simplified monthly calculation method.

5.1.3 Monthly method in ISO 52016-1

ISO 52016-1 contains also a specific monthly method to calculate the (monthly) energy needs for heating and cooling, plus a specific simple monthly method to calculate the (monthly) energy needs for (de-)humidification.

5.1.4 Overall and partial energy performance

5.1.4.1 Overall energy performance

An **undersized system** (or the extreme: an **absent system**) has by definition a negative impact on the indoor conditions: a too low or too high temperature and/or moisture level, compared to the same buildings with sufficient system size.

The undersized or absent system leads to a lower energy use and thus to a better energy performance compared to the same buildings with sufficient system size. This goes at the cost of not meeting the assumed standard conditions of use.

If this energetic benefit of the undersized or absent system is rewarded in the overall energy performance indicator and/or energy performance rating (ISO 52003-1[10]), there is no level playing field.

Consequently, the deficiency in meeting the standard conditions of use is reported along with the reporting of the energy performance. Or it is avoided by e.g. assuming a **fictitious system** or **fictitious system size** in the calculations (see also the choices in ISO 52000-1 and explanation in ISO/TR 52000-2 on this subject).

The reporting can be linked to the classification of indoor environment conditions (M1-6: ISO 17772-1, EN 16798-1; see ISO 52016-1:2017, Table B.1)

ISO 52016-1 produces the hourly values of the internal temperature and moisture. Because the hourly values are "polluted" by intermittency (like night or weekend time temperature set-back), the output contains also the accumulated differences between the set-point and the actual temperature (or moisture) level, for different threshold values.

5.1.4.2 Partial energy performance

The output of ISO 52016-1 is usable as input for the way or ways to express the overall energy performance and energy performance requirements at building level, for instance for indicators at the level of "the energy needs for heating" and "the energy needs for cooling". This subject is covered in ISO 52018-1[14] and ISO 52018-2[15].

5.2 General description of the methods in ISO 52016-1 and ISO 52017-1

5.2.1 Hourly calculation procedures in ISO 52016-1 and ISO 52017-1

ISO ISO 52017-1 is a generic reference hourly calculation method to calculate the thermal balance in a building or building zone.

ISO 52016-1 contains a specific hourly method to calculate the hourly energy loads and needs for heating and cooling and/or the indoor temperatures.

ISO 52016-1 contains also a specific monthly method to calculate the energy needs for heating and cooling.

5.2.2 The hourly method in ISO 52017-1

ISO 52017-1 is a generic reference hourly calculation method to calculate the thermal balance in a building or building zone. The main output quantities are the indoor air and indoor mean radiant temperature and (derived from these two) the operative temperature.

In case of heating or cooling needs the calculation can be carried out in such a way that the energy need for heating or cooling is the output, at given heating and/or cooling set points for the operative temperature. The required solution technique for this calculation mode is however not provided in the generic calculation method, because the choice of solution technique depends on the application (overall required accuracy, available input data, assumed control options, etc.). This is covered in ISO 52016-1.

ISO 52017-1 also contains a moisture balance formula, adopted from ISO 13791:2012, (informative) Annex K[6], but converted to more generic (normative) formulae. For instance, this made it possible to include the term absorption or desorption in materials in the moisture balance formulae, without specifying how these are obtained; such a specification is left to the standards aiming at specific applications (e.g. ISO 52016-1). The step from moisture balance to latent energy load and need is also provided, but again in a generic way, because the actual latent heat load depends on the specific application. This is covered in ISO 52016-1.

5.2.3 The hourly method in ISO 52016-1

The main purpose of the hourly calculation of the energy needs for heating and cooling, compared to the simple monthly method, is to have a more robust, transparent, easier and reliable treatment of dynamic interactions, due to direct use of hourly patterns of e.g. weather and operation. It is not the prime aim to increase the overall accuracy of the method, but only the accuracy of specific elements and the overall transparency of the method.

This is explained in more detail in Annex I.

The hourly method in ISO 52016-1 is a revised, more advanced method compared to the simplified hourly, three node (5RC1) method given in ISO 13790[5]. The main difference is that the building elements are not aggregated to a few lumped parameters, but kept separate in the model. ISO 52016-1 uses a (slightly simplified) thermal model for each building element separately. This is illustrated in Figure 3.

This leads to a number of advantages, in particular that the properties of each building element remain individually known, instead of being aggregated to only two thermal resistances, with as consequence, for example:

— there is no worry about how to combine e.g. the heat flow through the roof and through the ground floor, with their very different environment conditions (ground temperature and ground inertia, solar radiation on the roof);

— the thermal mass of the building or building zone can be specified per building element and there is no need for an arbitrary lumping into one overall thermal capacity for the building or building zone;

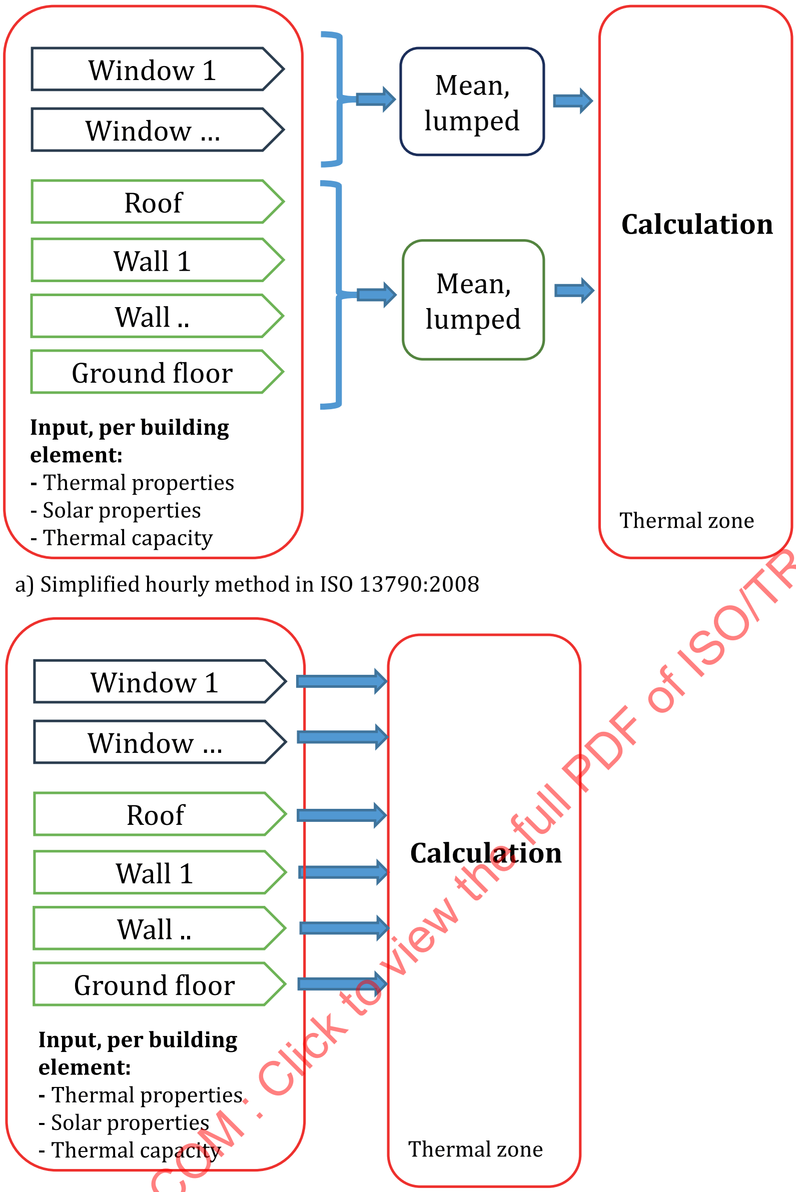
— the mean indoor surface temperature (mean radiant temperature) can be clearly identified and kept distinct from the indoor air temperature; and

— at the same time, the input data to be supplied by the user are (still) the same as for the monthly method.

These advantages respond to the recommendations to make the method better suited to deal with passive solar energy and other techniques (CENSE, [34], [35]).

Only the standard writers will have to introduce extra data: hourly operation schedules (EPB module M1-6) and weather data (EPB module M1-13).

On the other hand, the standard writers do not need to prepare tables with pre-calculated factors (e.g. on operation of blinds, effect of solar shading, etc.) as for the monthly method. For the preparation of such tables, hourly operation schedules and weather data are specified anyway.



a) Simplified hourly method in ISO 13790:2008

b) Improved hourly method (and similar for monthly method) in ISO 52016-1

Figure 3 — Improved hourly method in ISO 52016-1 (b) compared to simplified method in ISO 13790:2008 (a)

The main goal of the hourly calculation method compared to the monthly method is to be able to take into account the influence of hourly and daily variations in weather, operation (solar blinds, thermostats, heating and cooling needs, occupation, heat accumulation, etc.) and their dynamic interactions for heating and cooling. This limited goal enables to avoid the need for extra input to be supplied by the user compared to the monthly calculation method (with national/regional options for slightly more detailed data).

The hourly climatic data are given in ISO 52010-1[12] and the hourly and daily patterns of the conditions of use (operating schedules) are given in the relevant other EPB standards.

The drawback is, that due to the much higher number of nodes a robust numerical solution method is required (software). But, as the spreadsheet accompanying ISO 52016-1 shows, only the solving of the matrix needs to be done by programming (macro), the rest of the calculation can still be done in a spreadsheet, at least for demonstration. The actual use of the standard will normally be done with the aid of a real software tool, which can also include the calculation procedures of the other EPB standards.

The formulae are solved as a matrix. This is no new feature in EPB related standards: it is described in, for example, ISO 13791 and related documents. Solving the matrix can be compared with the technique of widely used thermal bridge calculations, e.g. cf. ISO 10211 (see ISO 52016-1:2017, Table B.1).

Annex I provided a more detailed introduction of the features of the improved method, compared to the simple hourly method in ISO 13790.

5.2.4 Monthly calculation procedures in ISO 52016-1

With the monthly calculation method in ISO 52016-1 the thermal balance of the building or building thermal zone is made up at a monthly time interval. The dynamic effects are taken into account by correction and adjustment factors.

The first versions of the method were developed in the eighties and early nineties of the previous century ([29], [30] and [31]). In the years to follow, several improvements were proposed ([32], [33]), which eventually lead to the development of ISO 13790, the first International Standard with a simple monthly calculation method for residential and non-residential buildings, to calculate both heating and cooling needs.

The correction and adjustment factors needed to take into account dynamic effects can be developed on the basis of series of calculations using the hourly calculation procedures.

Because conditions of use and assumptions (e.g. on the amount of ventilation) can be different during days with heating needs and days with cooling needs, two independent calculations are done for each month: first the calculation of the energy need for heating, using the assumed conditions for heating and secondly the calculation of the energy need for cooling, using the assumed conditions for cooling.

The monthly method is basically the same as the monthly method in ISO 13790. The main differences are:

— procedures to take into account the effect of intermittent heating and cooling;

— procedures to take into account the effect of thermally unconditioned zones adjacent to thermally conditioned zones;

— calculation procedures for sunspaces;

— estimation of (monthly mean) internal temperature in a thermally conditioned or thermally unconditioned zone (new); and

— estimation of the overheating.

5.2.5 Other differences between ISO 52016-1 and ISO 13790:2008 which it supersedes

Relevant editorial changes have been made based on the detailed technical rules for all EPB standards, including the application of a common template, moving all informative annexes, if still relevant, to this accompanying document and including the addition of a normative Annex A and an informative Annex B for choices in references, input data and options in calculation procedures.

— Integration in the set of EPB standards, as specified in the overarching EPB standard (ISO 52000-1), in particular:

  — removal of the conditions of use, which are now in a separate EPB standard at overarching level (EPB module M1-6);

  — expanding and modifying the rules for thermal zoning, in line with the overarching EPB standard ISO 52000-1;

  — removal of the procedures on assessment boundaries, now covered in the overarching EPB standard.

5.2.6 Input data and assumptions for hourly and monthly method in ISO 52016-1

The assumptions are described in ISO 52016-1:2017, 6.5.3 and 6.6.3.

In Annex I of this document more details can be found on the rationale behind or the effect of the assumptions. Both for the hourly and for the monthly method it is important to maintain consistency in the level of simplifications, in particular if it affects the amount of input data needed for the calculation (balanced accuracy).

In particular, concerning the usability of ISO 52016-1 for existing buildings, if gathering the full required input would be too labour-intensive for the purpose (relative to the cost-effectiveness of gathering the input), the focus is on the standards that provide the input data for ISO 52016-1.

5.2.7 Choices between methods in ISO 52016-1

5.2.7.1 Choice between hourly and monthly calculation method

The hourly and monthly method in ISO 52016-1 require the same input from the user, so limited access to input data is no reason to choose a simpler calculation tool (in casu: the monthly method).

Annex I contains a detailed discussion on the rationale for the use of the new hourly method (compared to the method in ISO 13790) and the advantages and disadvantages of the hourly method versus the monthly method.

5.2.7.2 Choice between basic or system specific load calculation

See discussion in 6.5.4 (hourly method) and 6.6.4 (monthly method).

The hourly calculation procedures in ISO 52016-1 are best suited to reveal the influence of the system on the energy loads and needs for heating and cooling: undersized heating or cooling power, recoverable heat losses, adjustment of the temperature set-points (value and time-schedule) due to imperfect system control and limitation of the heating or cooling season for the calculation defined by the operation time of the respective technical systems.

But also in the monthly calculation procedures some of the system specific influences can be taken into account: recoverable system heat losses, adjustment of the temperature set-points (value and time-schedule) due to imperfect system control and the (optional) lengths of the heating, cooling and (de-) humidification seasons defined by the operation time of the respective technical systems.

6 Calculation method in ISO 52016-1

6.1 Output data

6.1.1 General data on the assessed object and application

ISO 52016-1 inherits the types of objects, building or space categories, types of applications and types of assessment from ISO 52000-1, as explained in 6.3.2 (input). But also the standards using the output from ISO 52016-1 need to inherit this information.

Actually there is a distinction between:

— the **development of national or regional data sheet** according to the (normative) template of Annex A, replacing the informative default choices in Annex B. In this case, the list of types which should be inherited in each EPB standard, in Annex B; and

— the **actual use of the standard on a specific case**. This implies that they inherited from ISO 52000-1 the **actual** type of object, building or space category, type of application and type of assessment that has been identified for the specific case.

More explanations are given in ISO/TR 52000-2.

6.1.2 Calculated data

A summary of the output is already given in 5.1. The complete lists of output variables is given in ISO 52016-1, grouped per type.

6.2 Calculation time intervals and calculation period

No additional information beyond the accompanying document.

6.3 Input data

6.3.1 Source of data - General

IMPORTANT NOTICE The tabulated overview of input data does not imply that all these input data are needed for each calculation case

- **National or regional choices** can be made between **calculation methods** (via national data sheets, according to the normative template of Annex A, replacing the informative default choices in Annex B). Such national/regional choice will already rule out parts of the input data.
- ISO 52016-1 contains **input for different types of application** (calculation of energy loads and needs, design loads, internal temperature). For a single application only part of the input data is needed.
- **Many inputs** are outputs from other (EPB or product) standards. So it would be a mistake to count all inputs from all EPB standards as input data to be gathered by the user.
- **Many inputs** are national/regional choices (Annexes A and B).
- **Pareto's principle (the 80:20 rule)** can be projected to the calculation methods and the input data: a large part of the calculation procedures describes specific complicated cases. In 80 % of the cases only 20 % of the calculation procedures are needed. In 80 % of the cases only 20 % of the input data are needed.

6.3.2 Deviating subscripts

Some subscripts have been modified in ISO 52016-1 to be able to make distinctions, such as subscripts gl=glazing; gr=ground, instead of subscript g, distinctions that are not relevant in the source documents (standards) from where the data are obtained. Or because the source documents use symbols or subscripts that are crucial for that specific technology, but conflict with the common set of symbols and subscripts in the set of EPB standards. If there are such differences, these are listed in a special column in the tables with input data.

6.3.3 General data on the assessed object and application

This document contains choices between different methods, input data and/or references. Several of these choices depend on the type of object, type of building or space, type of application or type of assessment.

ISO 52016-1 inherits the types of objects, building or space categories, types of applications and types of assessment from ISO 52000-1.

<u>The type of object:</u>

EXAMPLE 1 Whole building, building unit, building part, or building element, building fabric or technical building system; new or existing building, as built or in the use phase; renovations of existing buildings, extensions to existing buildings; as specified in ISO 52000-1:2017, A.3 (normative template), with informative default types given in ISO 52000-1:2017, B.3.

The building category:

EXAMPLE 2 Residential, office, etc.; as specified in ISO 52000-1:2017, A.3 (normative template), with informative default categories given in ISO 52000-1:2017, B.3. The building category can have an impact on type of assessment, choices in method and input data. The building category usually also defines which energy services (with Identifier: EPB_LISTSERVICES_TYPE) is taken into account in the assessment of the energy performance; as specified in ISO 52000-1:2017, A.3 (normative template), with informative default types given in ISO 52000-1:2017, B.3.

The space category or categories:

EXAMPLE 3 Residential living space, kitchen, bed room, study, bath room or toilet; office space, meeting or seminar space, etc.; as specified in ISO 52000-1:2017, A.3 (normative template), with informative default categories given in ISO 52000-1:2017, B.3. The categorization of spaces defines the conditions of use for the energy performance assessment (calculation or measurement). The conditions of use can have an impact on which services are to be included in the assessment.

The type of application:

EXAMPLE 4 To check compliance with energy performance requirements, energy certification, to obtain building permit, to obtain permit to use, energy audit (tailored), energy performance inspection; as specified in ISO 52000-1:2017, A.3 (normative template), with informative default types given in ISO 52000-1:2017, B.3. The type of application can have an impact on choices in method and input data.

The type of assessment:

EXAMPLE 5 Calculated, design, calculated, as built, calculated, tailored, measured actual, measured standard (corrected for climate and use); as specified in ISO 52000-1:2017, A.3 (normative template), with informative default types given in ISO 52000-1:2017, B.3.

Consequently the complete list of identifiers from ISO 52000-1:2017, Tables A.2 to A.7 (normative template, with informative default choices in Tables B.2 to B.7) [3] are taken into account and respected in this document when there are choices based on type of object, type of building or space, type of application or type of assessment.

These lists are specified in national data sheets, so in the normative text a term as for instance “for existing buildings” is avoided as criterion for a choice, because it is an ambiguous term. For instance, at national level the following distinction can have been made in the national data sheet for ISO 52000-1 (see ISO 52000-1:2017, B.2):

— existing building as built (without long term use data);

— existing building after renovation (without long term use data);

— existing building extension (without long term use data); and

— existing building in use (with long term use data).

So in that case a tabulated choice in Annexes A and B is needed. This can be recognized in many tables in Annexes A and B, which give the possibility to add columns for different applications.

6.3.4 Geometrical characteristics

No additional information beyond the accompanying document.

6.3.5 Thermophysical parameters of the building and building elements

Most of the input parameters of ISO 52016-1 are obtained from other standards, mainly from module M1-6, M1-13, M2-5, M2-8 and M5-2. The justification of these input parameters is given in the Technical Reports belonging to these modules. In this clause only the justification of input parameters specifically defined in ISO 52016-1 is included.

The hourly method does not require more input data from the building or from the building elements than the monthly method.

The main difference is, that for the monthly method many input data can be combined into an aggregated value. In particular the thermal transmission properties. For instance: the *U*-values and areas (*A*) of the external construction elements, together with the thermal bridge values (*Ψ* and L plus χ, or an overall value $_{\text{Htb}}$), can be aggregated to an overall heat transfer coefficient by transmission (H_{tr}). This aggregation can often be done in the standards on thermal transmission properties, because that kind of output can also be needed for other purposes.

On the other hand, there are situations where, also for the monthly calculation method, specific information is needed that is known only in the context of the "holistic" energy performance assessment. For instance: information on the zoning and in particular the choices made with respect to thermally unconditioned zones. Or the solar heat gains in a sunspace or atrium. Or the temperature and moisture content of a specific ventilation flow element. Or the recoverable heat losses (included in the internal heat gains) from a specific technical building system.

Therefore, most of the input data, for both the hourly and monthly method are gathered per individual item (building element, flow element, heat gain element, etc.). For the effort to acquire input data it does not make a difference if these data are gathered in the context of other EPB modules, or as part of ISO 52016-1. The big advantage is: transparency and similarity between the hourly and monthly method.

For some specific elements a "short cut" in the form of (e.g. default) aggregated values is enabled for existing buildings with little information on the construction details (e.g. on thermal bridges).

6.3.6 Loops between input and output variables

Some of the input data depend on the output data. For instance:

— the recoverable heat losses from the heating and cooling system depend on the heating and cooling loads;

— the temperature of the supply air from a heat recovery unit depends (among other things) on the actual air temperature in the thermal zone;

— the decision to by pass the ventilation heat recovery unit depends on the actual temperature in the thermal zone;

— required moisture content in mechanical ventilation supply air (in case of central (de-) humidification) depends on the moisture content of the thermal zone; and

— use of e.g. solar blinds and free cooling (input) on the basis of the internal conditions (output), etc.

This implies that either - for each time interval - a calculation is repeated, e.g. once, with updated input data; or that the output data from the previous time interval are used to calculate the input data for the next time interval. This second option is not applicable to the monthly calculation method. This second option is for the hourly calculation method the simplest solution, but it could lead to oscillations in the calculation.

EXAMPLE Time interval 1, output: The internal temperature exceeds a certain limit, while the outdoor air temperature is low. Time interval 2, input: Decision to open the windows for extra ventilation (free cooling). Time interval 2, output: Due to this extra ventilation the internal temperature drops below the upper limit. Time interval 3, input: The windows are closed (etc.).

NOTE See also the calculation routes described in ISO 52000-1 and the explanation in the accompanying ISO/TR 52000-2.

6.3.7 Operating and boundary conditions

No additional information beyond the accompanying document.

6.3.8 Constants and physical data

No additional information beyond the accompanying document.

6.3.9 Input data from Annex A (Annex B)

See Annex B for explanation and justification of some of the choices.

6.4 Zoning of the assessed object

6.4.1 General

In agreement with the framework given in ISO 52000-1, the specific criteria in ISO 52016-1 of each of the steps are unambiguous but also flexible: they leave a choice in Annex A (normative template) and Annex B (informative default criteria) for other criteria.

EXAMPLE Criteria specifically suited for a national or regional context.

As already explained in 6.3.2 of this document, the differentiation into space categories and thus the differentiation into conditions of use is done at national or regional level and depends on the national or regional legal context or policy. Therefore it can range from very simple to very complex, depending on the national or regional choices; see the choices in the tables of A.2 (normative template), with an informative default differentiation in the tables of ISO 52000-1:2017, B.2.

This can also have a strong impact on the thermal zoning. This emphasizes that it is important to ensure consistency in the national data sheets replacing Annex B of the set of EPB standards.

6.4.2 Thermal zoning procedures

The procedure for assessing the thermal zones are highly inspired by DIN 18599-1[23]. The main difference is that the rules in ISO 52016-1 are made more flexible and more generic.

More flexible: choices are provided at each step (Tables in Annex A and Annex B of the standard).

More generic: instead of e.g. a criterion of homogeneity of domestic hot water needs and lighting (because of the recoverable thermal losses and dissipated heat), there is a criterion of homogeneity of the internal heat gains as such.

Of course, for each criterion it is important that a detailed calculation can be avoided, otherwise the calculation would still be unnecessarily detailed. Therefore a rough estimation is sufficient. A more precise estimation would lead to a fake accuracy anyway, given the variety of assumptions related to the subdivision and heat exchange between thermal zones.

6.4.2.1 Zoning step 1 - Assessment of space categories

As mentioned above (6.3.2): the number of possible space categories depends on the nationally chosen list of space categories (ISO 52000-1) and the conditions of use associated to each space category (from the relevant standard in EPB module M1-6).

Zoning step 2 - Grouping according to space category

No additional information beyond the accompanying document.

6.4.2.2 Zoning step 3 - Grouping in case of large openings in between

This grouping also applies, for instance, to a thermally unconditioned sunspace: if there is a permanent opening with the thermally conditioned zone, the sunspace is to be considered as part of the thermally conditioned zone. In that case, the external envelope of the sunspace is part of the boundary of the thermal zone. This is in line with the procedures for the assessment of the thermal envelope in ISO 52000-1.

6.4.2.3 Zoning step 4 - Split to have same combination of services

If the principle of “assumed system” according to ISO 52000-1:2017, Tables A.19 and B.19 is followed for both heating and cooling, then this step is redundant, because in that case the services needed to fulfil the required conditions of use for the given space category are assumed to be present in any case.

6.4.2.4 Zoning step 5 - Further grouping according to similar thermal conditions of use

These two criteria are based on best expert’s guess.

6.4.2.5 Zoning step 6 - Split according to specific system or subsystem properties

This is provided in system standards.

6.4.2.6 Zoning step 7 - (Further) split to have sufficient homogeneity in thermal balance

The three criteria are based on best expert’s guess; e.g 4 W/m^2 internal gains; plus 0,20 × 150 W/m^2 solar gains would make 34.

It is important that this part of the zoning rules does not require detailed input per individual space, otherwise there would be less benefit from grouping spaces into a larger thermal zone. Therefore, the criteria are formulated in such a way that no detailed calculations are needed to decide whether or not a split is needed. The drawback is that the formulation is not “software proof”. This is not a problem, because the zoning is done before the actual calculation is done; or even before the actual gathering of detailed (e.g. building envelope) properties is done.

This need to split can for instance occur in case of large differences in glazing area in the façade(s) and/or large differences in solar shading provisions.

In some countries the thermal zone is split if e.g. only one part is a daylight section or if only one part is serviced by a DHW system. The reason is the effect on the internal heat gains. This is implicitly taken into account in the condition given here, but only if it is estimated to have a significant effect on the internal gains.

This can for instance occur in case of large differences in glazing area or orientation of the façades if not compensated by adequate solar shading provisions. But e.g. also in case of large differences in heat dissipated by artificial lighting or (less likely) domestic hot water system. See also Note 1.

6.4.2.7 Zoning step 8 - (Further) grouping of thermally unconditioned zones

No additional information beyond the accompanying document.

6.4.2.8 Zoning step 9 - Simplification in case of small thermal zones

No additional information beyond the accompanying document.

6.4.2.9 Zoning step 10 - Simplification in case of very small thermal zones

No additional information beyond the accompanying document.

6.4.3 Size of the thermal zones

No additional information beyond the accompanying document.

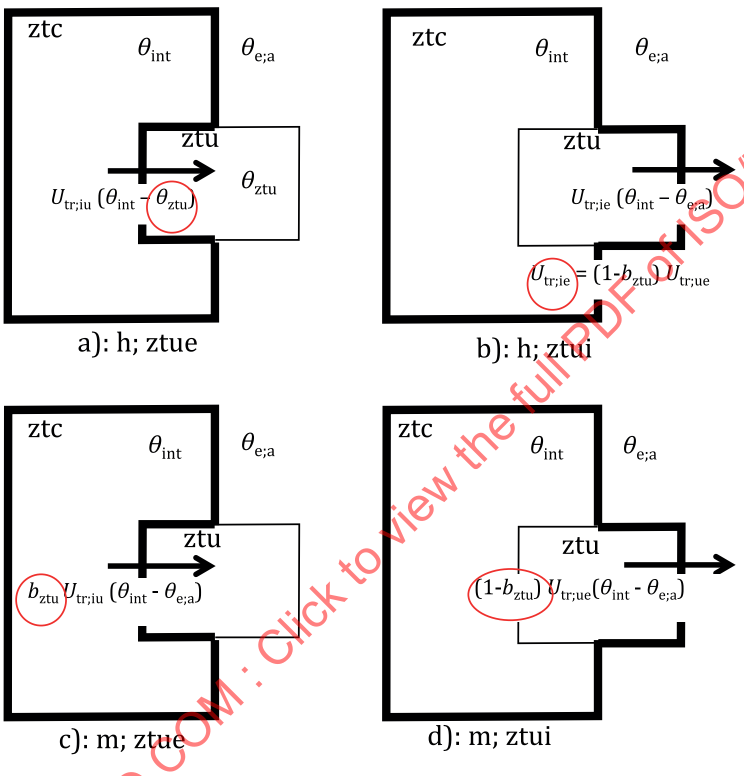
6.4.4 Heat exchange between thermal zones and service areas

If heat is exchanged between a thermal zone and a system related service area, the assignment rules given in ISO 52000-1:2017, 10.5, apply.

For instance, if recoverable system losses need to be taken into account in a thermal zone and the involved system related service area spans two or more thermal zone, or only a part of a thermal zone. Or, vice versa, if the indoor temperature or energy needs for heating and cooling from a thermal zone is needed as input for a service area. This is extensively explained in ISO/TR 52000-2.

6.4.5 Adjacent thermally unconditioned zones

The choice between the two types of thermally unconditioned zones is mainly practical: if it is easier to assess the thermal properties of the external partition, then the second type (internal unconditioned zone) can be preferred. However, this second type is not suited for spaces with high internal and solar gains, as explained further on.



Key

a) and c) External thermally unconditioned zone (ztue): internal construction of ztu is better known than external construction b) and d)

Internal thermally unconditioned zone (ztui): external construction of ztu is better known than internal construction a) and b): hourly method c) and d): monthly method

Figure 4 — External versus internal thermally unconditioned zones (illustration including formulae for thermal transmission as introduced in the next clauses)

The reason that type 2 (internal unconditioned zone) is not suitable for sunspaces or atria is, that the effect of the heat gains on the thermal balance in the thermal zone can be overestimated, despite the applied reduction factor (1-*b*), as shown further on. Type 2 is particularly suited for, for example, thermally unconditioned staircases that share more or less the external walls of the building with the thermally conditioned spaces, such as in a portico flat building.

An overview of the differences and similarities in treatment of heat transfer and heat gains in case of type 1 (external unconditioned zone) and type 2 (internal unconditioned zone), both for the hourly and the monthly calculation method is given in the following table:

Table 1 — Overview of the two types to deal with thermally unconditioned zones

Quantity	Hourly calculation procedures		Monthly calculation procedures	
	Approach	**Comments**	**Approach**	**Comments**
Type 1, External unconditioned zone (ztue):				
Transmission heat transfer through ZTU	External temperature is temperature of ZTU, instead of outdoor temperature	Temperature ZTU is calculated as function of adjustment factor *b* plus effect of gains	Transmission heat transfer is adjusted with adjustment factor *b*	
Ventilation heat transfer from ZTU	External temperature is temperature of ZTU, instead of outdoor temperature		Ventilation heat transfer is adjusted with adjustment factor *b*	
Gains inside ZTU	Included in temperature of ZTU (see above)	Optional: maximum to temperature of ZTU, as function of temperature of adjacent ZTC(s)) [a]	Gains inside ZTU are added to the gains in ZTC, but adjusted with (1-*b*)	Maximum to gains in heating mode [a]
Type 2, Internal unconditioned zone (ztui):				
Transmission heat transfer through ZTU	Thermal resistance of external partition is adjusted with 1/(1-*b*)		Transmission heat transfer through external partition is adjusted with (1-*b*)	
Ventilation heat transfer from ZTU	Ventilation heat transfer is adjusted with adjustment factor *b*		Ventilation heat transfer is adjusted with adjustment factor *b*	
Gains inside ZTU	Gains inside ZTU are added to the gains in ZTC, but adjusted with (1-*b*)	Maximum not needed because minor influence	Gains inside ZTU are added to the gains in ZTC, but adjusted with (1-*b*)	Maximum not needed because minor influence

[a] The maximum is introduced to avoid the need to calculate in full detail the thermal balance in the thermally unconditioned zone, including the use of measures to avoid excessive overheating by solar shading or extra ventilation.

For the hourly method the value is a compromise to avoid overestimation of gains for heating and underestimation of gains for cooling. For the monthly method it is a conservative choice, both for the heating and for the cooling mode.

ZTU: thermally unconditioned zone

ZTC: (adjacent) thermally conditioned zone(s)

6.4.5.1 In 6.4.5.4, concerning the default value for the contribution of ventilation in the heat transfer coefficient through the external partition

Due to air circulation from outside, through the external partition, back to outside, the ventilation rate through the external partition is often much larger than the ventilation rate through the internal partition. In particular if the external partition is thermally less insulated, it is probably also more air leaky.

6.4.6 Residential buildings or building units, adjustment for spatial average temperature

6.4.6.1 Simple method to adjust the set point temperature in residential buildings taking into account moderately versus fully conditioned spaces - Short description

For residential buildings where parts of the dwelling are predominantly thermally unconditioned (e.g. master and/or spare bedrooms, study, attic within the thermal envelope), the set-point temperature for heating and cooling that is based on the requirements of the living room (plus kitchen, etc.) is adjusted, if the dwelling is calculated as a single zone. The adjustment depends on the ratio between the overall heat transfer coefficient (transmission and ventilation) between these distinguished parts in the dwelling and the overall heat transfer coefficient (transmission and ventilation) between the building and external environment.

This leads to the formula given in ISO 52016-1:2017, 6.4.6.

The fixed values will lead to a rough approximation. A more refined approach is not justified because the actual variations of occupant behaviour in practice, certainly at individual space level, will be large and unpredictable and the required extra information on the properties of the internal constructions and internal air flow circulations is normally highly uncertain. The most important effect is that the trend is represented: more effect in badly insulated buildings than in highly insulated buildings. See also the worked example further on.

For cooling this is a conservative approach, justified by the fact that it is undesirable to allow high temperatures in the moderately conditioned spaces, while the than the heat transfer by transmission and ventilation. Moreover, the heat transfer coefficients can be variable, for instance due to night time ventilative cooling, the heat gains are often more important

6.4.6.2 Background

Residential buildings contain spaces that are used for inhabitants to live in, and other spaces. The other spaces can e.g. be unheated (unconditioned) spaces. The living spaces comprise living room, kitchen, bathroom, bedrooms, spaces for study and/or hobby and combinations of these.

The living room plus (depending on the national tradition or regulations) e.g. the kitchen and bathroom are assumed to be fully heated/conditioned ("**fully conditioned**"): the temperature set point for the calculation of the energy needs for heating and cooling is set to a level that provides adequate thermal comfort. At national or regional level a correction for night time temperature set back can be added plus the terms when and how energy use for heating and cooling are taken into account.

Some of the spaces, such as bedrooms, spaces for study and/or hobby and combinations of these are only heated/conditioned partially ("**moderately conditioned**"), depending on the occupation; for instance only a few days per week or a few hours per day heated/conditioned at high comfort level (same as living room) and for the other days often at a reduced comfort level.

The **unconditioned spaces** are taken into account in ISO 52016-1 by the adjustment factor b_{tr} and b_{ve}, for the adjusted temperature difference between the conditioned and unheated spaces compared to the indoor-outdoor temperature difference.

For taking into account the temperature difference between fully conditioned and moderately conditioned spaces, ISO 13790 does not provide a method, unless the building is partitioned into different zones, one for the fully conditioned, the other for the moderately conditioned spaces. Such partitioning is however not evident: is severely complicates the gathering of input data and it can be impossible (or against national/regional regulations) to assign a specific use to specific spaces. In the latter case only a certain (nationally set) percentage of the living spaces is assumed to be fully conditioned and the rest moderately conditioned.

To take into account the difference in fully and moderately conditioned living spaces, it is not sufficient to assume a reduced temperature set point. For instance: 20 °C for fully conditioned spaces leads to 18 °C as average indoor set point temperature for all conditioned spaces. This is because this reduction strongly depends on the spatial temperature levelling inside the building, which is a function of the ratio between the overall heat transfer coefficient between the fully conditioned and the moderately conditioned spaces and the overall heat transfer coefficient of the building envelope.

In other words: the moderately conditioned spaces will obtain some of the heat (cold) by transmission and ventilation from the fully conditioned spaces. This levelling of the internal temperature between the different spaces in the building will be much more significant in case of a highly insulated and airtight building envelope.

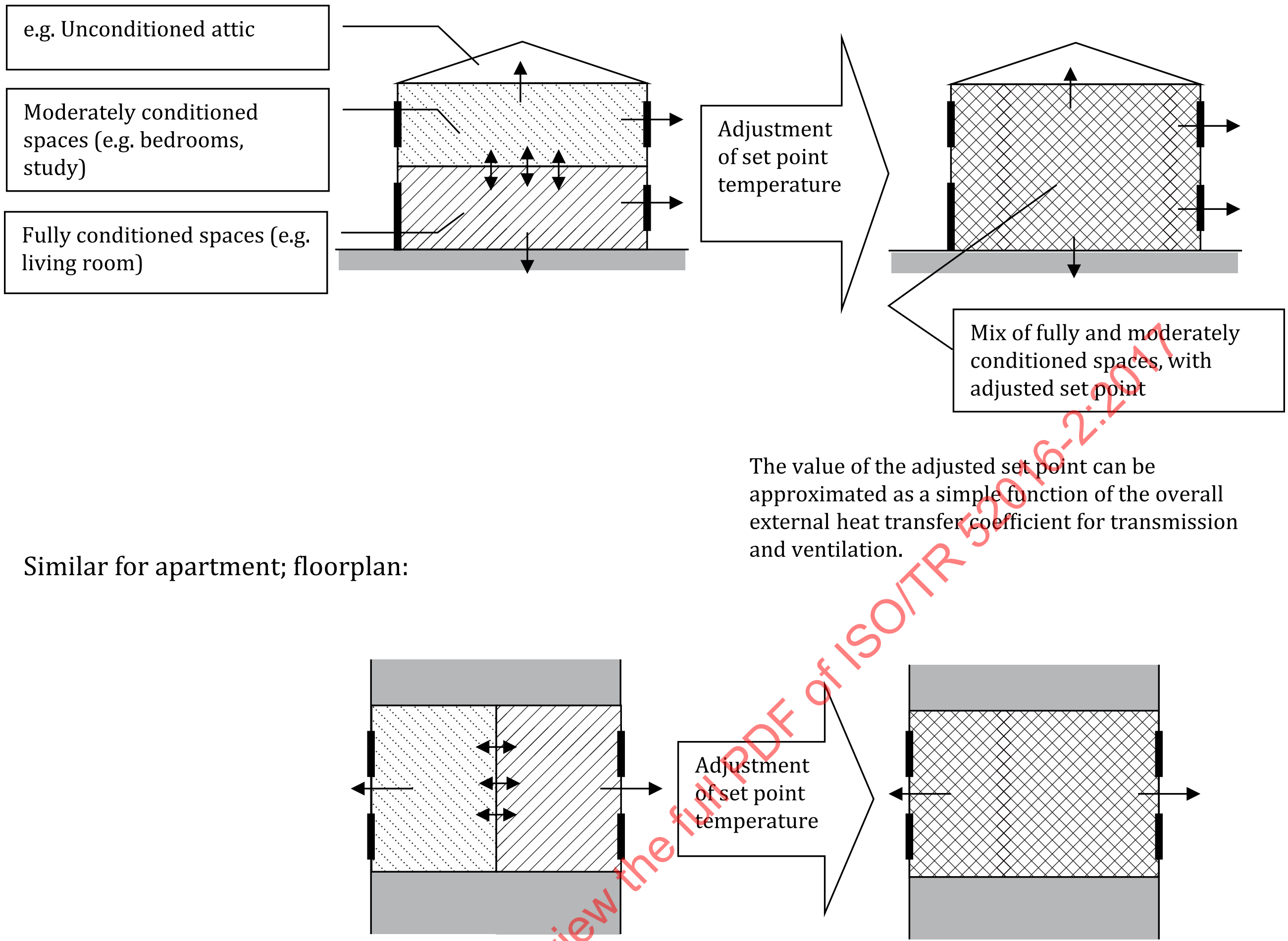


Figure 5 — Illustration of the adjustment explained in the text

This is one of the reasons why it makes sense to make a difference between the set point temperature of a “passive house” and an old uninsulated house.

Note that other reasons for a temperature difference between poorly and highly insulated buildings in general are (for heating, but similarly *mutatis mutandis* for cooling): are already taken into account in ISO 52016-1:

— Solar heat gains are more often a surplus in highly insulated building, leading to an increased indoor temperature. This effect is already taken into account in ISO 52016-1 by the gain utilization factor (monthly method) or by the hourly heat balance (hourly method).

— Air temperature in older buildings is often lower due to higher air leakages. This effect is already taken into account in ISO 52016-1 by recommending the use of the operative temperature as set point; in that case the lower air temperature is compensated by a higher radiation temperature.

— Older buildings are typically heated/conditioned at a reduced comfort level. If this effect is taken into account in the energy performance calculation it leads to a bonus for bad comfort. Therefore, the usual nationally/regionally determined assumption is that the calculation is to be done at equal thermal comfort level for the living spaces.

— Poorly insulated buildings have a lower time constant, so the effect of night time temperature set back is larger. This effect is already taken into account in ISO 52016-1 by the correction for intermittency (monthly method: a function of the time constant and other parameters) or by the hourly calculation (hourly method).

6.4.6.3 Solution

Introduction of a factor taking into account the variation in spatial temperature levelling for the conditioned spaces inside dwellings, as a function of the overall heat transfer coefficient of the building envelope.

The method is intended for use in case the fully conditioned spaces (such as living room, kitchen, etc.) and the moderately conditioned spaces (such as bedrooms, studies), for reasons explained above, are not calculated as separate calculation zones.

The result is a corrected average setpoint temperature that is a few degrees lower for old uninsulated dwellings than for e.g. passive solar houses.

6.4.6.4 Method

See ISO 52016-1. The formula is simply calculating the average temperature in the residential building, assuming two zones: zone 1 is kept at the set point temperature, zone 2 has a free floating temperature during part of the time. The temperature in zone 2 is the weighted average of the temperature of zone 1 and the outdoor temperature. The weighting depends on the ratio between the internal and external overall heat transfer coefficients.

The internal and solar gains are not taken into account, because these are taken into account by the gain utilization factor.

Night and/or day time temperature set back is not taken into account because it would introduce extra complexity which is not justified.

NOTE 1 But to be considered in later stage: to apply the correction also to the lower set point.

The fixed values will lead to a rough approximation. A more refined approach is not justified because the actual variations of occupant behaviour in practice, certainly at individual space level, will be large and unpredictable and the required extra information on the properties of the internal constructions and internal air flow circulations is normally highly uncertain. The most important effect is that the trend is represented: more effect in badly insulated buildings than in highly insulated buildings.

See also the worked example further on.

NOTE 2 $H_{e;H;spec}$ is in itself a function of the set point temperature (via $H_{tr;H}$ and $H_{ve;H}$ which are adjusted for the indoor-outdoor temperature difference) a calculation loop can be created, unless $H_{tr;H}$ and $H_{ve;H}$ are not dependent of the adjusted set point.

The same approach, mutatis mutandis, can be used for adjusting the cooling set point.

EXAMPLE Values for the fixed parameters: $H_{int;spec}$ = 2 W/(m²·K); $f_{mod;sp}$ = 0,5; $f_{mod;t}$ = 0,8. Conditions: $\theta_{e;m}$ = 5 °C; $\theta_{int;set;H}$ = 20 °C.

Table 2 — Example of adjustment for spatial average temperature in residential buildings

Type of residential building	Poorly insulated	Highly insulated	Passive house like
$H_{e;H;spec}$ (W/(m²·K))	2,0	0,8	0,4
$\theta_{int;set;H}$ (°C)	18,0	19,0	19,5

Conclusion: the correction is both simple and significant.

6.4.7 Thermally coupled or uncoupled zones

The calculations are done per so called "**thermal zone**", a concept that is introduced in ISO 52000-1[3]. It is up to national or regional choice to calculate different zones separately or thermally coupled. The main reasons for choosing for uncoupled zones is the lack of reliable input data on the heat exchange properties (thermal transmission, air circulation and ventilation) between zones plus the impact of variable user behaviour.

A multi-zone calculation with interactions between the zones requires significantly more and often arbitrary input data (on transmission properties and air flow direction and size). It can also lead to other technical and procedural complications that add uncertainties to the quality of the results, such as:

— possible constraints in the building regulations on the zoning rules (freedom of internal partitioning; and

— definitions of zoning in the case of combined use; e.g. a hospital generally also includes an office section, a restaurant section, etc.).

A further complication can be the involvement of different heating, cooling and ventilation systems for different zones, which adds to the complexity and arbitrariness of the input and modelling.

Therefore, the benefits of calculations with thermally coupled zones can be smaller than the drawbacks.

6.5 Hourly calculation procedures

6.5.1 Principle

No additional information beyond the accompanying document.

Extensive information is already given in 5.2.1.

6.5.2 Applicable time interval and calculation period

No additional information beyond the accompanying document.

6.5.3 Assumptions and specific conditions

This subclause in ISO 52016-1 shows that the same simplifications apply as in many full dynamic simulation methods. There are only a few additional simplification and most of these are inherited from other EPB standards.

A few simplifications have been introduced to ensure that the number of input data for the user is the same or similar to those for the monthly calculation procedures. These are:

— calculation of view factors between the internal facing surfaces of the construction elements. To avoid that the specific position of the construction is needed as input, these are simplified. However, the possibility for a more detailed approach is offered, as explained in ISO 52016-1:2017, 6.5.7.3.1;

— calculation of the dynamic heat transfer inside construction elements. To avoid that the specific composition of each layer of the construction is needed as input, these are simplified. However, the possibility for a more detailed approach is offered, as explained in ISO 52016-1:2017, 6.5.7.3.1;

— calculation of the variable solar transmittance of transparent elements (e.g. elements with Venetian blinds or other components with solar angle varying properties). To avoid that the solar (azimuth and altitude) angle dependent properties of the transparent elements is needed as input, a constant values is assumed.

6.5.4 Calculation procedure

6.5.4.1 On 6.5.4.1 Application - Calculation of the basic loads and needs and system specific loads and needs

See also 5.2.4 (choice between basic and system specific needs calculation) and compare 6.6.4 (monthly method).

6.5.4.2 Concerning the basic loads and needs calculation

This is the calculation of the loads and needs without the influence of a specific choice of technical building systems.

Excluded provisions are obtained from the relevant clauses of the standard under EPB module M2-4 (ISO 52018-1). This is not a trivial choice: if certain system related provisions (e.g. a high performance ventilation heat recovery unit) are ignored, the actual thermal balance can be far away from the real situation: the calculated heating season becomes much longer, the solar and internal heat gains are much better utilized than in reality, the effect of e.g. temperature set back is much larger than in reality and on the other hand the effects of solar shading provisions are much smaller. It is also not trivial to decide what a system component is. For instance, movable shading is typically not regarded as a technical building system component. But what about a mechanically controlled vent opening?

6.5.4.3 Concerning system specific calculation

In case of an **undersized or absent heating or cooling system**, a level playing field in the comparison with other buildings can only be maintained:

— if the report of the system specific energy use is accompanied by a **warning** that possibly the **standard conditions of use are not met** by the system, or

— if the system specific energy use is calculated with a properly dimensioned **fictitious** system, or

— if another kind of **penalty** is introduced.

This is related to the chosen principle of assumed or presence of systems. See ISO 52000-1 with more explanation in ISO/TR 52000-2.

The output of ISO 52016-1:2017 comprises the calculated monthly and annual amount of undersizing of the heating and cooling systems for different thresholds (see 6.5.15, key monthly data from hourly output).

6.5.5 Calculation of (sensible) heating and cooling loads and temperatures

For each hour and each zone the actual internal operative temperature and the actual heating or cooling load are calculated using a step-wise procedure. Illustration of the five situations that can occur:

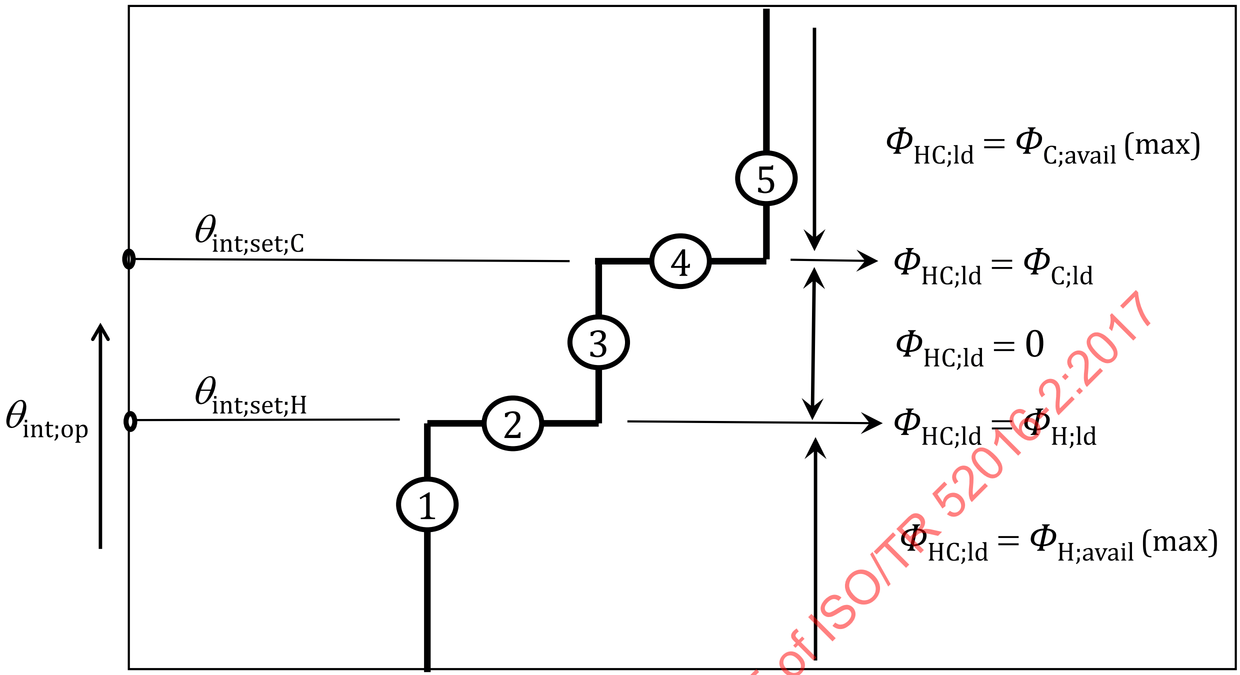
1) The thermal zone requires heating and the heating power is not sufficient to obtain the set-point. The heating need is limited to the maximum available heating power and the calculated internal temperature is lower than the heating set-point $\theta_{int;set;H}$. This usually happens in the boost period.

2) The thermal zone requires heating and the heating power is sufficient. The internal temperature is equal to $\theta_{int;set;H}$ and the calculated heating need is lower than its maximum value.

3) The thermal zone requires neither heating nor cooling (free floating conditions). No heating or cooling is applied, and the internal temperature is calculated.

4) The thermal zone requires cooling and the cooling power is sufficient. The internal temperature is equal to $\theta_{int;set;C}$ and the calculated cooling need is lower than its maximum value.

5) The thermal zone requires cooling and the cooling power is not sufficient. The cooling need is limited to the maximum available cooling power. The calculated internal temperature is higher than the cooling set-point $\theta_{int;set;C}$.



Key

Symbols	see text in ISO 52016-1
1-5	Thermal zone temperature behaviour, referring to the five possible situations

Figure 6 — Thermal zone temperature behaviour versus system behaviour

6.5.6 Overall energy balance of a thermal zone

6.5.6.1 Selected mathematical modelling

For the sake of reproducibility and transparency, ISO 52016-1 offers for the calculation of the hourly heating and cooling loads a fully described mathematical formulation in the form of a matrix of formulae per thermally conditioned zone. Specific details of the formulae are open for choice at national or regional level (Annexes A and B).

The formulae in ISO 52016-1:2017, 6.5.6, are in line with the generic calculation procedures in ISO 52017-1.

A finite difference approach has been chosen, in which each building element is subdivided into a finite number of parallel layers and in which the time-differential is approximated as a discrete time-interval.

In case of the standard assumptions, all the formulae involved are linear (or can be made linear). This means that there will be a square matrix of linear formulae that typically can be solved by standard mathematical techniques, e.g. the so called “Gauss-Jordan elimination through pivoting”.

6.5.6.2 Global explanation of the formulae used in the hourly method

6.5.6.2.1 Formula for a single RC-node

In the finite difference approach, each building element is subdivided into a finite number of parallel layers and the time-differential is approximated as a discrete time-interval in the following way, illustrated by one RC-node:

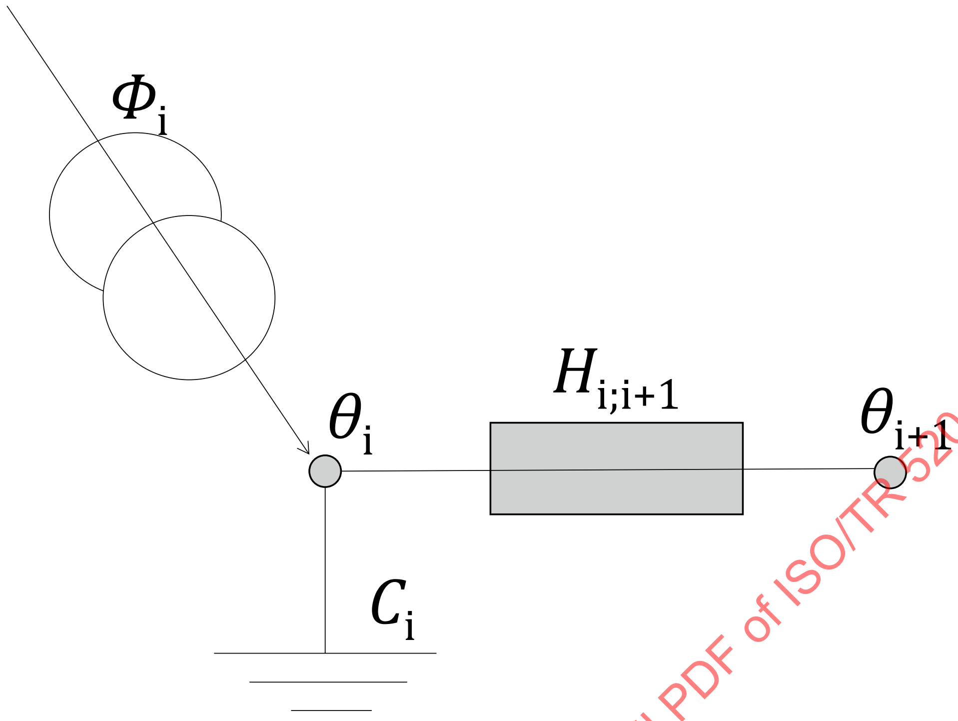


Figure 7 — Illustration of RC-model

The differential formula for the temperature as function of time is approximated as a finite difference: a temperature change per finite time step:

$$C_i \cdot \frac{d\vartheta_i}{dt} \approx \frac{C_i}{\Delta t} \cdot \left(\vartheta_{i;t} - \vartheta_{i;t-1}\right) \quad (1)$$

Similarly, the differential formula for the spatial temperature distribution is approximated by finite resistance elements.

This results in the following thermal balance formula for node *i* in time interval t:

$$\frac{C_i}{\Delta t} \cdot \left(\vartheta_{i;t} - \vartheta_{i;t-1}\right) = H_{i;i} \cdot \left(\vartheta_{i+1;t} - \vartheta_{i;t}\right) + \Phi_{i;t} \quad (2)$$

Unit: Watt

where

$\vartheta_{i;t}$ is the temperature of the node *i* at the given time interval (t), in °C;

$\vartheta_{i+1;t}$ is the temperature of the node *i* at the given time interval (t), in °C;

$\vartheta_{i;t-1}$ is the temperature of the node *i* at the previous time interval (t – Δt), in °C;

$H_{i;i}$ is the conductance between node *i* and node *i*+1, in W/K;

C_i The thermal capacity of the node *i*, J/(kg·K);

Δt is the time interval, in s;

$\Phi_{i;t}$ is the power injected to node *i* at time interval t, in W.

The conductance is the reciprocal of the thermal resistance ("R"). When dealing with planes as building elements: $H = A \;/\; R_c$, where R_c is the thermal resistance of the layer of the building element per m^2 of area and A is the area of the plane.

Note in Formula (2) that the quantity ($C_i \;/\; \Delta t$) is similar to a conductance, multiplied by a temperature difference, with the distinction that the temperature difference is not with another node at the same time step, but with the same node at the previous time interval. With Δt in seconds: $\kappa/\Delta t$ receives the unit W/(m^2·K): the same as the other coefficients.

6.5.6.2.2 Series of nodes

The formulae for the building elements in ISO 52016-1:2017, 6.5.6, consist of series of such layers:

Each building element is divided (discretized) into a number of parallel layers, separated by nodes: the internal (zone facing) surface node, the external surface node and nodes inside the building element.

EXAMPLE In case of four layers, the building element has five nodes: *pli*= 1 , 2, ..., 5.

The energy balance is set up for each node *pli*= 1 , 2, ..., pln of the building element *eli* . The balance formula for each building element is presented per square metre.

The power injected to a node can be, depending on the type of construction and the position of the layer: absorbed solar radiation, emitted long wave radiation to the sky, radiative part of the internal heat gains and heating or cooling load.

The conductance from the external surface to the external environment consists of the surface heat transfer coefficients by convection and (thermal) radiation, connected to the outdoor air temperature.

The conductance from the internal surface to the internal environment consists of the surface heat transfer coefficient by convection connected to the indoor air temperature and the surface heat transfer coefficient by (thermal) radiation, connected to the internal surfaces of the other construction elements in the thermal zone (radiative heat exchange with view factors).

For unvented building elements, cavities are simplified by one overall cavity resistance.

Illustration of the RC-network presentation per building element:

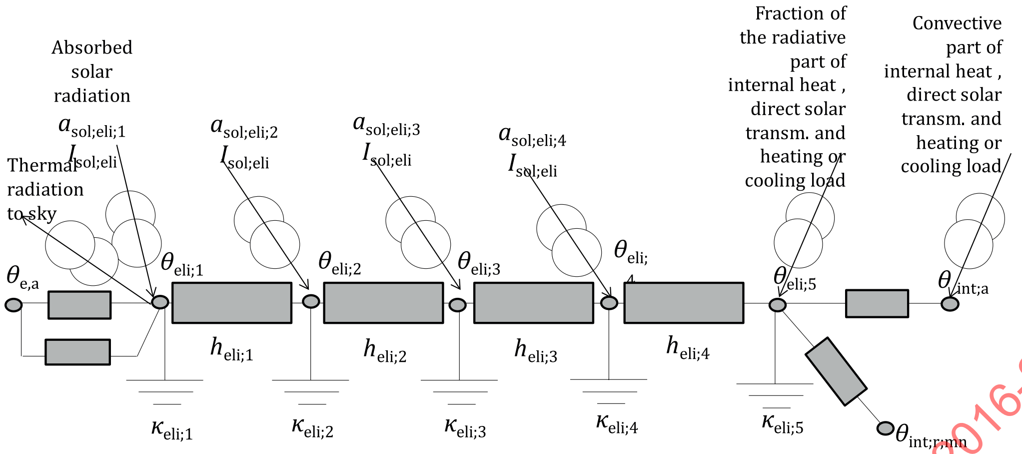


Figure 8 — Illustration of building element: so called electric equivalent “RC” model

For **internal partitions** and **ground floor** constructions specific adaptations are made.

For **transparent building elements** the thermal mass can normally be neglected. In that case the number of nodes is set to 2 (internal and external surface). Moreover, any solar radiation absorbed at the external surface or inside the transparent element (secondary solar heat gain) is approximated as being directly transmitted to the internal environment (thermal zone).

The number of formulae is equal to the number of building elements in the thermal zone, multiplied by the number of nodes (temperatures) per building element.

6.5.6.2.3 Node numbering convention

In line with the international convention, the numbering of layers (nodes) in the construction elements is from outside (node number *pli* = 1) to inside (node number *pli* = pln).

However, in the early drafts of ISO 52016-1 the numbering was in the opposite direction. This can still be the case in the calculation cores or some of the user interfaces of the accompanying spreadsheet and software modules that were based on these drafts.

6.5.6.2.4 Internal air node of the thermal zone

One extra formula is needed to solve the heat balance on the internal air node in the zone: this node is connected to all internal surfaces via the surface heat transfer coefficients by convection and is connected to the outdoor air by thermal bridges, connected to ventilation supply air temperature via the air flow rate and specific heat of air, is connected to the convective parts of the internal heat gains and the heating or cooling load and to the convective part of the solar radiation that is transmitted through transparent building elements.

The thermal radiation part is a simplification, ignoring long wave emissivities, thus long wave reflections. In the sum over all building elements (*elk*), the actual building element (eli) itself is one of the elements. The radiation exchange is approximated using the radiosity method (diffuse view or shape factors) with view factors approximated as if all elements are on the surface of a globe: the surface eli sees also itself. This approximation can be easily refined to take into account multiple reflections: configuration factors instead of view factors). It only makes sense if also the positions of each element (more than only the orientation and tilt) are taken into account. These refinements require extra input data. It is questionable if the results will become more accurate. The effect is not large; the thermal radiative heat exchange in reality is influenced by furniture and plants; the air temperature is also an approximation (disregarding horizontal and vertical stratification).

6.5.6.2.5 Rearrangement of terms

The energy balance per building element and the heat balance in the zone, described in the formulae in ISO 52016-1 might be less recognizable, due to the following:

In ISO 52016-1:2017, 6.5.6, the formulae have been rearranged in such a way that all terms with unknown temperatures (all nodes plus internal air) are placed at the left hand side of the formula and all terms independent of these unknown temperatures are placed at the right hand side.

For example for the single RC-node as presented above:

Rearranged formula for node *i* if the temperature $\vartheta_{i+1;t}$ is also unknown (next node):

$$\frac{C_i}{\Delta t} \cdot \vartheta_{i;t} - H_{i;i} \cdot \vartheta_{i+1;t} + H_{i;i} \cdot \vartheta_{i;t} = \frac{C_i}{\Delta t} \cdot \vartheta_{i;t-1} + \Phi_{i;t} \tag{3}$$

Rearranged formula for node *i* if the temperature $\vartheta_{i+1;t}$ is known, for instance: $\vartheta_{i+1;t}$ is the outdoor air temperature:

$$\frac{C_i}{\Delta t} \cdot \vartheta_{i;t} + H_{i;i} \cdot \vartheta_{i;t} = \frac{C_i}{\Delta t} \cdot \vartheta_{i;t-1} + H_{i;i} \cdot \vartheta_{\mathrm{e;a};t} + \Phi_{i;t} \tag{4}$$

6.5.7 Type of construction dependent properties of the nodes

6.5.7.1 On 6.5.7.2, Opaque elements (walls, roofs, etc.)

6.5.7.1.1 Concerning the specific heat capacity of opaque elements

The classes for the specific heat capacity of opaque elements, $\kappa_{\mathrm{m;op}}$, are based on the classes for the internal heat capacity of the building zone, C_{m}, as given in ISO 13790:2008, Table 12, assuming that $A_{\mathrm{tot}} \approx 1{,}5\, A_{\mathrm{use}}$. A more refined classification would not lead to a higher accuracy.

NOTE The default specification of each class is given in ISO 52016-1:2017, Annex B.

The position of the capacity in the opaque construction element: near the inside, near the outside, in the middle or evenly distributed is introduced as optional extra input (offered as a national choice) without complicating the calculation method. This adds to the accuracy. To this extent, simple classes have been introduced (Annex A), with simple (informative) descriptions of the criteria for each class (Annex B).

6.5.8 Thermal transmission properties

6.5.8.1 Concerning elements in thermal contact with the ground (1)

The output from ISO 13370, in terms of thermal transmission properties of building elements in thermal contact with the ground, is needed as input in ISO 52016-1, for the monthly and the hourly calculation procedures.

Due to the large inertia of the ground, the thermal transmittance through the ground floor is not a linear function of the indoor-outdoor temperature difference.

ISO 13370 produces output that takes this into account, both for the **hourly** and the **monthly** calculations of ISO 52016-1. For both methods, the basis for the output variables is the same (see 6.6.5 for the monthly method).

For the **hourly** calculation, ISO 13370 produces a (constant) thermal resistance of a virtual layer of the ground plus a monthly mean virtual ground temperature. In addition, another (fixed) layer with a certain thermal resistance and areal capacity is introduced in the model to take into account the hourly and daily fluctuations within a month.

The background of this calculation procedure is given in ISO/TR 52019-2:2017, Annex C.

The calculation procedure for ISO 13370 has been demonstrated and validated for a slab-on-ground floor, in the following way:

Because of the monthly variation of output, needed as input for ISO 52016-1, the spreadsheet calculation for ISO 13370 (expanded to twelve months) has been fully integrated in the spreadsheet for ISO 52016-1, connected to both the **monthly** and the **hourly** calculation of energy needs for heating and cooling.

By doing this, a few problems related to the connection between these two documents came to light. Problems for the monthly method, for the hourly method and/or for both. These problems have been solved in the final drafts of ISO 52016-1 and ISO 13370.

6.5.8.1.1 Input for hourly method of ISO 52016-1

The preparation of the ISO/DIS 52016-1 spreadsheet revealed a few shortcomings with respect to the formulae for the effective thermal resistance of the floor construction (including the effect of the ground) and the thermal resistance of the fixed and virtual layer and the virtual ground temperature.

6.5.8.1.2 More direct way to calculate the effective thermal resistance of the floor including the effect of the ground

First, from the spreadsheet validation exercises it appeared that the calculation of the effective thermal resistance of the floor including the effect of the ground, $R_{f;eff}$, contained a long unnecessary detour. There is a much more direct way to calculate this quantity. The new formula is adopted in ISO 13370:2017, 7.6.

6.5.8.1.3 Thermal bridge should not be integrated in virtual temperature

The validation exercises using the spreadsheet revealed that with the procedures in ISO/DIS 13370:2015 (based on ISO 13370:2007), the virtual ground temperature can reach an extremely low value in case of an edge thermal bridge associated to the wall/floor junction.

The thermal resistance of the virtual ground layer is constant, so the extra heat transfer due to the edge thermal bridge can only be obtained by increasing the temperature difference over this virtual layer. Result: a (sometimes extremely) low virtual ground temperature.

The solution is simple and obvious: calculate the edge thermal bridge associated to the wall/floor junction as a separate term, like it is done for the monthly method. It could not have been subjected to the same inertia as the area thermal transmission anyway.

See the example in the following table:

Table 3 — Example of effect of linear thermal bridge on the virtual ground temperature

	Monthly values of the virtual ground temperature $\theta_{ve;m}$ (°C)											
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Case A	6,99	6,49	6,93	8,19	9,94	11,70	13,01	13,51	13,07	11,81	10,06	8,30
Case B	5,21	4,71	5,15	6,41	8,16	9,92	11,23	11,73	11,29	10,03	8,28	6,51
Case C	1,65	1,15	1,59	2,85	4,60	6,36	7,67	8,17	7,73	6,46	4,72	2,95
With edge thermal bridge included in the virtual ground layer, thus affecting the virtual temperature (before revision of ISO 13370 in 2016):												
Case A:	For thermal bridge: l_k = 0 m Ψ_k = 0,00 W/(m·K)											
Case B:	For thermal bridge: l_k = 38 m Ψ_k = 0,05 W/(m·K)											
Case C:	For thermal bridge: l_k = 38 m Ψ_k = 0,15 W/(m·K)											
With edge thermal bridge kept separate from the virtual ground layer, thus not affecting the virtual temperature (after revision of ISO 13370 in 2016):												
Case A:	For any thermal bridge (independent)											
Case B, C:	Not applicable											

This has been corrected in ISO 13370:2017. Actually, there were three changes to make in ISO 13370 (and corresponding changes in ISO 52016-1):

Change 1: In the formula to calculate the virtual temperature in the ground: subtract the linear edge thermal bridge effect from the heat flow. See the formula for the virtual ground temperature in ISO 13370:2017, F.2, the thermal bridge term is explicitly subtracted from the heat flow term.

Change 2: Add the edge thermal bridge heat flow as a separate term, without inertia in the overall formula and as output (same as all other linear thermal bridges).

Change 3: The monthly heat flow in ISO/DIS 13370:2015 (as in ISO 13370:2007) consisted of a steady state term, a periodic term to account for monthly variations of the internal temperature and a periodic term to account for monthly variations in the external temperature. The thermal bridge effect was included in the steady state term. However, the monthly (edge) thermal bridge effect is a term that is proportional to the monthly indoor-outdoor temperature difference and not a constant heat flow over the year. Consequently, this term has been removed from the steady state term (by changing from H_g to UA) and added as separate term. See ISO 13370:2017, C.3.

6.5.8.1.4 Concerning elements in thermal contact with the ground (2)

6.5.8.1.4.1 Modelling ground floor for hourly method in ISO 52016-1; distribution of thermal and solar properties over the nodes

In ISO 52016-1 each opaque building element consists of five nodes: two surface nodes and three nodes inside the construction (four layers per building element).

For a ground floor element the same number of nodes is kept. But the ground floor needs two extra layers (see Introduction above). On the other hand, the ground floor has no external surface heat exchange coefficients.

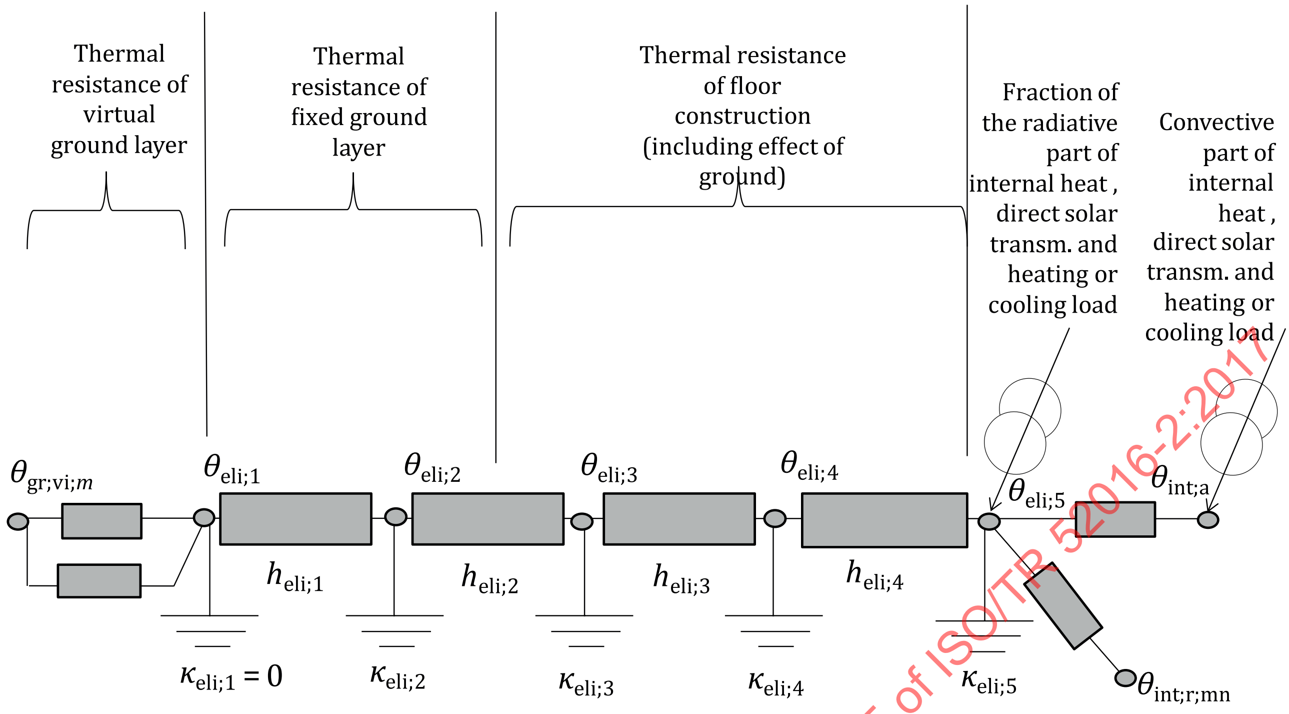


Figure 9 — Illustration of layer distribution ground floor

NOTE The BESTEST cases (see 7.2, validation) avoid heat transfer through a ground floor. Instead, the instructions for these BESTEST cases in ANSI/ASHRAE 140[24] state that the ground floor should be modelled as an opaque construction a fictitious thick thermal insulation layer behind the floor construction. This thermal insulation layer cannot be added to the value for the thermal resistance of the construction itself, because in that case also (part of) the mass of the construction might be hidden behind (part of) this fictitious thermal insulation layer. Instead: the thermal resistance of the fictitious layer replaces the thermal resistance between node 1 and 2 (the most external layer).

6.5.8.2 Windows

The internal and external surface thermal resistance of window, door and curtain walling elements for vertical position are in accordance with ISO 10077-1:2017, Annex D, for conventional cases, because the *U*-value is derived from the thermal resistance of the window or door element (for a given position) and the surface resistances for vertical position. In addition, in this way, for special cases, for example a low-emissivity coating on the outer surface of the interior pane, the effect of a higher surface resistance is included in the thermal resistance of the window or door element.

6.5.9 Temperature of adjacent thermally unconditioned zone

See also 6.4.5 of this document.

Concerning the coefficient to limit the assumed temperature in the thermally unconditioned zone: if the coefficient $c_{ztu,h;max}$, for example, is set to zero, there is no maximum. If the coefficient is set to 1 the temperature will not exceed the temperature of the adjacent thermally conditioned zone(s). The maximum is introduced to avoid the need to calculate in full detail the thermal balance in the thermally unconditioned zone, including the use of measures to avoid excessive overheating by solar shading or extra ventilation. The value can be a compromise to avoid overestimation of gains for heating and underestimation of gains for cooling.

6.5.10 Ventilation heat transfer coefficient, supply temperature and moisture content

There is a difference between pre-heating or pre-cooling and **air heating or cooling**:

In case of pre-heating or – cooling by mechanical ventilation, the energy loads for heating and cooling are calculated with pre-set air supply temperature, e.g. as function of the season. This is determined in the relevant system standard. The supply temperature is not immediately controlled by feedback from the difference between the internal temperature of the thermal zone and the temperature set-point.

In case of air heating or cooling, the (air) heating or cooling system supplies the exact amount of heat or cold to maintain the temperature set-point. Therefore, the supply temperature is fully controlled by the internal temperature. There can be recirculation as well, to keep the supply temperature within certain limits while still providing enough heat or cold.

In that case the amount of heat or cold to be supplied by the (air) heating or cooling system in order to maintain the temperature set-point is no different than the energy load for heating or cooling. So it is to be treated in the same way as the energy load for heating or cooling for a liquid based heating or cooling system.

6.5.11 Thermal capacity of the internal environment of the thermal zone

No additional information beyond the accompanying document.

See Annex B for explanation on informative default values.

6.5.12 Internal heat gains

See also 6.4.5 of this document.

Concerning the coefficient to limit the assumed temperature in the thermally unconditioned zone: for the external thermally unconditioned zones (see 6.4.5) the gains in the ztu are taken into account in the temperature of the ztu; see 6.5.9. On the other hand, for the internal thermally unconditioned zones (see 6.4.5) the gains in the ztu are taken into account by adding these to gains in the thermally conditioned zone, weighted with the factor $(1 - b_{ztu,\mathrm{m}})$, but without extra precaution to avoid overestimation of the gains.

See also 6.5.9.

6.5.13 Solar gains

Concerning thermally unconditioned zones: similar as for internal gains, see 6.5.12.

6.5.14 Moisture content and latent heat load

The calculation consists of successive steps:

The calculation of the required amount of moisture to be supplied to or extracted from the thermal zone to remain within the limits of the moisture set-points.

This leads to the humidification or dehumidification **moisture load**, in $\mathrm{kg_{H2O}}$/s.

The humidification or dehumidification moisture load can be converted to the latent heat (humidification or dehumidification) load by multiplying the moisture load with the latent heat of evaporation.

However, this can be a bit more complicated, depending on the type of system.

6.5.14.1 Central (de-)humidification

In case of a central (de-)humidification system, the humidification or dehumidification moisture load is covered by the air flow of the **supply air of the mechanical ventilation**.

In that case the output of ISO 52016-1 is **the minimum or maximum required moisture content of the supply air**, based on a given air flow rate for mechanical ventilation.

Because it is not ensured that the system can supply or extract enough moisture via the mechanical ventilation system, the (**system specific**) **actual moisture content of the supply air** is obtained from the relevant system standard to recalculate the (**system specific**) **actual moisture and latent heat load** and the (**system specific**) **actual moisture content** of the internal air in the zone.

The hourly output of ISO 52016-1 is the basic and system specific moisture load and latent heat load, the required moisture content of the supply air and the actual internal air moisture content.

6.5.14.2 Local (de-)humidification

In case of local (de-)humidification or no (de-)humidification, there is no need to consider an interaction with a system.

The required amount of moisture to be supplied to or extracted from the thermal zone to remain within the limits of the moisture set-points is based on the given moisture content of the ventilation (mechanical and natural ventilation and infiltration) air supply.

The humidification or dehumidification moisture load is converted to the latent heat (humidification or dehumidification) load by multiplying the moisture load with the latent heat of evaporation.

The hourly output of ISO 52016-1 is the moisture load, the latent heat load and the internal air moisture content.

6.5.15 Calculation of key monthly data from hourly output

6.5.15.1 Monthly utilization factors

These data are essential for a quick understanding of the main processes involved and as a means to derive correction and adjustment factors for the monthly method.

More explanation on the methods to derive the gain utilization factor for heating and heat transfer utilization factor for cooling is given in K.3.

6.5.15.2 Monthly system undersizing, overheating and underheating

The key monthly data also comprise the monthly amount of undersizing of the heating and cooling systems for different thresholds.

Undersizing leads to “undertemperature” (undersized heating) or “overtemperature” (undersized cooling). The accumulated undertemperature (“underheating”) / overtemperature (“overheating”) are also provided.

See also discussion in 6.5.4 on basic energy needs versus system specific energy needs calculations.

6.6 Monthly calculation procedures

6.6.1 Principle

No additional information beyond the accompanying document.

Extensive information is already given in 5.2.2.

6.6.2 Applicable time interval and calculation period

The monthly method uses monthly climatic data and monthly mean conditions of use and occupancy patterns.

Because the physical processes are highly nonlinear (to start with because of the one-directional set points for heating and cooling and the inertia of the building), there are many dynamic effects, which cannot be explicitly accounted for by taking monthly mean values. These are approximated by correlation or simple correction factors.

Because there are possibly months with both heating and cooling needs, and because this cannot be predicted without doing the actual calculation, for each month two independent calculations are performed:

1) Calculation of the heating needs, with assumptions for the heating mode (e.g. on the use of solar blinds, ventilation, etc.)

2) Calculation of the cooling needs, with assumptions for the cooling mode (e.g. on the use of solar blinds, ventilation, etc.)

In reality there will be days in heating mode and days, alternating, in cooling mode.

6.6.3 Assumptions

No additional information beyond the accompanying document.

6.6.4 Energy need for space heating and cooling

6.6.4.1 Concerning system specific energy needs

In case of an undersized or absent heating or cooling system, a level playing field in the comparison with other buildings can only be maintained if the report of the system specific energy use is accompanied by a warning that possibly the standard conditions of use are not met by the system; or the system specific energy use is calculated with a properly dimensioned fictitious system.

See also 5.2.4 (choice between basic and system specific needs calculation) and see the more extensive discussion in 6.5.4 (same subclause on the hourly method).

6.6.4.2 On 6.6.4.2 Heating

6.6.4.2.1 Concerning the overall monthly heat balance formula

The terms “total heat transfer” and “total heat gains” in the heat balance formulae are an approximate naming. Heat balance:

$$H_{\mathrm{ht}} \cdot \Delta\theta = Q_{\mathrm{gn}} \tag{5}$$

Left hand side of the balance: in fact, the “total heat transfer” (H_{ht}) covers all terms in the energy balance that are proportional to the difference in temperature between the internal and external environment ($\Delta\theta$).

Right hand side of the balance: The “total heat gains” covers all other terms: the amounts of heat (or cold) that are not proportional to the temperature difference, but “autonomous”, like the solar and (most) internal heat gains.

The energy need for heating or cooling is then added (cooling: with negative sign) to the right hand side of this formula, to avoid a too low temperature difference at the left hand side.

Although this, to a very great extent, corresponds to the actual heat transfer versus the actual heat gains, there are situations where it is different.

For example, the extra heat transfer due to a sky temperature that is different from the external air temperature, is a negative gain, because it is not proportional to the indoor-outdoor temperature difference. The transmission heat transfer from a warmer external environment to the thermal zone is a negative loss. See Annex K for more background information.

6.6.4.2.2 Concerning the formula for the gain utilization factor

The second part of the first condition (if $\gamma_{H;ztc;m} \leq 0$ and $Q_{H;gn;ztc;m} > 0$) is introduced to avoid that the heating needs are set to zero in the exceptional cases with small solar and internal gains, combined with the negative gains from sky radiation.

The second condition ($\gamma_{H;ztc;m} > 2{,}0$) is introduced to avoid that even in summer months the heating need never becomes exactly zero (by the mathematical nature of the formulae). The need then becomes a (very) small value, which is shown as zero due to rounding in the presentation, but in the internal calculations it is not.

6.6.4.3 On 6.6.4.3 Cooling

6.6.4.3.1 Concerning the formula for the heat transfer utilization factor

The condition $(1/\gamma_{C;ztc;m}) > 2{,}0$ is introduced to avoid that even in winter months the cooling need never becomes exactly zero (by the mathematical nature of the formulae). The need then becomes a (very) small value, which is shown as zero due to rounding in the presentation, but in the internal calculations it is not.

6.6.5 Heat transfer by transmission

6.6.5.1 On 6.6.5.1 Calculation procedures

6.6.5.1.1 Concerning the two formulae for the total heat transfer by transmission for heating and for cooling

By convention, the heat transfer by transmission and ventilation is from inside to outside. The heat transfer or part of the heat transfer can have a negative sign during a certain period, in which case heat is added to the zone.

NOTE 1 If the total heat transfer is negative, and the solar and internal gains are positive (more or less theoretically: these could be negative, due to thermal radiation to the sky), the heat balance ratio is negative, while it is for sure that the heating need is zero; this situation is foreseen in the formulae of ISO 52016-1:2017, 6.6.10.2).

NOTE 2 The negative heat transfer cannot be confused with gains. See discussion in K.2.3 (Heat-balance ratio: the difference between gains and heat transfer) of this document.

6.6.5.1.2 Concerning the heat transfer by transmission of building elements in thermal contact with the ground

The output from ISO 13370, in terms of thermal transmission properties of building elements in thermal contact with the ground, is needed as input in ISO 52016-1, for the monthly and the hourly calculation procedures.

Due to the large inertia of the ground, the thermal transmittance through the ground floor is not a linear function of the indoor-outdoor temperature difference.

ISO 13370 produces output that takes this into account, both for the **hourly** and the **monthly** calculations of ISO 52016-1. For both methods, the basis for the output variables is the same (see 6.5.8 for the discussion on the hourly method).

The calculation procedure for ISO 13370 has been demonstrated and validated for a slab-on-ground floor, in the following way:

Because of the monthly variation of output, needed as input for ISO 52016-1, the spreadsheet calculation for ISO 13370 (expanded to twelve months) has been fully integrated in the spreadsheet for

ISO/DIS 52016-1:2015, connected to both the **monthly** and the **hourly** calculation of energy needs for heating and cooling.

By doing this, a few problems related to the connection between these two documents came to light. Problems for the monthly method, for the hourly method and/or for both. These problems have been solved in the final drafts of ISO 52016-1 and ISO 13370.

6.6.5.1.3 Input for the monthly method of ISO 52016-1

What in essence is needed as input for ISO 52016-1 is the monthly mean heat flow through the ground floor, including the effect of thermal inertia and including the effect of edge thermal bridges associated to the wall/floor junctions.

6.6.5.1.3.1 Heat flow

This value can be obtained directly from ISO 13370:2017, C.2.

However, this value is calculated on the basis of an annual mean indoor and outdoor temperature plus a periodic (monthly) variation. In ISO 52016-1 the actual monthly mean outdoor temperature could be not exactly the same. And the actual monthly mean indoor temperature in ISO 52016-1 is calculated on the basis of heating resp. cooling set point, intermittency and possibly other correction factors.

Therefore, we would risk a large error in the heat flow through the ground floor if we would disregard the specific conditions.

The original idea (in ISO 13370:2007) was to solve this problem by providing the monthly mean ground heat transfer coefficient, $H_{\mathrm{g,m}}$.

The ground heat transfer coefficient, $H_{\mathrm{g},m}$, in month m is given by:

$$H_{\mathrm{g},m} = \frac{\Phi_m}{\theta_{\mathrm{int},m} - \theta_{\mathrm{e},m}} \tag{6}$$

NOTE The subscripts have been modified in ISO 52016-1 to be able to make distinctions, such as gl=glazing; gr=ground; the differences in subscripts are listed in the tables in ISO 52016-1 with the overview of input data (6.3).

Having this quantity as input in ISO 52016-1, the heat flow would be calculated by multiplication with the actual (calculated) temperature difference.

However, this calculation is done for each month, including the months with small (or even zero or negative) indoor-outdoor temperature difference. This can occur (and did occur during validation exercises), because the monthly heat flow is not a linear function of the monthly mean temperature difference.

This problem has been solved by using as input 6.6.6.1.3.2.

6.6.5.1.3.2 Monthly heat transfer coefficient related to annual temperature difference

The ground heat transfer coefficient, $H_{\mathrm{g;an,m}}$, in month m, based on annual temperature difference, is given by

$$H_{\mathrm{g;an},m} = \frac{\Phi_m}{\theta_{\mathrm{int,an}} - \theta_{\mathrm{e,an}}} \tag{7}$$

But again, if in ISO 52016-1, the monthly heat flow is calculated by multiplication of $H_{\mathrm{g;an},m}$ with the annual (calculated) temperature difference, then the differentiation of the indoor temperature over the months is still lost.

On the other hand, if the monthly heat flow is calculated by multiplication of $H_{\mathrm{g;an},m}$ with the difference between the actual (calculated) **monthly** indoor temperature minus the **annual** average outdoor temperature, then the effect of the variation in indoor temperature that is already calculated in ISO 13370 and thus embedded in Φ_m is taken into account twice. However, this variation in indoor temperature in ISO 13370 is small. The main point is that the effect of intermittency, chosen set points, etc. is now reflected in the heat flow in ISO 52016-1.

Note that the monthly calculation method has several other limitations due to which attempts to reach high accuracy are not justified. For instance: the separate calculation of energy need for heating and energy need for cooling for each month, without any interaction, each with their own assumptions on conditions of use.

So this led finally to the formulae in ISO 52016-1:2017, 6.6.6.1:

$$Q_{\mathrm{H/C;tr};m} = \ldots + H_{g;an;m} \cdot \left(q_{\mathrm{int,calc,H}/C;m} - q_{\mathrm{e;an}} \right) \cdot t \quad (8)$$

6.6.5.1.3.3 Derivation of time constant in monthly method of ISO 52016-1

One issue remained to be solved: the monthly method in ISO 52016-1 needs the monthly time constant for both the heating and the cooling mode.

The time constant is calculated as a thermal capacity divided by the (monthly) overall heat transfer coefficient for transmission and ventilation. The monthly overall heat transfer coefficient for transmission includes the thermal transmission through the ground.

But again, the value obtained from ISO 13370:2017, Annex C, is not suitable as explained above. On the other hand, the revised version, $H_{\mathrm{g;an},m}$ is also not suited, because it is not related to the monthly temperature difference.

The solution was to calculate a seasonal average overall heat transfer coefficient for transmission through the ground floor, adjusted for the seasonal temperature difference, see the new formulae in ISO 13370:2017, C.7:

$$H_{\mathrm{g;H;adj}} = \frac{\sum_{m;H} H_{\mathrm{g;an;m}}}{6} \times \frac{\sum_{m;H} \left(\theta_{\mathrm{int};m;H} - \theta_{\mathrm{e};m;H} \right)}{6 \times \left(\theta_{\mathrm{int;an}} - \theta_{\mathrm{e;an}} \right)} \quad (9)$$

$$H_{\mathrm{g;C;adj}} = \frac{\sum_{m;C} H_{\mathrm{g;an;m}}}{6} \times \frac{\sum_{m;C} \left(\theta_{\mathrm{int};m;C} - \theta_{\mathrm{e};m;C} \right)}{6 \times \left(\theta_{\mathrm{int;an}} - \theta_{\mathrm{e;an}} \right)} \quad (10)$$

with *m;H* is sum over Oct - March (North hemisphere) or Apr – Sept (South hemisphere)

with *m;C* is sum over Apr – Sept (North hemisphere) or Oct - March (South hemisphere)

These values are now used in the calculation of the time constants in ISO 52016-1:2017, 6.6.11.4.

These formulae have been implemented in the ISO 52016-1 spreadsheet with satisfying results.

6.6.5.2 Concerning 6.6.5.2 - Overall heat transfer coefficient by transmission

The area of building elements and their thermal transmittance, as well as the lengths and linear thermal transmittance of thermal bridges are obtained from or via the same source, because the values depend on the choice of dimensions (internal, external, etc.), in such a way that the overall thermal transmittance is the same (“communicating vessels”). These quantities are calculated in other standards and listed in ISO 13789 as part of centralized data transfer to destination modules such as this document. Another reason is to facilitate as alternative (e.g. for existing buildings) an aggregated input, such as the overall heat transfer coefficient for thermal bridges.

6.6.6 Heat transfer by ventilation

6.6.6.1 On 6.6.6.2 - Overall heat transfer coefficient by ventilation

There is a difference between pre-heating or pre-cooling and **air heating or cooling**:

See the explanation in 6.5.11 for the hourly method, which applies to the monthly method as well, if the term "(hourly) load" is replaced by the term "(monthly) need".

6.6.6.2 On the dynamics correction factor

The dynamics correction factor corrects for significant differences between the pattern of the ventilation rate and/or supply temperature over the day (hourly) and week (work days, weekend) and the pattern of indoor and/or outdoor temperature and/or energy needs. It can be argued that such kind of corrections are already included in the gain and heat transfer utilization factor curves for the heating and cooling needs respectively. In particular because any additional correction factor such as this dynamics correction factor cannot be more than a rough approximation and could easily lead to a false sense of accuracy.

The Method B to obtain the value for the overall ventilation heat transfer coefficient from ISO 13789 and ISO/TR 52019-2:2017, Annex J, is not applicable to the CEN area, because this is only a very crude method. The CEN set of EPB standards comprises all necessary standards needed for the assessment of the overall energy performance including the effect of specific ventilation systems. ISO/TR 52019-2:2017, Annex J is the method of ISO 13790:2004.

6.6.7 Internal heat gains

6.6.7.1 Concerning aggregated monthly input data

Common cases of scaling are:

— multiply a daily value with the number of days of the month;

— divide a weekly value by 7 and then multiply this value with the number of days of the month.

This procedure ensures that week days and weekend days are considered in the correct proportion on a long term (annual or multiannual) average.

6.6.8 Solar heat gains

No additional information beyond ISO 52016-1.

6.6.9 Internal effective heat capacity of a zone

The *internal effective* heat capacity of a zone is different from the heat capacity in the hourly method. In the hourly method there are two "kinds" of thermal capacity:

— the thermal capacity of the internal environment of the thermal zone as such, consisting of air plus furniture (6.5.12); and

— the thermal capacity of each construction element, divided over the layers (nodes).

In the monthly method the effective capacity combines the thermal capacity of the internal environment and the thermal capacity of the construction elements into one aggregated quantity, considering from the thermal capacity of the construction elements only the part that is "seen from the inside".

The classes of the internal heat capacity for the simple method are the same as the classes for the internal heat capacity of the building zone, C_m, in ISO 13790:2008, Table 12.

6.6.10 Utilization factors

6.6.10.1 On parameters for the gain utilization factor (heating)

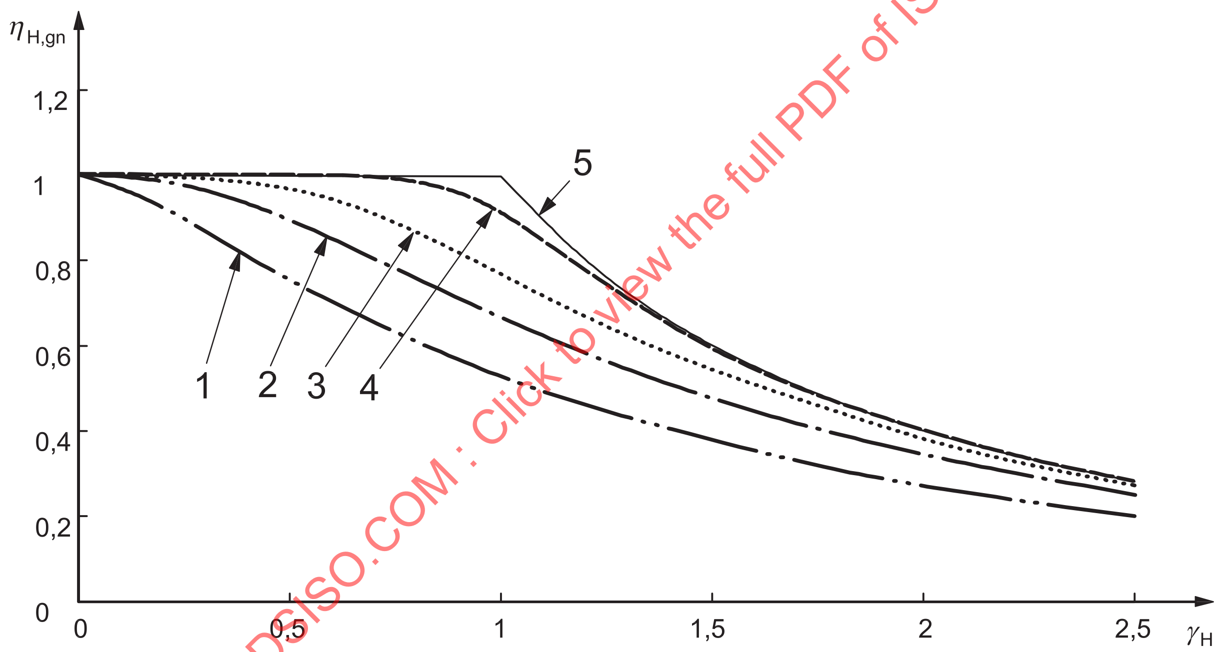
In exceptional cases negative heat gains can occur in case of small solar and internal gains, combined with the negative gains from sky radiation. With the utilization factor set to 1 the negative gains are added to losses without reduction. If the heat balance ratio is negative due to negative overall heat transfer, the heating needs are zero, which is the case with $\eta_{\mathrm{H;gn;}ztc;m} = \frac{1}{\gamma_{\mathrm{H;}ztc;m}}$.

Default values of the reference numerical parameter, $a_{\mathrm{H,0}}$, and the reference time constant, $\tau_{\mathrm{H,0}}$, for the gain utilization factor were based on the values given in ISO 13790:2008, Table 9.

See also Annex K for an extensive explanation and derivation of the gain utilization factor.

The gain utilization factor is defined independently of the heating system characteristics, assuming perfect temperature control and infinite flexibility. A slowly responding heating system and a less-than-perfect control system can significantly affect the use of the heat gains.

Figure 10 illustrates gain utilization factors for the monthly calculation method and for various time constants.



Key

1 time constant of 8 h (low inertia)
2 time constant of 1 d
3 time constant of 2 d
4 time constant of 7 d
5 time constant infinite (high inertia)

Figure 10 — Illustration of gain utilization factor for heating mode

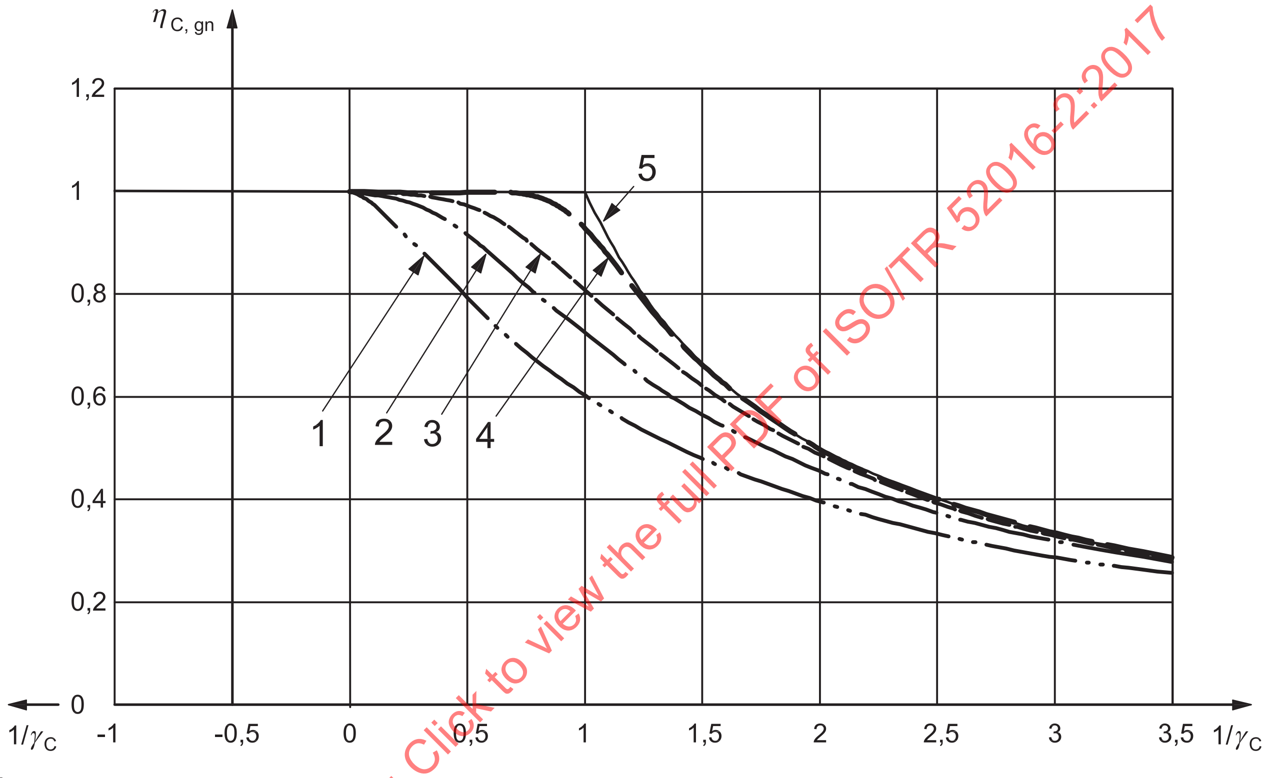
6.6.10.2 On parameters for the heat transfer utilization factor (cooling)

Default values of the reference numerical parameter, $a_{\mathrm{C,0}}$, and the reference time constant, $\tau_{\mathrm{C,0}}$, for the heat transfer utilization factor were based on the values given in ISO 13790:2008, Table 10.

See also Annex K for explanation and procedures for the derivation of the parameter values. Bibliography [29] (PASSYS I SDT report), [30] (IEA Annex 12), section 2.1 of [31] (PASSYS II SDT report) and [33] (ENPER study) provide background information on the development of the method.

The heat transfer utilization factor is defined independently of the cooling system characteristics, assuming perfect temperature control and infinite flexibility. A slowly responding cooling system and a less-than-perfect control system can significantly affect the utilization of the losses.

Figure 11 illustrates heat transfer utilization factors for the monthly calculation method and for various time constants.



Key

1 time constant of 8 h (low inertia)
2 time constant of 1 d
3 time constant of 2 d
4 time constant of 7 d
5 time constant infinite (high inertia)

Figure 11 — Illustration of heat transfer utilization factor, for cooling mode

6.6.11 Calculation temperature and intermittency modes

ISO 52016-1 contains a method to take into account intermittent heating and cooling, such as (depending on the category of building and (nationally) specified conditions of use):

— heating and/or cooling thermostat night time set back (residential, non-residential);

— heating and/or cooling thermostat day time set back (e.g. residential);

— weekend reduction or interruption of heating and/or cooling (e.g. non-residential); and

— longer term reduction or interruption of heating and/or cooling (residential, non-residential; e.g. holidays).

On one extreme, if the intermittency period length is very large compared to the time constant of the building (zone) the period with reduced heating and/or cooling can be calculated separately (see ISO 52016-1:2017, 6.6.12.6).

For shorter intermittency period lengths (see ISO 52016-1:2017, 6.6.12.4 and 6.6.12.5), the indoor temperature will gradually go down (period with heating need) or up (period with cooling need), depending on the time constant of the building (zone) and the heat losses by transmission and ventilation.

The challenge is to develop a simple method that provides a rough approximation of the mean internal temperature over the intermittency period, since a refined approximation would not be justified, because there are many inevitable simplifications anyway:

the monthly method is not capable to deal accurately with the dynamics in the heat balance (see also discussion in Annex I of this document, for instance:

- no distinction in ventilation rate, operation of solar blinds, internal heat gains (incl. lighting) during occupancy periods (e.g. office hours) and during the periods with reduced heating or cooling set-point temperature (e.g. for offices: nights and weekends): the monthly method can only deal with monthly mean values;
- no distinction between operational and air temperature;
- no possibility to take into account a boost mode, with –optionally- a maximum heating or cooling power during the boost period; and
- no distinction between periods (e.g. days or hours) in heating or cooling mode - the monthly method calculates for each month both the heating need and the cooling need as two completely separate calculations, without interaction.

6.6.12 Corrections for intermittency

6.6.12.1 Heating

The intermittency method for heating is new compared to ISO 13790:2008. It is based on the formulae for first order (exponential) temperature decay.

Here below the formulae from ISO 13790:2008 are presented, followed by an explanation why these formulae need to be replaced.

Formulae from ISO 13790:2008:

In the case of intermittent heating which does not fulfil the conditions in the previous clause, the energy need for heating, $Q_{H,nd,interm}$, expressed in megajoules, is calculated by using Formula (67):

$$Q_{H,nd,interm} = a_{H,red} \, Q_{H,nd,cont} \tag{67}$$

where

$Q_{H,nd,cont}$ is the energy need for continuous heating, calculated in accordance with 7.2.1.1, expressed in megajoules;

$a_{H,red}$ is the dimensionless reduction factor for intermittent heating, determined in accordance with Formula (68).

NOTE 1 Occupant-related data for intermittent heating applies.

The dimensionless reduction factor for intermittent heating, $a_{H,red}$ is calculated as given by Formula (68):

$$a_{H,red} = 1 - b_{H,red}(\tau_{H,0}/\tau)\gamma_H(1 - f_{H,hr}) \tag{68}$$

with minimum value: $a_{red,H} = f_{H,hr}$ and maximum value: $a_{H,red} = 1$.

where

$f_{H,hr}$ is the fraction of the number of hours in the week with a normal heating set-point (no reduced set-point or switch-off), e.g. (14 × 5)/(24 × 7) = 0,42;

$b_{H,red}$ is an empirical correlation factor; value $b_{H,red} = 3$;

τ is the time constant of the building zone, determined in accordance with 12.2.1.3, expressed in hours;

$\tau_{H,0}$ is the reference time constant for the heating mode, determined in accordance with 12.2.1.1, expressed in hours;

γ_H is the heat-balance ratio for the heating mode, determined in accordance with 12.2.1.1.

6.6.12.2 Problem with these formulae

The formula appears to lead to unintended results.

The physical process is, that when the temperature set-point is lowered, the actual indoor temperature gradually decreases and hence the heat transfer by transmission and ventilation decrease. Often the indoor temperature will not reach the lowered set-point during the period with reduced set-point.

In any case, an estimate needs to be made for the correction (reduction) on the monthly mean difference between the set-point temperature and the outdoor temperature which is used to calculate the monthly transmission and ventilation heat transfer.

In ISO 13790:2008 it was decided not to introduce such reduction factor on the temperature difference, but to introduce, instead of this, a reduction factor on the monthly energy **need** for heating. In this way the reduction factors for the various types of not-continuous heating and cooling would all be reduction factors on the calculated energy need for continuous heating and cooling.

However, for low energy buildings the energy need for heating is typically a small difference between two relatively large numbers: heat transfer by transmission and ventilation minus (utilized) solar and internal gains.

6.6.12.3 Case

Heat transfer (= transmission and ventilation losses) = 100 kWh

Utilized heat gains (= solar and internal gains) = 90 kWh

If e.g. the effect of night time temperature set back (NTTB) is 5 % on the temperature difference:

Heat transfer (= transmission and ventilation losses) including NTTB = 0,95 × 100 = 95 kWh

6.6.12.4 Result

Heating need, continuous heating: 100 – 90 = 10 kWh

Heating need, NTTB: 95 – 90 = 5 kWh

6.6.12.5 Discussion

So if the reduction factor for the reduced heating set point is applied on the energy need for heating (as in ISO 13790:2008) the values would be very high (in the example: 0,5), while the actual reduction, on the heat transfer, is much smaller (in the example: only 5 %).

And even worse: the actual reduction factor required for the monthly mean temperature difference is smaller for buildings with better energy performance (less effect of night time temperature setback), while due to the mechanism shown above, if the reduction factor is applied on the heating need, the reduction factor becomes (much) stronger for buildings with better energy performance.

Of course, with a good estimate of the reduction factor, the effect will be the same.

But:

— this seemingly "inverse trend", although in itself correct, is very difficult to explain;

— the reduction factor applied on the heating need pulls the physical mechanism out of its context: especially in good energy performing buildings many other small uncertainties in the heat transfer have the same relatively large effect on the heating need.

This effect was much less apparent in the past, with buildings with a poor energy performance, when the heat gains were normally much lower than the heat transfer (the heat losses) by transmission and ventilation[1)].

— The formula for the reduction factor was intended to take into account two facts:

  — the fact that the effect of the intermittency increases with low inertia buildings (factor τ in the denominator of the second term);

  — the fact that the effect of the intermittency on the energy need for heating increases in case of higher ratio between gains and losses (see the first point above). This is taken into account by γ_H in the numerator.

However, in the way it is formulated these two effects are cancelled out: the factor τ in the denominator is inversely proportional to (H_{tr} + H_{ve}), while γ_H in the numerator is also inversely proportional to (H_{tr} + H_{ve}).

Ergo: the reduction factor becomes independent of the specific heat losses, which is obviously not correct.

6.6.12.6 Solution

Both problems are solved if the reduction factor is directly applied on the temperature difference, where it belongs.

NOTE The reason for applying, in ISO 13790:2008 the reduction factor to the energy needs for heating was to have the same type of reduction factor for both heating and cooling and for both short and long intermittency periods.

And if the reduction factor is directly applied on the temperature difference, it is better to introduce separate reduction factors for night set back and for weekends, because of the different time scales involved.

Also day time set back can be added.

This new method also covers the situation that in ISO 13790:2008 was separately described as "quasi-continuous heating".

1) In the past, the issue already arose for poorly performing buildings in months at the beginning and end of the heating season. But on an annual basis the impact was smaller.

6.6.12.7 New simple formulae in ISO 52016-1

See ISO 52016-1:2017, 6.6.12.4.

NOTE 1 The notation of subscripts in this document are elaborated less precisely and less elaborated as in ISO 52016-1.

The total dimensionless reduction factor on the indoor-outdoor temperature difference for intermittent heating, $a_{\mathrm{H,red;tot}}$ is approximated by multiplication of the individual reduction factors (for day time, night time and weekend set back or switch off). This is an approximation, justified because the corrections itself are approximations and the total effect is limited.

The individual reduction factors are the time weighted average of the set point temperature and the mean temperature during the set-back period.

The mean temperature during set-back is calculated on the basis of first order exponential decay, taking into account the time-average heat gains and an optional lower set-point.

The quantities are defined in ISO 52016-1.

If there is no lower set-point and if the period of intermittency is infinite, the temperature reaches the “free floating temperature”. It can be easily proven, that the temperature difference between the free floating temperature and outdoor, compared to the set-point temperature and outdoor, $d\vartheta_{\mathrm{float}}$, is simply equal to the heat balance ratio, $\gamma_{H;\mathrm{m}}$, the ratio between the heat gains and the heat transfer based on set-point:

NOTE 2 This formula is precise if there is no overheating; monthly balance:

$$0 = \left(H_{\mathrm{H;tr}} + H_{\mathrm{H;ve}}\right) \cdot \left(\theta_{\mathrm{int;float};m} - \theta_{\mathrm{e};m}\right) \cdot \Delta t - Q_{\mathrm{H;gn};m} \tag{11}$$

$$\text{So: } 0 = Q_{\mathrm{H;ht}} \cdot \frac{\left(\theta_{\mathrm{int;float}} - \theta_{\mathrm{e}}\right)}{\left(\theta_{\mathrm{int;set;H}} - \theta_{\mathrm{e}}\right)} - Q_{\mathrm{H;gn}} \tag{12}$$

$$\text{And thus: } \mathrm{d}\theta_{\mathrm{float}} = \frac{Q_{\mathrm{H;gn}}}{Q_{\mathrm{H;ht}}} = \gamma_{\mathrm{H}} \tag{13}$$

However, if we refer to γ_{H}, we may create a circular loop, so it is better to write:

$$\mathrm{d}\theta_{\mathrm{float}} = \frac{Q_{\mathrm{H;gn}}}{\left(H_{\mathrm{H;tr}} + H_{\mathrm{H;ve}}\right) \cdot \left(\theta_{\mathrm{int;set;H}} - \theta_{\mathrm{e}}\right) \cdot \Delta t} \tag{14}$$

In case of strong overheating (large γ_{H}) there is no heating, so no decay. In case of moderate overheating, the monthly method is not accurate, but in that case accuracy is not expected.

The temperature at time Δt_1 after the start of the decay is given by the following formula:

$$d\theta\left(\Delta t_1 / \tau_H\right)_{H;red} = d\theta_{float} + \left(1 - d\theta_{float}\right) \cdot e^{-\left(\Delta t_1 / \tau_H\right)} \quad (15)$$

From this we can derive the **mean** temperature from start of decay until time Δt_1 :

$$d\theta\left(\Delta t_1 / \tau_H\right)_{H;red;mn} = \frac{d\theta_{float} \cdot \left(\Delta t_1 / \tau_H\right) + \left(1 - d\theta_{float}\right) \cdot \left(1 - e^{-\left(\Delta t_1 / \tau_H\right)}\right)}{\left(\Delta t_1 / \tau_H\right)} \quad (16)$$

If the lower set point is higher than the free float temperature and if the lower set point is reached before the end of the intermittency period, the decay is stopped. The time at which the lower set point is reached is given by:

If $d\theta_{set;H;low} > d\theta_{float}$:

$$\Delta t_{H;red;low} / \tau_H = -\ln\left(\frac{\left(d\theta_{set;H;low} - d\theta_{float}\right)}{\left(1 - d\theta_{float}\right)}\right) \quad (17)$$

where:

$\Delta t_{H;red;low} / \tau_H$ is the time (compared to τ_H) until the lower set-point is reached.

If this time is shorter than the length of the period with reduced set point, the average temperature is the weighted average of the mean temperature during the period before and the mean temperature after reaching the lower limit.

The (relative) mean temperature **until** the low set point is reached is given by:

$$d\theta\left(\Delta t_{H;red;low} / \tau_H\right)_{H;red;mn} = \frac{d\theta_{float} \cdot \left(\Delta t_{H;red;low} / \tau_H\right) + \left(1 - d\theta_{float}\right) \cdot \left(1 - e^{-\left(\Delta t_{H;red;low} / \tau_H\right)}\right)}{\left(\Delta t_{H;red;low} / \tau_H\right)} \quad (18)$$

Knowing that (see above, for $\Delta t_1 = \Delta t_{H;red;low}$):

$$d\theta_{set;H;low} = d\theta\left(\Delta t_{H;red;low} / \tau_H\right)_{H;red} = d\theta_{float} + \left(1 - d\theta_{float}\right) \cdot e^{-\left(\Delta t_{H;red;low} / \tau_H\right)} \quad (19)$$

we can now simplify the formula for the mean temperature:

$$d\theta_{H;red;low;mn} = d\theta\left(\Delta t_{H;red;low} / \tau_H\right)_{H;red;mn} = \frac{d\theta_{float} \cdot \left(\Delta t_{H;red;low} / \tau_H\right) + \left(1 - d\theta_{set;H;low}\right)}{\left(\Delta t_{H;red;low} / \tau_H\right)} \quad (20)$$

The mean temperature **after** the lower limit is reached is of course constant and equal to: $d\vartheta_{set;H;low}$

This leads us to the final step:

If we define:

$$f_{\mathrm{H;red;low}} = \frac{\left(\Delta t_{\mathrm{H;red;low}} / \tau_{\mathrm{H}}\right)}{\left(\Delta t_{\mathrm{H;red}} / \tau_{\mathrm{H}}\right)} \tag{21}$$

with (as shown earlier):

$$\Delta t_{\mathrm{H;red;low}} / \tau_{\mathrm{H}} = -\ln\left(\frac{\left(\mathrm{d}\theta_{\mathrm{set;H;low}} - \mathrm{d}\theta_{\mathrm{float}}\right)}{\left(1 - \mathrm{d}\theta_{\mathrm{float}}\right)}\right) \tag{22}$$

we can write as final step:

If $f_{\mathrm{H;red;low}} > 1$, or if $\mathrm{d}\theta_{\mathrm{float}} > \mathrm{d}\theta_{\mathrm{set;H;low}}$ or in case of switch off of the heating:

Mean temperature over the whole period of reduction is (as shown above, for $\Delta t_1 = \Delta t_{\mathrm{H;red}}$; slightly reorganized formula):

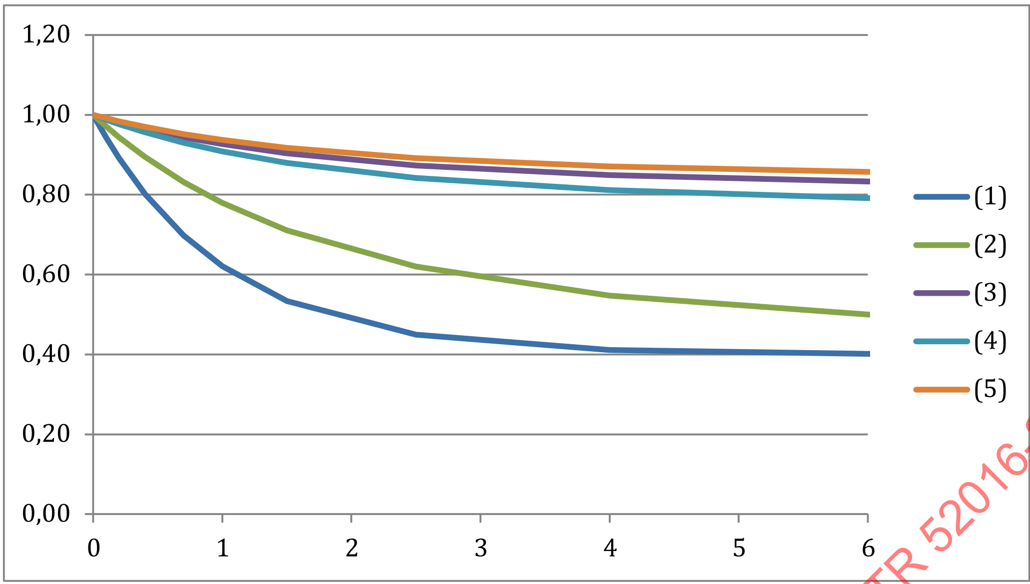
$$\mathrm{d}\theta_{\mathrm{H;red;mn}} = \mathrm{d}\theta_{\mathrm{float}} + \frac{\left(1 - \mathrm{d}\theta_{\mathrm{float}}\right)}{\left(\Delta t_{\mathrm{H;red}} / \tau_{\mathrm{H}}\right)} \cdot \left(1 - \mathrm{e}^{-\left(\Delta t_{\mathrm{H;red}} / \tau_{\mathrm{H}}\right)}\right) \tag{23}$$

In other cases:

Mean temperature over the whole period of reduction

$$\mathrm{d}\theta_{\mathrm{H;red;mn}} = \frac{\left(1 - \mathrm{d}\theta_{\mathrm{set;H;low}}\right)}{\left(\Delta t_{\mathrm{H;red}} / \tau_{\mathrm{H}}\right)} + f_{\mathrm{H;red;low}} \cdot \mathrm{d}\theta_{\mathrm{float}} + \left(1 - f_{\mathrm{H;red;low}}\right) \cdot \mathrm{d}\theta_{\mathrm{set;H;low}} \tag{24}$$

NOTE 3 Maybe the value for $\Delta t/\tau$ is useful as parameter to determine the boundary between this decay method and the long periods of unoccupancy according to ISO 52016-1:2017, 6.5.9.2.3.



Key

(1) Momentary decay of the indoor-outdoor temperature difference as function of t_{red}/τ_H

(2) Time average decay of indoor-outdoor temperature difference from start of decay as function of t_{red}/τ_H;

(3)-(5) Same as (2), but weighted over the periods without and with intermittency. This is $a_{red;H}$

(3) Example for night time temperature set back (here: 7 times per week, duration 8 hours);

(4) Example for day time temperature set back (here: 7 times per week, duration 10 hours);

(5) Example of weekend interruption (here: 1 time per week, duration 48 hours)

Figure 12 — Intermittent heating: Illustration of temperature decay as function of ratio between time and time constant

6.6.12.8 Examples

No reduced set point, but switch off:

Table 4 — Intermittent heating examples 1 and 2

	Example 1:	τ_H	20	**Example 2:**	τ_H	100
		γ_H	0,4		γ_H	0,4
	Night set back	**Daytime set back**	**Weekend set back**	**Night set back**	**Daytime set back**	**Weekend set back**
$\Delta t_{H;red;y}$	8	10	48	8	10	48
$n_{rep;red;y}$	7	7	1	7	7	1
$f_{H;red;y}$	0,33	0,42	0,29	0,33	0,42	0,29
$\Delta t_{H;red;y}/\tau_H$	0,40	0,50	2,40	0,08	0,10	0,48
$d\vartheta_{float}$	0,40	0,40	0,40	0,40	0,40	0,40
$d\theta_{H;red;mn;y}$ without lower limit	0,89	0,87	0,63	0,98	0,97	0,88
$d\theta_{H;red;mn;y}$	0,89	0,87	0,63	0,98	0,97	0,88
$a_{H;red;y}$	0,96	0,95	0,89	0,99	0,99	0,96
The content of the blanc cells is input; the content of the grey shaded cells is calculated						

Table 5 — Intermittent heating examples 3 and 4

	Example 3:	τ_H	20	Example 4:	τ_H	100
		γ_H	0,4		γ_H	0,4
	Night set back	**Daytime set back**	**Weekend set back**	**Night set back**	**Daytime set back**	**Weekend set back**
$\Delta t_{H;red;y}$	8	10	48	8	10	48
$n_{rep;red;y}$	7	7	1	7	7	1
$f_{H;red;y}$	0,33	0,42	0,29	0,33	0,42	0,29
$\Delta t_{H;red;y}/\tau_H$	0,40	0,50	2,40	0,08	0,10	0,48
$d\vartheta_{float}$	0,40	0,40	0,40	0,40	0,40	0,40
$d\vartheta_{set;H;low;y}$	0,70	0,80	0,60	0,70	0,80	0,60
$d\theta_{H;red;mn;y}$ without lower limit	0,89	0,87	0,63	0,98	0,97	0,88
$\Delta t_{H;red;low;y}/\tau_H$	0,69	0,41	1,10	0,69	0,41	1,10
$f_{H;red;low;y}$	1,73	0,81	0,46	8,66	4,05	2,29
$d\theta_{H;red;mn;y}$ until lower limit	--	0,89	0,76	--	--	--
$d\theta_{H;red;mn;y}$	0,89	0,88	0,68	0,98	0,97	0,88
$a_{H;red;y}$	0,96	0,95	0,91	0,99	0,99	0,96
The content of the blank cells is input; the content of the grey shaded cells is calculated.						

NOTE For old buildings we would expect the reduction factor for night set back to be in the order of 0,9.

6.6.12.9 Combinations

Table 6 — Combined heating intermittencies

Temperature set back	**Example 3**	**Example 4**
7 times per week: day time plus night time	0,91	0,98
	Example 5	**Example 6**
5 times per week: day time plus night time	0,94	0,99
5 times per week: day time plus night time plus 1 time per week: weekend	0,85	0,95
The content of the blank cells is input; the content of the grey shaded cells is calculated.		

6.6.12.10 Corrections for intermittency, cooling

For intermittent cooling, the daytime is obviously more relevant than the night time. Even when there are no or less temperature requirements during the daytime (in case of absence of occupants during daytime), the day time thermal balance will have a large influence on the evening and night time internal temperature (unless in case of very light constructions).

Consequently, the reduction factor for cooling uses the number of consecutive intermittency days as parameter.

In the case of cooling the reduction factor remains a reduction factor to the energy need for cooling, because the indoor outdoor temperature difference is not the driving force (there may be cooling need even if the temperature difference is zero).

6.6.12.11 Problem

However, for similar reasons as discussed for heating above, the formula needed to be changed and simplified.

Moreover, the calculation of the energy need for cooling by a monthly calculation method requires extra precaution anyway, because of the issues mentioned above.

6.6.12.12 Solution

The simplification is to omit the thermal inertia as parameter, because the effect of thermal inertia is not straightforward and cannot be predicted without hourly calculation of all the hourly phenomena listed above.

NOTE 1 This does not mean that the thermal inertia is not an important parameter to calculate the monthly energy need for cooling; this is expressed by the utilization factor curves.

Typically the time constant of a building is less than circa five days. Therefore, and because the most obvious application is in distinguishing different occupancy periods per week, it makes sense to use a simple formula that relates the reduction factor to the number of days in the week with no cooling needs.

NOTE 2 In case of reduced cooling set point during parts of the day, one assumes switch off and accept that the result is not accurate, or use an hourly calculation method.

This leads to the formula given in ISO 52016-1.

The default value for the empirical correlation factor $b_{\mathrm{C;red}}$ is based on comparison of hourly calculations with and without weekend interruption, using the test cases of EN 15265 [9], applied on three different climates (see ISO 13790:2008, Annex H).

Table 7 — Example cooling intermittence

$\Delta t_{\mathrm{C;red;wknd}}$	48
$f_{\mathrm{C;red;wknd}}$	0,29
$b_{\mathrm{C;red;wknd}}$	0,30
$a_{\mathrm{C;red;wknd}}$	0,80
The content of the blank cells is input; the content of the grey shaded cells is calculated	

NOTE 3 Indeed, with this simple formula, the value of $a_{\mathrm{C;red;wknd}}$ is a constant. For the monthly method a more accurate result is not justified.

6.6.13 Overheating indicator

When there would be no gains in a building, its temperature would never increase above the temperature set-point. However, at times when the instantaneous total internal and solar heat gains raise above the instantaneous heat losses, higher temperatures occur. These excess heat gains do not immediately contribute to the heating needs, but cause overtemperatures.

So, in short, overheating is the result of (solar and internal) heat gains that are not utilized to decrease the heating needs and which are not passively or actively cooled away.

When these superfluous heat gains are divided by the overall transmission and ventilation heat loss coefficient of the building, the time-integrated overtemperatures are obtained. As this value becomes larger and larger, also the thermal comfort temperature gets more often exceeded. Extensive parameter studies (see [36] to [40]) have shown that there is a good correlation between the thermal discomfort and large values of the normalized non-useful gains. They can therefore be used as overheating indicator. This indicator is also shown in K.4 of this document.

However, the main occurrence for overheating is in months where there is no heating. Therefore, it makes no sense to "fabric" a heating, just to get a gain utilization factor, as proposed in studies mentioned above. Moreover, if there is no heating, the gain utilization factor is known: it is simply equal to $(1/\gamma_{H;gn})$. Moreover, in case of heating the "overheating" is "corrupted" by the intermittency of the heating: if the temperature remains higher than the lower set-point, it is automatically included in the overheating indicator. For that reason this is better called "superfluous heat" than "overheating".

So, because the main occurrence for overheating is in months where there is no heating we can make it more simple and just take the total balance as shown in K.3. In short: heat balance if no heating or cooling:

$$H_{ht} \cdot \left(\theta_{int;set} - \theta_{e}\right) + H_{ht} \cdot \left(\theta_{int;mn} - \theta_{int;set}\right) = Q_{gn} \quad (25)$$

If we then use the set-point and boundary conditions for cooling, the calculation is done

Note that there is *no conflict* with the formula using the gain utilization factor as proposed and validated in studies mentioned above; but in case of no heating the latter simply converts to the first.

So the monthly mean temperature increase above the cooling set-point is well suited as a first order overheating indicator. A maximum value can be specified in project specifications or public regulations. Above a (lower) threshold value, fictitious cooling can be taken into account (cf. ISO 52018-1[12] and ISO/TR 52018-2[15]). Appropriate maximum and threshold values can be determined by establishing the correlation between the value of the overheating indicator and discomfort as determined by hourly calculations for a wide range of cases (geometry, thermal insulation level, ventilation rates, thermal mass, internal gains, window area and shading, etc.).

The set of boundary conditions under option A allows for the valuation of specific design features to reduce the risk of overheating. Notably mobile solar shading and intensive ventilation for heat removal from the building. By applying typical values representative for warm periods, the maximum potential of these approaches are considered on a year-round basis. In reality, these anti-overheating means will of course not be used as intensively outside periods with overheating risks, but by establishing the proper correlation with the detailed, more realistic hourly simulations, useful maximum and threshold values can nevertheless be obtained.

6.6.14 Length of the heating and cooling season for operation of season-length-dependent provisions

No additional information beyond the accompanying document.

6.6.15 Humidification and dehumidification

This monthly method to calculate the latent energy need for humidification and dehumidification was added to ISO 52016-1 because a monthly method was requested by some countries in their comments to ISO/DIS 52016-1.

It is a simple method, using correlation factors. These factors highly depend on the climate. The values can be provided at national or regional level by a national data sheet according to the normative template in Annex A, replacing the informative default values provided in Annex B of ISO 52016-1.

7 Quality control in ISO 52016-1

7.1 Calculation report

A plot of e.g. weekly averaged energy needs against outdoor temperature is strongly recommended to obtain a quick impression of the important influential factors and to enable quick comparison with similar plots that are frequently used in real buildings as indication of the energy quality. See the discussion on the examples cases.

7.2 Hourly method: verification cases

7.2.1 Choice for BESTEST cases

A subset of the BESTEST cases as described in ASHRAE 140 [24] has been chosen as verification cases in ISO 52016-1.

There are two reasons for this choice:

— The calculation engine used to generate the reference results for the validation cases in ISO 13791 is not accessible and other software tools applied on the test cases were, according to the experts involved in the preparation of ISO 13791, not exactly in line with the calculation procedures of ISO 13791. Moreover, there are differences in the results for the same cases between ISO 13791 and ISO 13792.

— The relevant subset of BESTEST cases is similar to the test cases of ISO 13791, but well established since decades (several IEA ECBCS annexes and IEA SHC tasks), widely used worldwide, well described (e.g. ANSI/ASHRAE 140) and regularly extended with additional cases. The successive series of test cases are also very powerful as diagnostic tool. Renowned institutes participate in the set-up of the test cases. The calculation results of several renowned software tools are available for comparison. Examples of input data for BESTEST cases are available for several building simulation tools and within different ICT environments.

The “drawback” of the BESTEST cases is that there is no single reference “true” result and no acceptance criteria.

However, the hourly calculation procedures in ISO 52016-1 are fully described (‘prescribed’). This means that the results of the test cases should be the same for all users, if the same input data and boundary conditions are used. So there is no need to validate application of ISO 52016-1. As a consequence, the test cases and the results are presented in the document, not to *validate* the method, but to enable a *verification* by others (e.g. software developers).

Of course, as part of the *development* of this document, it is interesting to compare the results with the results available from the renowned software tools; some results are presented below.

The term “**validation**” is applicable if there are different calculation options. A method or tool is accepted if its results are within a given band width of reference results. The reference results are based on the results of a set of renowned software tools, and/or based on results of a higher order (more detailed or analytical) method (if applicable) and/or based on measurements (empirical validation, if feasible).

EXAMPLE ISO 10211 on detailed.

The term “**verification**” is applicable if the calculation procedures are fully described. With the aid of test cases it can be verified if a tool that is based on these procedures has correctly implemented the procedures.

The same BESTEST cases are also used for the validation of the procedures in ISO 52010-1[12], to calculate the distribution of solar radiation on a non-horizontal plane based on measured hourly solar radiation data on a horizontal surface. These results are presented in ISO/TR 52010-2[13]. The results of that calculation, the hourly irradiation at vertical planes of different orientation, are input for the validation tests of ISO 52016-1.

In the BESTEST cases the validation of the conversion to solar irradiance at vertical and tilted plane is an intrinsic part of the validation of the calculated energy loads and needs and internal temperatures. For the cases to verify against the hourly calculation procedures of ISO 52016-1 the solar irradiance at the vertical planes is part of the input data set. So in this case the verification related to the hourly method in ISO 52016-1 is separated from the verification of the solar conversion calculation procedures in ISO 52010-1.

7.2.2 Description of the verification test cases

The chosen BESTEST verification cases are described in ISO 52016-1. These include only case 600, 640, 900 and 940: lightweight and heavyweight base case and with temperature setback for heating. More details are given in 7.2.8.

7.2.3 Results of the verification test cases

The results are presented in ISO 52016-1:2017, 7.2.4.

7.2.4 Comparison with available BESTEST results of other programs

To build up extra confidence in the verification cases and results, the results of the verification cases can be compared with the results of the original reference calculation programs or other tools.

See results presented in 7.2.8.

However, note that, as extensively discussed in ASHRAE 140, each program has some more detailed and some more simplified elements in the calculation procedures. So the reference programs are not necessarily more precise than ISO 52016-1. For the same reason, the base cases use sometimes simplifying assumptions that would not be appropriate for ISO 52016-1. In the specifications in ISO 52016-1:2017, Clause 7, these are mentioned. So, in a perfect world, it would be needed to perform two different calculations per case:

a) for comparison: as close as possible to the case descriptions;

b) as verification cases for ISO 52016-1: slightly adapted to be more suitable for ISO 52016-1.

In ISO 52016-1 only option b) is chosen.

According to the BESTEST case input data, the convective fraction for heating and cooling has to be set to =1, which means: fully convective heating and cooling. This can have a significant effect on the results and is closely linked to the assumed thermostat setting, as discussed in ANSI/ASHRAE 140[24], B11.1. It could be investigated if it is not better to change this to 0,5 (in combination with the operative temperature for the temperature setting). See also discussion of the results on peak heating and cooling power.

7.2.5 Limited scope

The verification is restricted to the thermal balance calculation procedures and will not include special calculations. These can however relatively easy be verified by specific tests or analysis of the code. For instance on ground floor heat transfer, as introduced further on.

7.2.6 Specific deviations allowed

In addition to the application as verification of tools based on the hourly method in ISO 52016-1, the test cases can also be used as validation cases for methods that, concerning very specific aspects, deviate from the prescribed procedures in ISO 52016-1. See 7.3.

7.2.7 Availability of the data file with hourly values

Finally, both the building data and the hourly climatic data as the test case descriptions are free of copyright. The climatic data are measured data. The measured hourly solar irradiance values have been converted to solar irradiance at vertical and tilted plane. This is the object of ISO 52010-1[12] (see ISO/TR 52010-2[13]), as explained above. For the cases to verify against the hourly calculation procedures of ISO 52016-1 the solar irradiance at the vertical planes is part of the input data set. The thus created hourly climatic data file is made available as a free downloadable file at a dedicated location of the ISO web site, referenced in the standard.

7.2.8 More details on description of the verification test cases

In principle, ANSI/ASHRAE 140[24] provides for each BESTEST case a uniform and complete description.

However, as explained in ANSI/ASHRAE 140, there is always a need for tailoring the input. Different calculation methods use different types of input, because of a different ways of modelling (more simple or more detailed or simply different modelling). For instance: a calculation method that uses heat transfer coefficients at the external surface of building elements that are a function of local wind speed, could not be able to deal with prescribed fixed values, and vice versa. This is also the case for the hourly calculation procedures of ISO 52016-1. In that case ISO 52016-1 mentions the required input and –separately- the input chosen for the calculation according to ISO 52016-1.

Note that the selected BESTEST test cases do not include for instance:

- ground floor heat transfer coupled to ground;
- thermal coupling between two or more zones;
- the effect of thermal bridges;
- sunspace or other thermally unconditioned spaces;
- solar shading by external obstacles (distant, remote or from own building elements); and
- complex control patterns (e.g. weekend interruption of mechanical ventilation and/or heating and cooling and/or solar shading, etc.; night time ventilation as free cooling, heat recovery by pass, etc.).

The ground floor heat transfer was tested separately, as described above. In the selected BESTEST cases the heat transfer is decoupled from the ground.

The solar shading by external obstacles has been validated separately, see Annex F.

The other features can be tested analytically or require dynamic links with system related calculation standards.

7.2.9 Results of comparison with “reference” programs

See discussion and ‘disclaimer’ in 7.2.3 on the comparison with “reference” programs.

Figure 13 provides the main results of the Case 600 and 600FF (light weight cases). Case 600 concerns continuous heating and cooling; case 600FF is free floating (no heating or cooling).

Note that the climate is Denver (Col., USA), with quite cold but sunny winter and warm and sunny summer.

The results are similar for Case 900 and 900FF (heavy weight cases).

The results are also similar for the Case 640 and Case 940, with night time temperature set back.

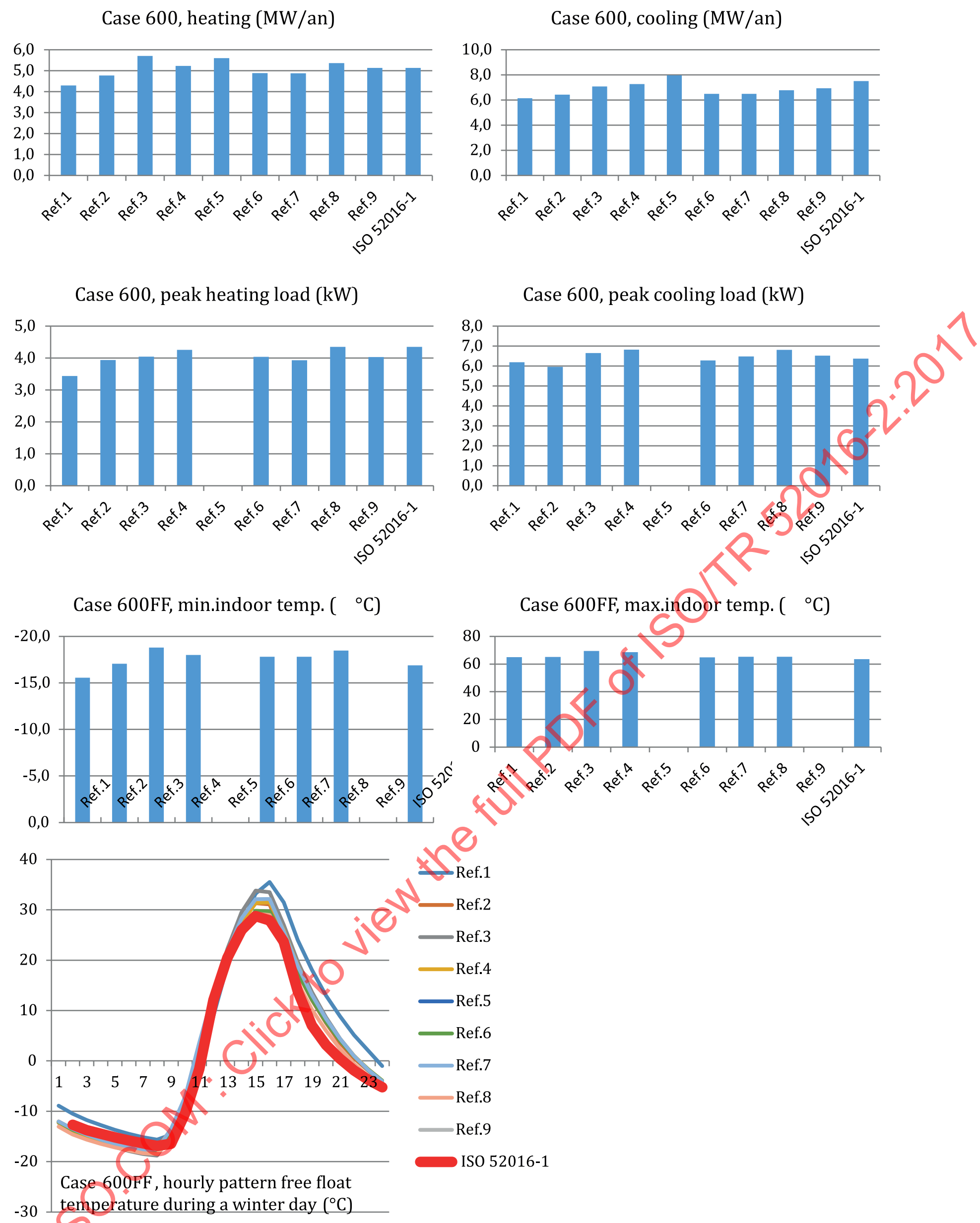


Figure 13 — BESTESTS: Main results for Case 600 and 600FF (lightweight), ISO 52016-1 compared with the available 9 reference tools

It also has to be taken into consideration that not each software program whose results are available for the comparison use nowadays state-of-the-art algorithms (in that sense these are not reference results). This is because these base cases of the BESTEST series were created and tested many years ago.

7.2.10 Peak hourly loads

The result of comparison of **peak hourly heating load** against the “reference” programs for Case 940 (heavy weight, night set back) is the only result that shows a significant discrepancy:

ISO 52016-1, 8 kW, with the reference programs between 4,0 kW and 6,4 kW.

Probably this is the result of the fact that in ISO 52016-1 the operative temperature is used for the set-point. This requires much more power than only heating the air. It is obvious that heating up only the air temperature to the set-point and disregarding a low mean radiative temperature does not lead to the thermal comfort that is expected by the occupants and required by the standard conditions of use or expected from the calculation of the system capacity under design conditions.

The peak hourly cooling load does not show a significant discrepancy, so it is especially for the fast heating up after night set back (in the given cold climate!) that this phenomenon occurs.

7.3 Hourly method: validation in case of specific alternative calculation procedures

In addition to the application as verification of tools based on the hourly method in ISO 52016-1, the test cases can also be used as validation cases for methods that, concerning very specific aspects, deviate from the prescribed procedures in ISO 52016-1. Typical details where deviations could be allowed, if safeguarded by validation, without jeopardizing the reproducibility and transparency of the standard are:

— the calculation of the view factors for thermal (longwave) radiation exchange between the surfaces in the thermal zone; and

— the subdivision of each construction elements into a number of nodes of thermal resistances and capacitances.

In that case, as explained in ISO 52016-1, the kind of deviation is reported as well as the results of the test cases (difference compared to the results according to the standard).

The list of acceptable deviations from the standard method is kept limited to those deviations that can be assumed to have very limited influence on the calculation results. Otherwise it would be necessary to provide acceptance criteria, which is far from trivial (not even available from the base cases from the BESTESTS).

7.4 Specific validation cases

7.4.1 Heat transfer through ground floor

The selected validation/verification cases do not comprise ground-floor heat transfer or heat transfer to adjacent enclosed spaces. This is no problem as long as the fully prescribed calculation procedures of these details are followed carefully.

Special attention has been paid to testing the link with the procedures to calculate the thermal transmission through the **ground floor**, taking into account the inertia of the ground. These procedures are given in ISO 13370[17], for monthly or seasonal calculation methods, but also for hourly calculation methods (based on dynamic simulations as described in the accompanying Technical Report, ISO/TR 52019-2 [18]). Because of the dynamic, time dependent interactions, these procedures were also integrated in the spreadsheet for ISO 52016-1.

With minor adaptations in ISO 13370 compared to the 2007 version, the calculation procedures of ISO 13370 have been proven to work as intended as input for the monthly and hourly building calculations of ISO 52016-1. See extensive explanation in 6.5.8 (hourly method) and 6.6.5 (monthly method).

The example cases presented in Clause 9 include ground floor heat transfer. These examples (with different climatic conditions) formed part of the validation of the calculation procedures for thermal transmission through the ground floor.

7.4.2 Solar shading

See Annex F.

8 Compliance check in ISO 52016-1

The aim of this common clause for each EPB standard is to provide procedures that enable to check if the calculation procedure is applicable and/or has been applied correctly and that the calculation assumptions, in particular the input data, are correct. In ISO 52016-1, most of the input is gathered through other EPB standards; relevant procedures for compliance check are provided in those standards. If serious errors are made in the input data, this often shows quickly in the results, especially when examining the special monthly output data such as the monthly solar and internal gains, monthly heat flow by thermal transmission and by ventilation, monthly gain and heat transfer utilization factors (used in the monthly method; generated in the hourly method) plus, for the hourly method: the hourly plots of the main quantities for a few selected weeks and the weekly average energy needs for heating and cooling plotted against the outdoor temperature (energy signature). See examples in Clause 9 and Annex L.

9 Worked out examples on ISO 52016-1

9.1 Example 1

9.1.1 Description

Example 1 represents a single family house with ground floor and heated attics. House is without cellar. It has 150 m^2 net heated area, 345 m^3 net heated volume and 483 m^3 gross volume. Area of envelope circumcising heated volume is 386 m^2 and it consists of floor on the ground, facade, windows, doors, pitched roof and horizontal ceiling towards unheated roof space.

9.1.2 Description of construction elements of envelope

Table 8 — Construction element: Facade

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K))	Specific heat (J/(kg·K))
Plaster	2,5	1 700	0,85	1 050
Brick	19	1 400	0,61	920
XPS	15	30	0,038	1 500
Plaster	0,3	1 600	1,00	1 050
Final layer	0,3	1 600	0,87	1 050

Thermal transmittance (U_{eli} – W/(m^2·K)	0,224
Thermal resistance (R_{eli} – m^2·K/W)	4,294
1/R [W/(m^2·K)]	0,223
$K_{m;eli}$ [J/(m^2·K)]	306 000
$a_{sol;eli}$	0,8
$g_{w;eli}$	-

Table 9 — Construction element: floor between heated spaces

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K)	Specific heat (J/(kg·K))
Flooring (wood)	2	700	0,210	1 670
Concrete	5	2 200	1,400	1 050
XPE foam	0,5	50	0,041	1 260
XPS	6	32	0,035	1 050
Concrete	14	2 400	2,040	960

Thermal transmittance (U_{eli} – W/(m^2·K))	0,421
Thermal resistance (R_{eli} – m^{2}K/W)	2,035
1/R [W/(m^2·K)]	0,491
$K_{m;eli}$ [J/(m^2·K)]	464 000
$a_{sol;eli}$	0,8
$g_{w;eli}$	-

Table 10 — Construction element: horizontal ceiling towards unheated roof space

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K)	Specific heat (J/(kg·K))
Gypsum board	1,5	900	0,210	840
PE foil	0,02	1 000	0,190	1 250
Mineral wool	30	23	0,034	940
Wood fibre board	1,8	600	0,099	2 090

Thermal transmittance (U_{eli} – W/(m^2·K))	0,108
Thermal resistance (R_{eli} – m^{2}K/W)	9,08
1/R [W/(m^2·K)]	0,110
$K_{m;eli}$ [J/(m^2·K)]	40 000
$a_{sol;eli}$	-
$g_{w;eli}$	-

Table 11 — Construction element: pitched roof

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K)	Specific heat (J/(kg·K))
Gypsum board	1,5	900	0,210	840
PE foil	0,02	1 000	0,190	1 250
Mineral wool	30	23	0,034	940
PE foil	0,04	450	0,190	960

Thermal transmittance (U_{eli} – W/(m^2·K))	0,110
Thermal resistance (R_{eli} – m^{2}K/W)	8,898
1/R [W/(m^2·K)]	0,112
$K_{m;eli}$ [J/(m^2·K)]	17 500
$a_{sol;eli}$	-
$g_{w;eli}$	-

Table 12 — Construction element: internal wall

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K)	Specific heat (J/(kg·K))
Plaster	2	1 700	0,850	1 050
Brick	19	1 200	0,520	920
plaster	3	1 700	0,850	1 050

Thermal transmittance (U_{eli} – W/(m^2·K))	1,772
Thermal resistance (R_{eli} – m^{2}K/W)	0,424
1/R [W/(m^2·K)]	2,358
$K_{m;eli}$ [J/(m^2·K)]	299 000
$a_{sol;eli}$	-
$g_{w;eli}$	-

Table 13 — Construction element: floor on the ground

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K)	Specific heat (J/(kg·K))
Ceramic tiles	1	2 300	1,280	920
Concrete	5	2 200	1,400	1 050
XPE foil	0,5	50	0,041	1 260
XPS	20	32	0,040	1 500
Bituminous water barrier	1	1 100	0,190	1 460

Thermal transmittance (U_{eli} – W/(m^2·K))	0,187
Thermal resistance (R_{eli} – m^{2}K/W)	5,263
1/R [W/(m^2·K)]	0,190
$K_{m;eli}$ [J/(m^2·K)]	162 000
$a_{sol;eli}$	-
$g_{w;eli}$	-

Construction element: window

Double low-E glazing, 5 chamber PVC profile

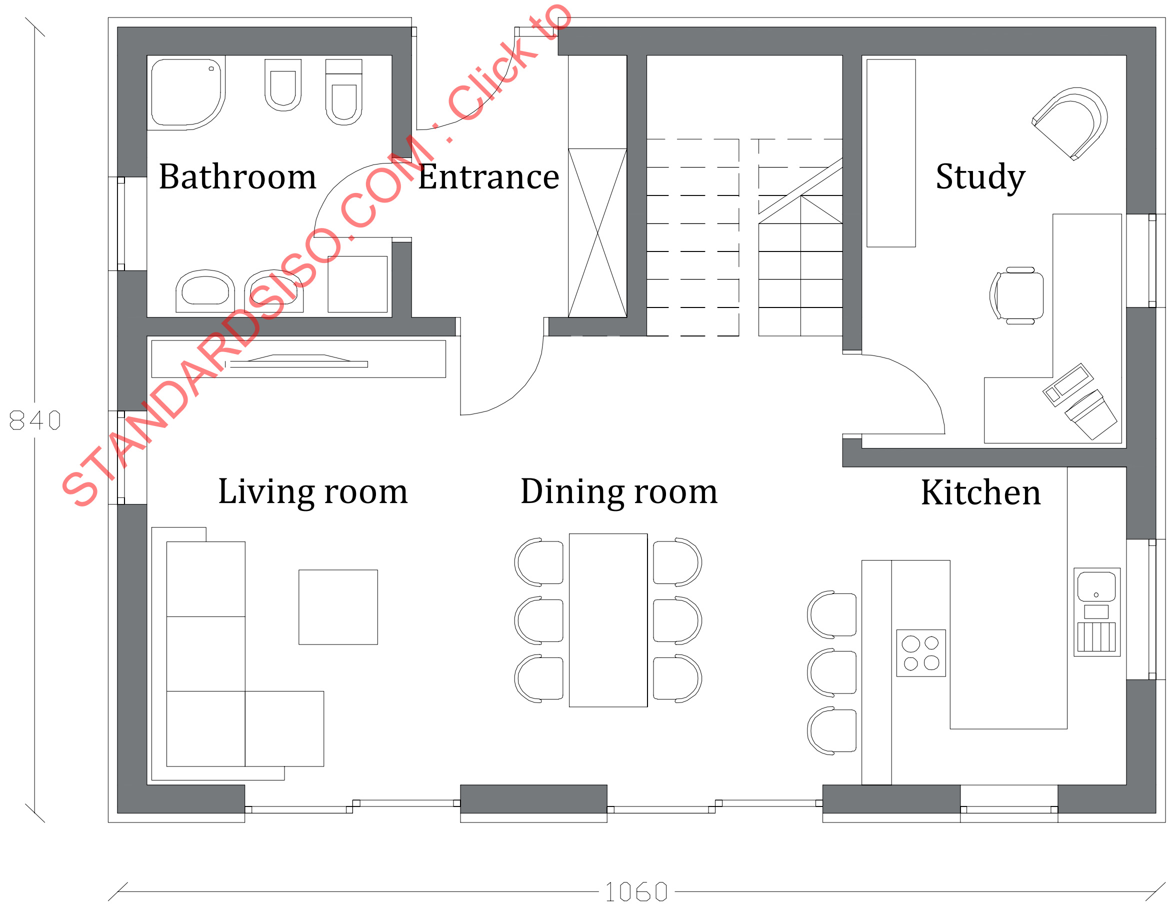
Thermal transmittance (U_{eli} – W/(m^2·K))	1,1
Thermal resistance (R_{eli} – m^{2}K/W)	-
1/R [W/(m^2·K)]	-
$K_{m;eli}$ [J/(m^2·K)]	-
$a_{sol;eli}$	-
$g_{w;eli}$	0,68

glass area (%)	70
Construction element: door	
Thermal transmittance (U_{eli} – W/(m²·K))	1,3
Thermal resistance (R_{eli} – m²K/W)	-
1/R [W/(m²·K)]	-
$K_{m;eli}$ [J/(m²·K)]	-
$a_{sol;eli}$	0,8
$g_{w;eli}$	-

Table 14 — Areas of construction elements (m²)

Element	tilt	N	E	S	W	Horizontal
Facade	V	41,3	40,7	32,2	39,8	
Incl. roof	40°	30,9		30,9		
Ceiling	H					55
Window	V		4,88	11,80	5,80	
Door	V	2,70				
Floor/ground	H					91,8
Floor/heated	H					85
Internal wall	V	70				

Other data



Max heating power:	12 kW
Max. Cooling power:	5 kW
Air exchange:	1,15 m^3/(h·m^2)

Figure 14 — BESTESTS: Example 1, floor plan ground floor

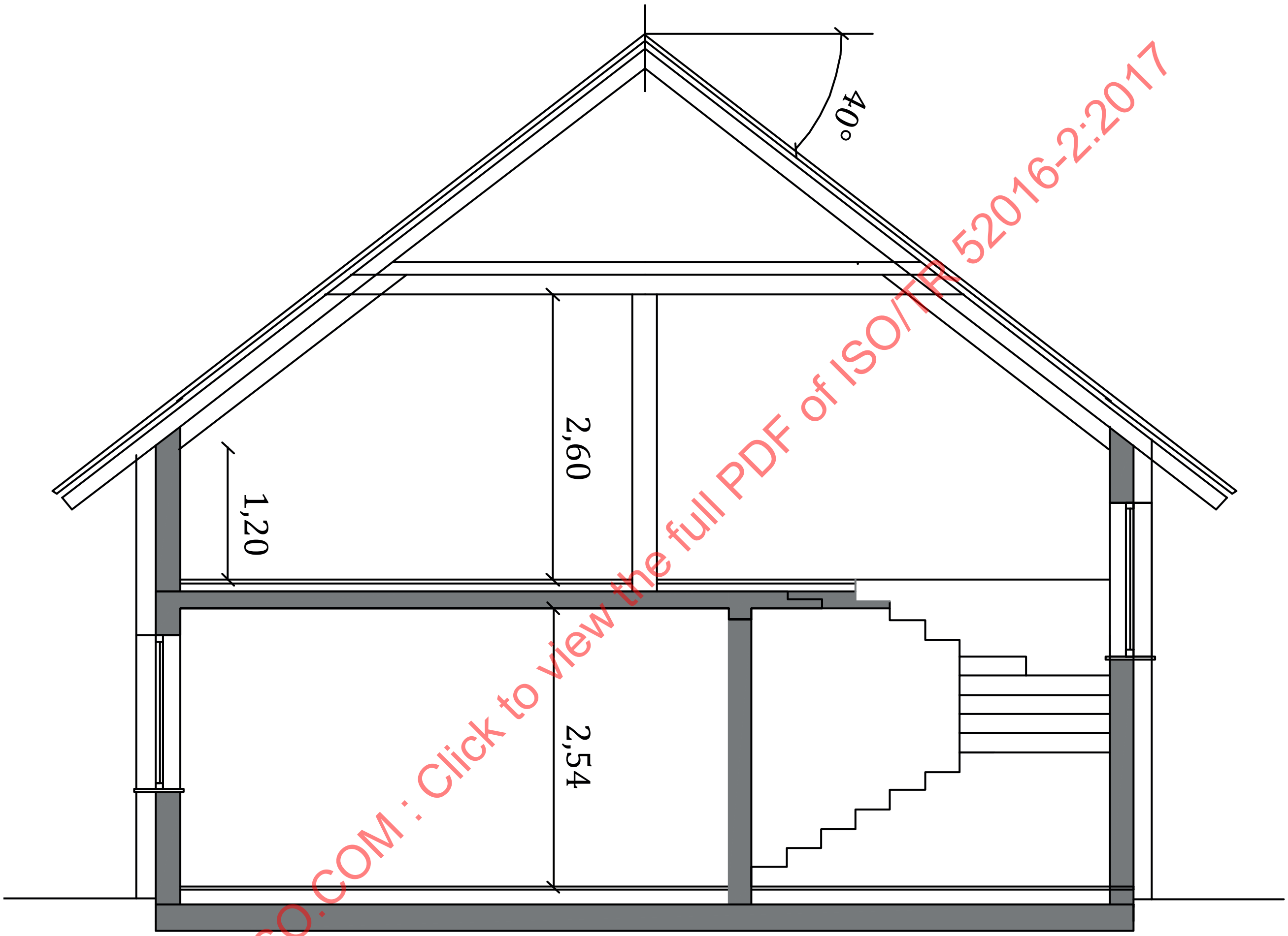


Figure 15 — Example 1, vertical cross section

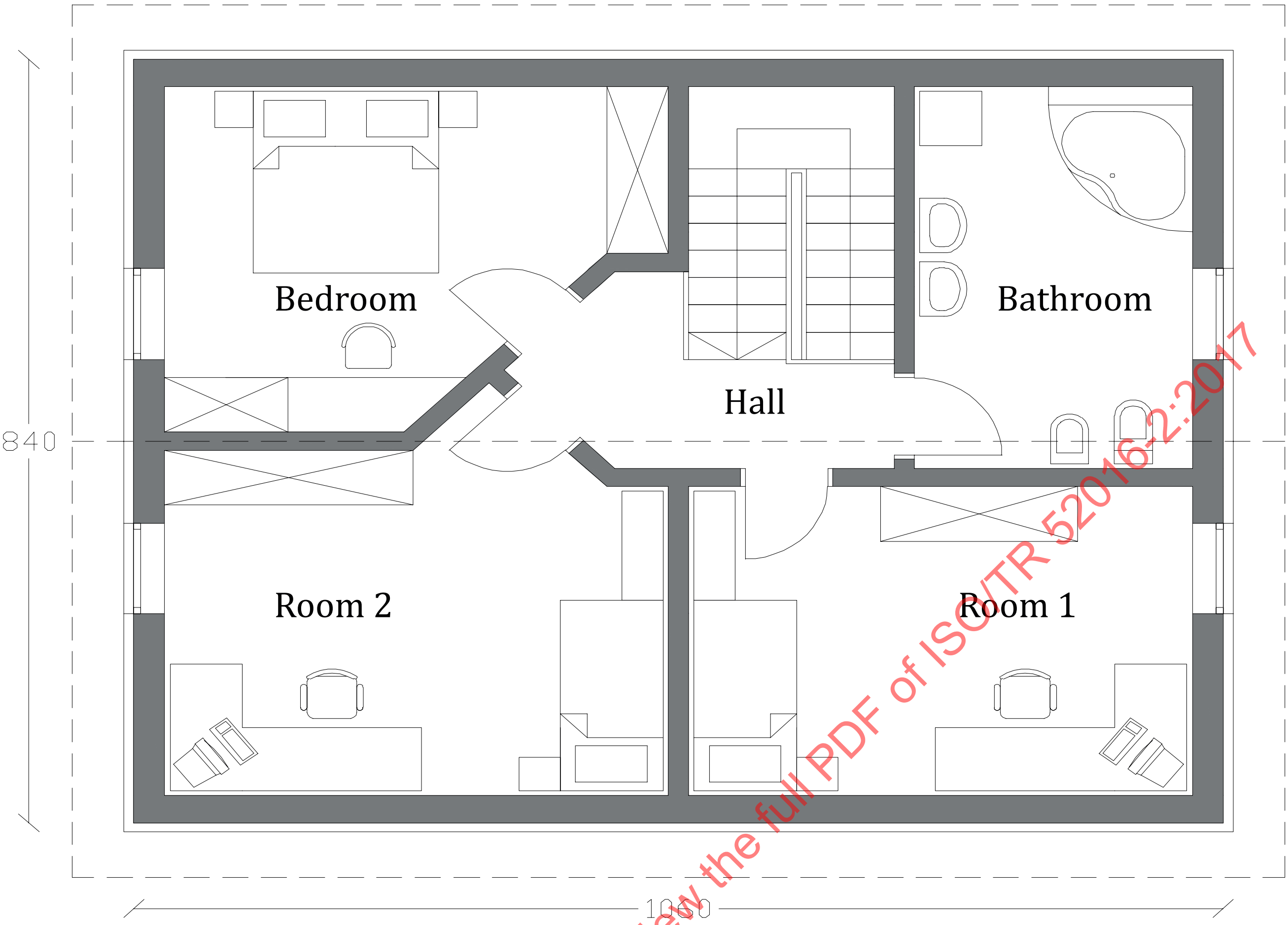


Figure 16 — Example 1, floor plan second floor

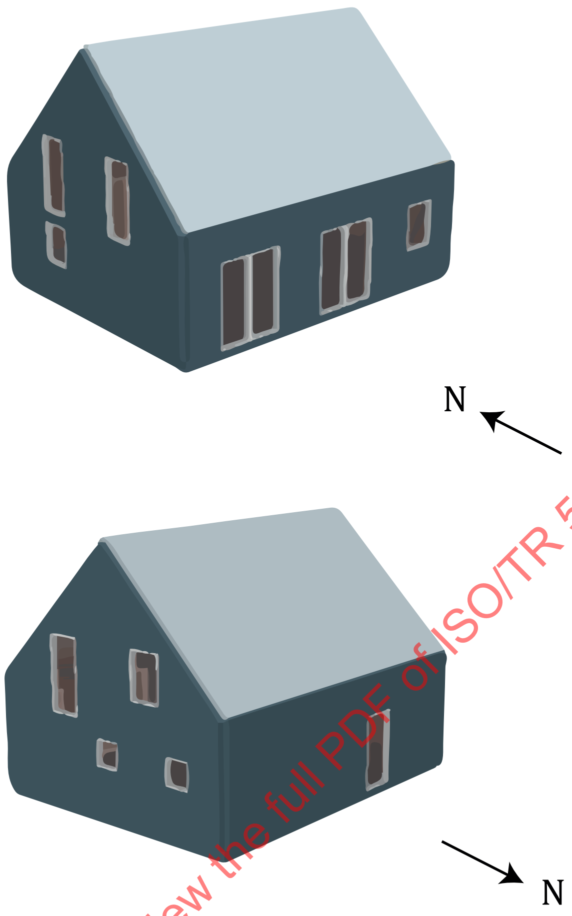


Figure 17 — Example 2, overview

9.1.3 Calculation details

The results are presented in Annex L.

9.1.4 Remarks and comments

This example is also offered for use at EPB overarching level (ISO 52000-1, ISO/TR 52000-2). For this example also a version consisting of two thermal zones has been prepared, to demonstrate the transfer of data between thermal zones and system service areas at EPB overarching level.

9.2 Example 2

9.2.1 Description

Example 2 represents a dwelling in the middle of bigger building with 2 external walls and adiabatic ceiling, floor and 2 walls. It has 80,1 m^2 net heated area, 208 m^3 net heated volume and 276 m^3 gross volume. Area of external envelope of heated volume is 41,2 m^2 and it consists of floor on the ground, facade, windows,

9.2.2 Description of construction elements of envelope

Table 15 — Construction element: Facade

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K))	Specific heat (J/(kg·K))
Concrete	20	2 400	2,040	960
EPS	15	20	0,038	1 260
Plaster	0,2	1 450	0,700	1 050
Final layer	0,2	1 450	0,700	1 050

Thermal transmittance (U_{eli} – W/(m^2·K))	0,237
Thermal resistance (R_{eli} – m^{2}K/W)	4,049
$1/R$ [W/(m^2·K)]	0,247
$K_{m;eli}$ [J/(m^2·K)]	471 000
$a_{sol;eli}$	0,8
$g_{w;eli}$	-

Table 16 — Construction element: internal wall

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K))	Specific heat (J/(kg·K))
Concrete	20	2 400	2,040	960
Mineral wool	2	80	0,034	940
Gypsum board	1,5	900	0,210	840

Thermal transmittance (U_{eli} – W/(m^2·K))	0,992
Thermal resistance (R_{eli} – m^{2}K/W)	0,833
$1/R$ [W/(m^2·K)]	1,200
$K_{m;eli}$ [J/(m^2·K)]	473 000
$a_{sol;eli}$	-
$g_{w;eli}$	-

Table 17 — Construction element: floor/ceiling

Material	Thickness (cm)	Density (kg/m^3)	Thermal conductivity (W/(m·K))	Specific heat (J/(kg·K))
Flooring (wood)	2,2	700	0,210	1 670
Concrete	7	2 200	1,400	1 050
XPE foam	0,5	50	0,041	1 260
EPS	4	20	0,038	1 260
Concrete	20	2 400	2,040	960

Thermal transmittance (U_{eli} – W/(m^2·K))	0,597
Thermal resistance (R_{eli} – m^{2}K/W)	1,500
1/R [W/(m^2·K)]	0,667
$K_{m;eli}$ [J/(m^2·K)]	650 000
$a_{sol;eli}$	-
$g_{w;eli}$	-

Construction element: window

Double low-E glazing, 5 chamber PVC profile

Thermal transmittance (U_{eli} – W/(m^2·K))	1,1
Thermal resistance (R_{eli} – m^{2}K/W)	-
1/R [W/(m^2·K)]	-
$K_{m;eli}$ [J/(m^2·K)]	-
$a_{sol;eli}$	-
$g_{w;eli}$	0,68
glass area (%)	70

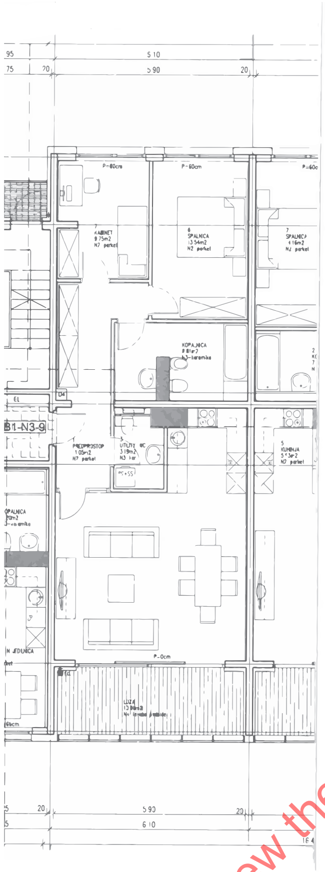
Construction element: internal door

Thermal transmittance (U_{eli} – W/(m^2·K))	2,5
Thermal resistance (R_{eli} – m^{2}K/W)	-
1/R [W/(m^2·K)]	-
$K_{m;eli}$ [J/(m^2·K)]	-
$a_{sol;eli}$	-
$g_{w;eli}$	-

Table 18 — Areas of construction elements (m^2)

Element	tilt	N	E	S	W	Horizontal
Façade	V	11,4	-	8,2	5,8	
Window	V	6,3		9,5		
Door	V				2,1	
Floor/heated	H					95,1
Ceiling	H					95,1
Internal wall	V	10				

9.2.3 Other data



Max heating power: 5 kW

Max. Cooling power: 2,5 kW

Air exchange: 1,72 $m^3/(h \cdot m^2)$

Figure 18 — Example 2, floor plan

9.2.4 Calculation details

Preliminary results are available but not presented in Annex L, because no specific issues were found that add to the findings of example 1.

9.2.5 Remarks and comments

None.

10 Validation of the calculation procedures

This is a common clause for each EPB Technical Report.

The set up and results of validation and verification tests are provided in Clause 7 (parallel to ISO 52016-1:2017, Clause 7).

Annex A
(informative)

ISO 52016-1: Input and method selection data sheet — Template

A.1 General

This subclause in the accompanying standard is a common subclause for all EPB standards. In ISO 52016-1 it is a normative annex.

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 standard is a common subclause for all EPB standards.

If ISO 52016-1 is adopted (e.g. in national regulations), then also all the normative references (in Clause 2) to other standards are adopted, including the (referenced parts of the) standards that are not or not yet published or do not have a national data sheet yet. Sometimes this causes a problem.

To solve this problem, the references to other EPB standards are placed in the input and method selection data sheet. In the normative Annex A, the template for the normative references to other EPB standards is given (Table A.1), and the default references (in casu: the EPB standards) are provided in the informative Annex B (Table B.1), according to the template in Annex A.

These informative default choices can be replaced by a national datasheet according to the template in Annex A, replacing the references in Annex B. This national data sheet can replace the default choices by references to national standards that are in line with the set of EPB standards, or to tables or with other alternatives. However, this can only be done if the input-output matches!

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) of the accompanying standard is given in ISO/TR 52000-2.

A.3 Selection of main method

No additional information beyond the accompanying standard.

A.4 Zoning

No additional information beyond the accompanying standard.

A.5 Hourly calculation procedures

No additional information beyond the accompanying standard.

A.6 Monthly calculation procedures

No additional information beyond the accompanying standard.

Annex B
(informative)

ISO 52016-1: Input and method selection data sheet — Default choices

B.1 General

This subclause in the accompanying standard 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.

In ISO 52016-1:2017, Annex B, deliberate (informative default) choices were made on simplifications aiming at a balance between accuracy and the feasibility or the required effort to obtain reliable input data. For instance:

— simple method to adjust the set point temperature in residential buildings taking into account moderately versus fully conditioned spaces;

— no specification of internal partitions;

— solar absorption coefficient of the external surfaces of building elements: no differentiation in colour;

— fixed value for specific heat capacity of air and furniture;

— fixed value for the difference between external air temperature and sky temperature;

— no moisture absorption and desorption in materials (walls, furniture, etc.); methods to calculate this effect are described in [41] and [42] (IEA Annex 41);

— window frame area: either the actual or a fixed frame fraction can be chosen; but the choice is for all windows, because otherwise it would lead to “shopping” for each window to see whether the default or the actual frame fraction would be more favourable; fixed frame fraction is preferred, for simplicity and to avoid uncertainties introduced by the measurements;

— fixed correction and weighting factor for the total solar energy transmittance for non-scattering and scattering transparent glazings and blinds;

— shading objects from the own building are only taken into account for transparent building elements (glazing); and

— no differentiation of solar reflectivity of surrounding buildings: although physically relevant, it would introduce a lot of extra input data, with high uncertainty, which are difficult to verify and impossible to maintain.

B.2 References

The references, identified by the module code number, are given in ISO 52016-1:2017, Table B.1.

It is possible for each module to replace an EPB standard with a national standard or even a table with fixed input and output values, as long as all input and output data from the replaced standard are available. The input and output data can be found in Clause 6 of each EPB standard.

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 Selection of main method

No additional information beyond the accompanying standard.

B.4 Zoning

No additional information beyond the accompanying standard.

B.5 Hourly calculation procedures

Explanation on some specific choices of default input data:

Table B.11: Convective fractions (hourly method only):

Justification of the default values for the convective fractions:

— for the internal heat gains into the zone, $f_{int;c}$: most internal heat gains dissipate heat at a temperature and from a surface that the heat transfer by convection and by thermal radiation are in the same order of magnitude. As arbitrary value the value 0,4 has been chosen. The result (energy needs for heating and cooling) is very insensitive for the choice, unless the value is more extreme (close to 0 or close to 1), which is not the case.

— for the solar radiation into the zone, $f_{sol;c}$: the solar radiation entering the building zone through the windows will be absorbed by the internal shading devices (if any) or glass curtains, by furniture and plants and by the internal surfaces; partly directly and partly after multiple reflections. Solar heat absorbed by furniture and plants is assumed to be mostly and quickly converted to convective heat. A rough estimate is that the resulting heat transfer by convection and by thermal radiation are in the same order of magnitude. Therefore, originally an arbitrary value of 0,4 was chosen. As a result of comment on the draft standard, the value has been changed to 0,1. The result (energy needs for heating and cooling) is very insensitive for the choice, unless the value is more extreme (close to 0 or close to 1), which is not the case. The fraction of solar radiation entering the zone that leaves the zone without absorption (through one or more windows) is assumed to be zero. In practice this amount may be not negligible (e.g. when two windows face each other), but taking this into account would require more input data: the position of each building element.

— for the heating system into the zone, $f_{H;c}$: again an arbitrary value of 0,4. Evidently this directly depends on the type of emitters (air heating, convectors, radiators) and (for radiators) it depends on the operating temperature. There is no objection against using that particular information instead of the default value, as long as it has been checked whether there are no other related and still unknown factors which have an effect of the same order of magnitude. In that case the higher accuracy would be a fake accuracy. Such factors can be: (for radiators) variation in time of the mean radiator temperature, (general) horizontal and vertical temperature stratification, position of heat emitters, (for embedded floor heating) inertia, etc.

— for the cooling system into the zone, $f_{C;c}$: Similar arguments as for heating.

Table B.15: Solar absorption coefficient of external opaque surfaces:

A national choice is offered to use a fixed or a differentiated value for the solar absorption coefficient, α_{sol}.

When a differentiation is made in solar absorption coefficient, three categories are defined for the solar absorption coefficient of external opaque surfaces.

A more refined classification would not lead to a better accuracy, especially given the uncertainty in input data and the limited possibility for assessment and verification *in situ*.

NOTE These categories are the same as the categories in ISO 13791:2012, Table 5.

If no differentiation is made in solar absorption coefficient (e.g. for existing buildings) the category that is the most representative for the average buildings stock, can be chosen as fixed value for the solar absorption coefficient.

As default choice the value of an intermediate colour is taken as a fixed value, because it is assumed that this is a representative value for the average solar absorption coefficient.

Table B.17: Specific heat capacity of air and furniture

The default value for the specific heat capacity of air and furniture, $\kappa_{m;int;a}$, is based the following rough assumptions:

If the average net room height is assumed to be circa 2,4 m, the air mass per square metre of floor area is circa 3 kg. The thermal capacity for air is circa 1 000 J/(kg·K). This equals circa 3 000 J/(m^2·K). With thermal capacity of furniture added, the estimated specific heat capacity of air and furniture per m^2 floor area is in the order of 10 000 J/(m^2·K).

Table B.19: Average difference between external air temperature and sky temperature

Default values for the average difference between the external air temperature and the sky temperature, $\Delta\theta_{sk}$, for different climates are the same as the values given in ISO 13790:2008, 11.4.6.

It could be discussed to use in the hourly method varying difference between the external air temperature and the sky temperature. The question is then: would this require extra input from the user or could this be related to the hourly climatic data?

Table B.21: Frame area fraction

The default value for the frame area fraction, F_{fr}, is an average value of what is found in practice. An alternative would be to take different, conservative, values for heating and for cooling dominated periods (0,30 and 0,20 respectively), but then the values would be different during different parts of the (hourly or monthly) calculation.

NOTE The values are the same as the values given in ISO 13790:2008, 11.4.5.

Table B.22: Factors related to the solar energy transmittance

Default values for the correction factor for non-scattering glazing, F_{w},.

For solar shading devices such as Venetian blinds, the weighting factor representative of the position of the window, climate and season, a_g, and the altitude angle, alt_g, are based on a moderate climate.

NOTE The values are the same as the values given in ISO 13790:2008, 11.4.2.

It could be discussed to use in the hourly method varying properties of the total solar energy transmittance, especially for Venetian blinds and other louvre type of solar shading provisions. But this would require additional input on the products.

B.6 Monthly calculation procedures

See B.5 (hourly method), because most of the explanation in B.5 is also valid for the input data for the monthly calculation method.

Annex C
(informative)

ISO 52016-1: Regional references in line with ISO Global relevance policy

ISO 52016-1:2017, Annex C, contains specific parallel routes in referencing standards, in order to take into account existing national and/or regional regulations and/or legal environments while maintaining global relevance.

Annex D
(informative)

ISO 52016-1: Multi-zone calculation with thermal coupling between zones

No additional information beyond the accompanying standard.

Annex E
(informative)

ISO 52016-1: Heat transfer and solar heat gains of windows and special elements

E.1 General

The subclauses E.4 to E.6 in this document contain informative calculation procedures for special elements, copied from ISO 13790:2008 and adapted to become consistent with the formulae in ISO 52016-1.

E.2 Windows

The reason for assuming, also for the hourly calculation procedures, constant (not solar angle dependent) solar properties for all transparent elements is given in 6.5.3 of this document.

E.3 Thermally unconditioned zone with internal or solar gains (including sunspace or atrium)

This calculation procedure has been revised compared to ISO 13790:2008:

— more uniformity between hourly and monthly calculation procedures; see also 6.4.5 of this document;

— more uniformity between thermally unconditioned zones in general, and thermally unconditioned zones with high solar gains (atria or sunspaces).

E.4 Opaque elements with transparent insulation

E.4.1 Heat transfer

For the calculation of the heat transfer, opaque elements with transparent insulation are treated as opaque construction elements.

E.4.2 Solar heat gains

E.4.2.1 General

The following applies to opaque building elements provided with transparent insulation material, designed to collect solar energy. The calculation method (origin: proposed by Platzer[43] and Richtlinie TWD[44] for ISO 13790:2004) quantifies the positive effect during the heating season. However, the same procedure is also used to calculate the solar gains for the cooling (summer) mode, taking into account any extra (seasonal) solar protection and ventilation provisions, if present.

The calculation procedure is simplified and is applicable to both the hourly and monthly calculation procedures. It produces for the hourly method component data as (adapted) input to the formula of 6.5.7.3.2 and for the monthly method an effective *g*-value as (adapted) input of ISO 52016-1:2017, 6.6.9.2.

E.4.2.2 Required input data

A total area of the element;

A_t area of the element covered with transparent insulation;

R_i thermal resistance of the opaque element behind transparent insulation;

R_t thermal resistance of transparent insulation;

$g_{t;\perp}$ total solar energy transmittance of transparent insulation (normal incidence);

$g_{t;hem}$ total solar energy transmittance of transparent insulation (diffuse-hemispherical incidence);

R_{al} thermal resistance of the air layer (enclosed) between the opaque element and transparent insulation;

R_{si} internal thermal surface resistance;

R_{se} external thermal surface resistance.

Depending on the type of transparent insulation, the following quantity is required (it is not required for products that include a solar absorber):

α_{sol} solar absorption coefficient of the opaque element behind transparent insulation.

E.4.2.3 Derived properties

U thermal transmittance of the element, from environment to environment;

U_{te} external thermal transmittance of the element, from the surface facing the transparent insulation product to the external environment;

g_t effective total solar energy transmittance of the transparent insulation component;

F_{fr} reduction factor due to non-transparent frame area of the transparent insulation (frame area fraction);

$g_{j;m}$ effective total solar energy transmittance for the complete element, for orientation *j* and month *m*.

E.4.2.4 Calculation method

The heat transfer is calculated in accordance with Clause 6, as for usual envelope elements, including possible thermal bridges in framed constructions. The solar heat gains of an opaque element with transparent insulation, having the orientation *j*, are calculated for month *m* in accordance with Clause 6.

The frame area fraction is determined from the total area, A, of the element:

$$F_{fr} = \frac{A_t}{A} \quad (E.1)$$

The following thermal transmittances are needed for the efficiency factor to be calculated:

$$U_{te} = \frac{1}{R_{se} + R_t + R_{al}}$$
$$U = \frac{1}{R_{se} + R_t + R_{al} + R_i + R_{si}} \quad (E.2)$$

The calculation of the effective total solar energy transmittance depends on the type of the transparent insulation. It takes into account the angle of incidence of direct solar radiation, using the coefficients $c_{j,m}$ of Table E.1.

For products with non-negligible solar energy transmittance, the effective value is proportional to the solar absorption coefficient of the opaque element behind transparent insulation:

$$g_{t;j,m} = \alpha_{sol} \cdot \left(g_{t;hem} - c_{j,m} \cdot g_{t;\perp} \right) \quad (E.3)$$

For transparent insulation with negligible solar transmittance (e.g. products with solar absorber included), the value determined from measurements are only modified to take account of the thermal resistance, R_g, of the air gap between the transparent insulation and the opaque element:

$$g_{TI;j,m} = \frac{R_{se} + R_t}{R_{se} + R_t + R_g} \cdot \left(g_{t;h} - c_{j,m} \cdot g_{t;\perp} \right) \quad (E.4)$$

Table E.1 — Coefficients $c_{j,m}$ for calculation of the effective total solar energy transmittance of transparent insulation using the measured values for normal and hemispherical incidence (for vertical walls)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
S	−0,105	−0,067	−0,023	0,042	0,073	0,089	0,094	0,062	0,005	−0,054	−0,093	−0,105
SW/SE	−0,034	−0,027	−0,010	0,002	0,022	0,037	0,036	0,013	−0,015	−0,025	−0,034	−0,026
W/E	0,054	0,033	0,016	−0,012	−0,005	−0,002	−0,012	−0,007	−0,001	0,024	0,049	0,052
NE/ NW	0,002	0,008	0,016	0,030	0,018	0,013	0,013	0,024	0,033	0,014	0,004	0,000
N	0,000	0,000	0,000	0,011	0,021	0,031	0,042	0,012	0,000	0,000	0,000	0,000

For the **monthly calculation procedures** the following effective total solar energy transmittance for the complete element, $g_{j;m}$, for orientation j and month m, replaces the g-value of a glazing in the formula of ISO 52016-1:2017, 6.6.9.2:

$$g_{j;m} = \frac{U}{U_{te}} \cdot g_{t;j;m} \quad (E.5)$$

For the **hourly calculation procedures** the individual component properties are used in the formula for an opaque construction element (ISO 52016-1:2017, 6.5.7.3.2), with the effective total solar energy transmittance of the transparent insulation component, $g_{t;j;m}$, or $g_{TI;j;m}$, connected to the node that represents the external surface of the opaque construction behind the transparent insulation.

E.5 Ventilated solar walls (Trombe walls)

E.5.1 Heat transfer

E.5.1.1 General

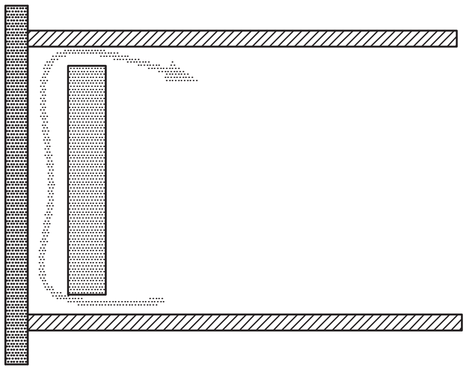


Figure E.1 — Air flow path in a ventilated solar wall

The following applies to walls designed to collect solar energy, in accordance with Figure E.1, where

— the air flow is stopped automatically when the air layer is colder than the heated space and during summer,

— the air flow rate is set mechanically at a constant value, $q_{V,sw}$, when the air layer is warmer than the heated space.

The heat transfer coefficient of such a wall is:

$$H = H_0 + \Delta H \qquad \text{(E.6)}$$

where

H_0 is the heat transfer coefficient of the non-ventilated wall

ΔH is an additional heat transfer coefficient to be calculated in accordance with E.5.1.3.

Required data

A_{sw} area of the ventilated solar wall;

R_i internal thermal resistance of the wall, between the air layer and the internal environment;

R_e external thermal resistance of the wall, between the air layer and the external environment;

R_l thermal resistance of the air layer;

$q_{V;sw}$ set value of the air flow rate through the ventilated layer;

h_c convective surface heat transfer coefficient in the air layer;

h_r radiative surface heat transfer coefficient in the air layer;

$Q_{gn;sw}$ solar heat gains of the air layer during the calculation step: $Q_{gn;sw} = I_w \cdot A_{sw}$

$Q_{ht;al}$ heat loss of the air layer during the calculation step: $Q_{ht;al} = U_e\, A_{sw} \cdot (\theta_{int} - \theta_e)\, t$

E.5.1.2 Calculation method

The additional heat transfer coefficient of such a wall is calculated by:

$$\Delta H = \rho_a \cdot c_a \cdot q_{ve;sw} \cdot \left(\frac{U_e}{U_i}\right)^2 \cdot \delta \cdot \kappa_{sw} \tag{E.7}$$

where

$\rho_a \cdot c_a$ is the heat capacity of air per volume, as determined in Table 1;

U_i and U_e are the internal and external thermal transmittances:

$$U_i = \frac{1}{R_i + \frac{R_l}{2}}$$

and

$$U_e = \frac{1}{R_e + \frac{R_l}{2}} \tag{E.8}$$

δ is the ratio of the accumulated internal-external temperature difference when the ventilation is on, to its value over the whole calculation step. It is given in Figure E.2.

This ratio can be calculated by:

$$\delta = 0{,}3 \times \gamma_{al} + 0{,}03 \times \left(0{,}0003^{\gamma_{al}} - 1\right) \tag{E.9}$$

where

γ_{al} is the ratio of the solar heat gains, $Q_{gn,sw}$, to the heat loss of the air layer, $Q_{ht,al}$, during the calculation step.

κ_{sw} is a factor determined by:

$$\kappa_{sw} = 1 - \exp\left(\frac{-A_{sw} \cdot Z}{\rho_a \cdot c_a \cdot q_{V;sw}}\right) \tag{E.10}$$

where Z is a parameter determined by

$$\frac{1}{Z} = \frac{h_r}{h_c \cdot \left(h_c + 2h_r\right)} + \frac{1}{U_i + U_e} \tag{E.11}$$

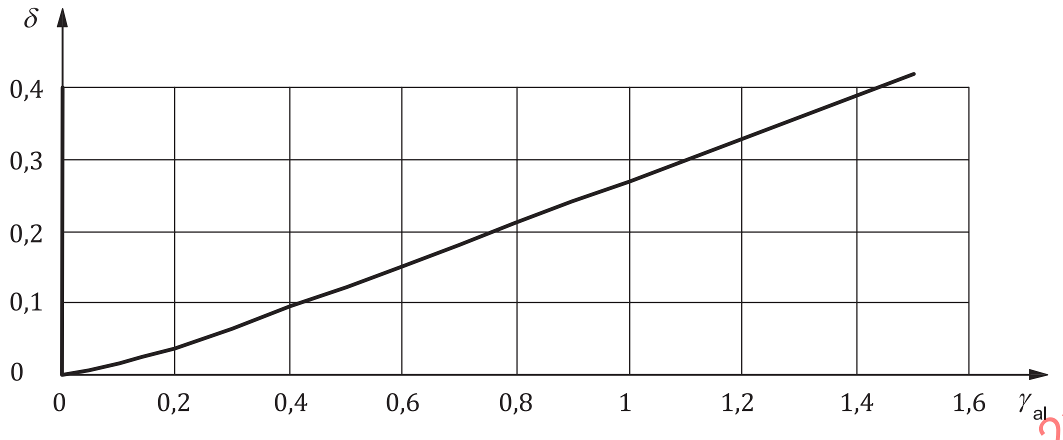


Figure E.2 — Ratio δ of the accumulated internal-external temperature difference when the ventilation is on, to its value over the whole calculation step, as a function of the gain/load ratio of the air layer, γ_{al}

E.5.2 Solar heat gains

E.5.2.1 General

The following applies to ventilated solar walls, designed to collect solar energy. The calculation method quantifies the positive effect during the heating season. However, the same procedure is also used to calculate the solar gains for the cooling (summer) mode, taking into account any extra (seasonal) solar protection and ventilation provisions, if present.

The calculation procedure is simplified and is applicable to both the hourly and monthly calculation procedures. It produces for the hourly method component data as (adapted) input to the formula of 6.5.7.3.2 and for the monthly method an effective g-value as (adapted) input of ISO 52016-1:2017, 6.6.9.2.

E.5.2.2 Required data

The following applies to ventilated solar walls.

In addition to data listed in E.5.1, the following input data are needed:

α_{sol} absorption coefficient of the surface behind the air layer;

g total solar energy transmittance of the glazing covering the air layer.

E.5.2.3 Calculation method

For the **monthly calculation procedures** the following effective total solar energy transmittance for the complete element, g, replaces the g-value of a glazing in the formula of ISO 52016-1:2017, 6.6.9.2:

a) If the ventilated layer is covered by an opaque external layer:

$$g = \alpha_{sol} \cdot \frac{U_0}{U_i^{\,2}} \cdot \rho_a \cdot c_a \cdot \frac{q_{V;sw}}{A_{sw}} \cdot \kappa_{sw} \cdot \omega \qquad \text{(E.12)}$$

where

U_i and κ_{sw} are calculated in accordance with E.5.1;

ω is the ratio of the total solar radiation falling on the element when the air layer is open to the total solar radiation during the whole calculation interval; ω is given in Figure E.3. It can be calculated by:

$$\omega = 1 - \exp\left(-2,2 \times \gamma_{al}\right) \tag{E.13}$$

where γ_{al} is the heat-balance ratio of the air layer during the calculation interval.

$$U_0 = \frac{1}{R_i + R_l + R_e} \tag{E.14}$$

is the thermal transmittance of the wall.

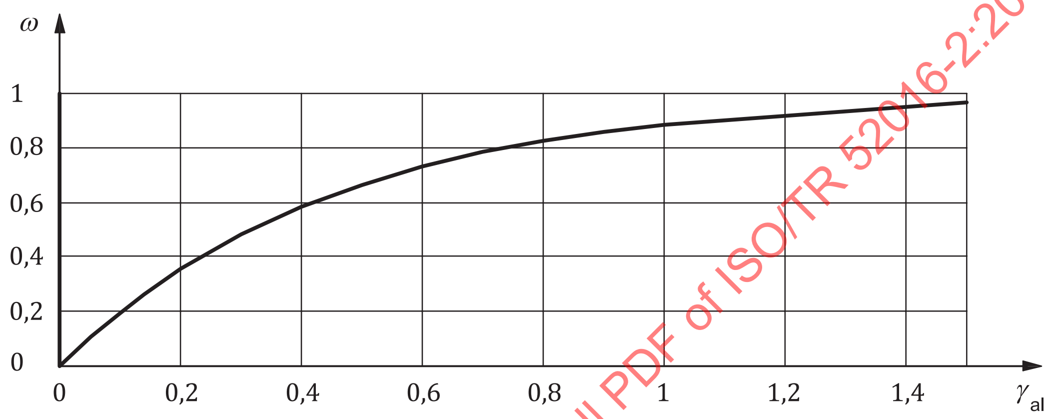


Figure E.3 — Ratio ω of the total solar radiation falling on the element when the air layer is open to the total solar radiation during the calculation interval, as a function of the heat-balance ratio of the air layer, γ_{al}

b) If the air layer is covered by glazing:

$$\alpha_{sol} \cdot g_w \cdot \left(U_0 \cdot R_e + \frac{U_0^{2} \cdot R_i}{U_i \cdot U_e} \cdot \rho_a \cdot c_a \cdot \frac{q_{V;sw}}{A} \cdot \kappa_{sw} \cdot \omega \right) \tag{E.15}$$

NOTE This procedure is implicit: formulae (E.12) and (E.13) are used in an iterative process to calculate the solar heat gains, starting with $\gamma_{al} = 1$.

For the **hourly calculation procedures** the individual component properties are used in the formula for an opaque construction element (ISO 52016-1:2017, 6.5.7.3.2), with the thermal resistances distributed over the nodes and adjusted heat fluxes connected to each node, including time and temperature dependent heat flow due to air circulation across part of the construction.

E.6 Ventilated envelope elements

E.6.1 Heat transfer

E.6.1.1 General

Circulating ventilation air within parts of the building envelope (wall, window, roof) decreases the overall heat losses by heat recovery, although the transmission heat loss is increased in these building envelope elements. This overall effect can be expressed through an equivalent heat exchanger between exhaust and supply air. The efficiency of this equivalent heat exchanger can be calculated with the simplified method given in E.6.1.2, which is applicable under the following conditions:

— the air flow is parallel to the envelope surface (see Figure E.4);

— the thickness of the air layer is between 15 mm and 100 mm;

— the air permeability of the remaining parts of the envelope is low, so that most (about 90 %) of the air circulating through the building passes through the ventilated envelope element;

— the ventilation system meets the requirements in Table E.2;

— air supply, if natural, is controlled through adjustable or self-controlled inlets located on the internal part of the envelope. During summer the inlets are closed.

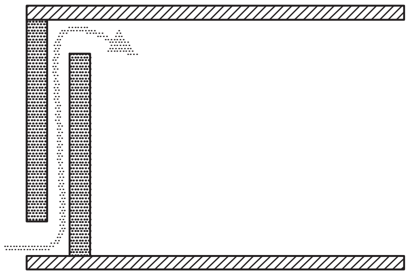


Figure E.4 — Air path in the wall

Table E.2 — Ventilation requirements for the application of the method

Shielding class	Requirement
No shielding	Mechanical exhaust and supply
Moderate	Mechanical exhaust or supply
Heavy shielding	No requirement

NOTE This method mainly applies where supply air is circulated within the building envelope elements. Exhaust air can also be used, provided that suitable provisions be made to avoid condensation.

E.6.1.2 Calculation method

The efficiency factor of the equivalent air-to-air heat exchanger is:

$$\eta_{\mathrm{v}} = \frac{U_0^2}{U_{\mathrm{i}} \cdot U_{\mathrm{e}}} \cdot \kappa \tag{E.16}$$

where

U_{i} and U_{e} are, respectively, the thermal transmittances of the internal and external parts of the envelope element containing the air space;

U_0 is the thermal transmittance of this envelope element, assuming the air space is not ventilated;

κ_{sw} is the factor determined by Formula (E.10).

This efficiency factor of the equivalent air-to-air heat exchanger is always less than 0,25.

E.6.2 Solar heat gains

E.6.2.1 General

If the supply air for ventilation is taken through envelope elements, it can be heated on the one hand by the transmission heat loss through the element (see E.6.1) and on the other hand by solar radiation absorbed either by the external opaque pane or by the internal surface of the air layer if this layer is covered by glazing.

The calculation method quantifies the positive effect during the heating season. However, the same procedure is also used to calculate the solar gains for the cooling (summer) mode, taking into account any extra (seasonal) solar protection and ventilation provisions, if present.

The calculation procedure is simplified and is applicable to both the hourly and monthly calculation procedures. It produces for the hourly method component data as (adapted) input to the formula of 6.5.7.3.2 and for the monthly method an effective *g*-value as (adapted) input to ISO 52016-1:2017, 6.6.9.2.

E.6.2.2 Required data

In addition to data listed in E.6.1, the following input data are necessary:

A	area of the element;
a_{sol}	solar absorption coefficient of the surface receiving the solar radiation;
R_i	internal thermal resistance of the wall, between the air layer and the internal environment;
R_e	external thermal resistance of the wall, between the air layer and the external environment;
R_l	thermal resistance of the air layer;
$q_{V;sw}$	air flow rate through the ventilated layer;
h_e	surface heat transfer coefficient at external surface;
g	total solar energy transmittance of the glazing covering the air layer;
h_c	convective surface heat transfer coefficient in the air layer;
h_r	radiative surface heat transfer coefficient in the air layer.

E.6.2.3 Calculation method

The efficiency of the equivalent heat exchanger is calculated in accordance with E.6.1.

For the **monthly calculation procedures** the following effective total solar energy transmittance for the complete element, *g*, replaces the *g*-value of a glazing in the formula of ISO 52016-1:2017, 6.6.9.2:

e) If the ventilated layer is covered by an opaque external layer:

$$g = \alpha_{sol} \cdot \frac{U_0}{h_e} \cdot \left(1 + \frac{U_0}{U_i^{\,2}} \cdot \rho_a \cdot c_a \cdot \frac{q_{V;sw}}{A} \cdot \kappa_{sw} \right) \tag{E.17}$$

e) If the air layer is covered by glazing:

$$g = \alpha_{sol} \cdot g_w \cdot \left(U_0 \cdot R_e + \frac{U_0^{\,2} \cdot R_i}{U_i \cdot U_e} \cdot \rho_a \cdot c_a \cdot \frac{q_{V;sw}}{A} \cdot \kappa_{sw} \right) \tag{E.18}$$

For the **hourly calculation procedures** the individual component properties are used in the formula for an opaque construction element (ISO 52016-1:2017, 6.5.7.3.2), with the thermal resistances distributed over the nodes and adjusted heat fluxes connected to each node, including time and temperature dependent heat flow due to air circulation across part of the construction.

Annex F
(informative)

ISO 52016-1: Calculation of solar shading reduction factors

F.1 Selection of methods

For the calculation of the solar shading reduction factors, due to obstacles blocking part of the solar radiation, two methods are provided.

— Method 1, Shading of direct radiation.

— Method 2, Shading of direct and diffuse radiation.

Method 1 is fully described in ISO 52016-1:2017, F.2.

The same Method 1, but only for distant obstacles, is described in ISO 52010-1, because it could be an option to pre-calculate the effect of distant obstacles along with the calculation of the irradiance. However, this is not recommended, because then all detailed components of the solar irradiance need to be provided as output of ISO 52010-1, otherwise it is unclear if additional obstacles, e.g. nearby or on the building itself, are overlapping to the shading from distant obstacles or are complementary (additional). The informative default choice in ISO 52010-1 and ISO 52016-1 is to deal with all obstacles in the application standard, in this case ISO 52016-1.

The alternative method, **Method 2**, is to take also shading by diffuse solar radiation into account.

This approach is presented as an option in ISO 52016-1:2017, F.3, but the calculation procedures are provided as informative calculation procedures in F.3. The reason for placing it in this informative report is that the method requires more input data (e.g. solar reflectivity of the shading objects) and more feedback on the experience with the application of this method in the context of building regulations.

F.2 Background information

More information on the development of the simplified solar shading reduction factors (correlation factors) can be found already in reports from the nineties of the last century [45]: and [31] (PASSYS II, SDT reports); a publication with an update of this information is in preparation [46].

For the purpose of ISO 52016-1, the existing calculation procedures have been expanded to be not only applicable to the Northern hemisphere, but also to the Southern hemisphere.

F.3 Spreadsheets for demonstration and validation

Different spreadsheets have been prepared for demonstration and testing.

For the hourly solar shading reduction factors: see the spreadsheet accompanying ISO 52010-1. It is being considered to include these procedures also in an update of the spreadsheet accompanying ISO 52016-1.

A spreadsheet is available that contains more details, such as the derivation of the monthly coefficients of the more detailed method.

Also a spreadsheet is available for demonstration of the monthly method for simple shading objects.

Not all spreadsheets are publicly available (yet), because they require extra explanation as they were originally developed in another context and e.g. use different symbols for geometry data and angles and different angle conventions.

F.4 Not in ISO 52016-1:2017: Directional (spatial) distribution of hourly solar irradiation or illumination (Tregenza elements)

The distribution of irradiation on a non-horizontal plane calculated hourly with the method described in ISO 52016-1 can be used to provide a more detailed spatial distribution.

Such detailed spatial distribution can be used for situations where the directional distribution of the solar radiation or luminance is relevant, for instance in case of non-isotropic window elements (e.g. Venetian blinds), (other) daylight elements with Bi-directional Transmission (and Reflection) Distribution Functions (BTDF), for instance for the assessment of task illuminance levels and/or to assess the luminance distribution in a room, discomfort glare or other visual comfort related parameters in a room (with or without additional artificial lighting). It was Tregenza who suggested the distribution of the sky into 145 elements. In ISO/TR 52010-2[13] it is described how this idea has been used to develop a method in which the hourly solar radiation components from ISO 52010-1 (direct, circumsolar, isotropic diffuse, near-horizon and ground reflected irradiance) are used as the basis for the hourly spatial distribution into 145 elements in the hemisphere seen from a plane (e.g. window with Venetian blinds)). Combined with the angle dependent solar or light transmittance of the window (e.g. pre-calculated for each of the 145 angles of view), the hourly total solar or light transmittance can be calculated quickly, and e.g. monthly mean characteristics can be derived. See ISO/TR 52010-2 for more details and references.

F.5 Application on system components, such as thermal solar collectors and photovoltaic panels

F.5.1 Method 1, Shading of direct radiation

F.5.1.1 Explanation and examples of the more detailed (general) method, hourly

The general method is a straightforward method using geometrical data of the objects only, plus the hourly solar irradiance split into a total direct and total diffuse component and the position of the sun (altitude and azimuth).

The following tables are copied from the spreadsheet accompanying ISO 52010-1 (see introduction in F.1 of this document) and also reported in ISO/TR 52010-2.

This calculation example covers the BESTEST case.

Example of input of shaded plane:

South vertical shaded surface, with height from 1,0 m to 3,0 m above ground.

The tables illustrate some of the input and output.

Table F.1 — Sample input: weather station and position of shaded surface

Name	Symbol		Unit	Value	Range	Origin	Varying	Notes
Weather station data								
Station and/or file name				DRYCOLD.TMY (Denver (Col, USA))				
Optional special notes				Disregarding daylight saving time				
Optional special notes				Winter: MST = UTC - 7				
Optional special notes				Summer: MDT = UTC - 6				
latitude	φ_w		deg	39,76	-90 to +90	Annex A/B	NO	North +90, South, -90
longitude	λ_w		deg	-104,86	-180 to +180	Annex A/B	NO	East is positive West is negative
time zone	TZ		h	-7	-12 to +12	Annex A/B	NO	
Geometrical characteristics of plane								
Tilt angle of the inclined surface from horizontal, measured upwards facing	β_{ic}		deg	90	0 to 180	local	NO	0 = horizontal up , 90 vertical, 180 facing down
Orientation angle of the inclined surface, expressed as the geographical azimuth angle of the horizontal projection of the inclined surface normal	γ_{ic}		deg	0	-180 to +180	local	NO	Convention in this standard: angle from South, eastwards positive, westwards negative
Base height of the shaded surface, from ground level	$H_{0;ic}$		m	1	≥ 0	local	NO	
Height of the shaded surface, from bottom to top; if tilted: vertical projection	$H_{1;ic}$		m	3	>0	local	NO	If horizontal: choose small value, e.g. H_1 =0,01 m

Example of input of shading objects:

Skyline divided into (flexible) segments. In the spreadsheet, for demonstration and validation, in each segment up to 3 obstacles (with distance and highest height from the ground) can be entered, plus one overhang (with distance and lowest height from the ground).

Table F.2 — Sample input: examples of 3 shading obstacles and 1 overhang

												For information:	
Shading		Create azim angle segments		Obstacles						Overhangs		Plane azim angle	0
NOTE: For strongly tilted planes the results for close-by obstacles or overhangs are not correct		Absolute angles from -180 to + 180 (S=0;E=90;N=180;W=-90;N=-180)										Relative angles as seen from plane (-90 <-> + 90)	
	Shading Sector	1st angle	2nd angle ($\gamma_{sh;obst/ovh;max}$)	$L_{sh;obst;1}$	$H_{sh;obst;1}$	$L_{sh;obst;2}$	$H_{sh;obst;2}$	$L_{sh;obst;3}$	$H_{sh;obst;3}$	$L_{sh;ovh}$	$H_{sh;ovh}$	1st angle	2nd angle
Don't change the dark grey cells	1	-180	-135									-180	-135
	2	-135	-90	100	20	20	8			2	5	-135	-90
	3	-90	-45			30	6			2	4,5	-90	-45
	4	-45	0	100	15	40	4			2	4	-45	0
	5	0	45	100	10	50	6			2	3,5	0	45
	6	45	90	100	30	60	8	3	2			45	90
	7	90	140					3	2			90	140
	8	140	180					3	2			140	180
	9	180											
		180											
		180											
		180											
		180											
		180											
		180	180										

Table F.3 — Sample output of hourly data: few of the 8760 hourly values for 3 shading obstacles and 1 overhang

(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)
											max.of 3 obstacles							Compare:
Check view sun (azimuth)	Check view sun (altitude)	Shading Sector, $n_{sh;segm}$	$L_{sh;obst;1}$	$H_{sh;obst;1}$	$L_{sh;obst;2}$	$H_{sh;obst;2}$	$L_{sh;obst;3}$	$H_{sh;obst;3}$	$L_{sh;ovh}$	$H_{sh;ovh}$	$h_{sh;obst}$	$h_{sh;ovh}$	$F_{dir;unsh}$	$F_{dir;sh;obst}$	$F_{dir;sh;ovh}$	$F_{dir;sh;tot}$	$I_{tot;sh}$	I_{tot}
F.3 in ISO/FDIS 52016-1	F.3 in ISO/FDIS 52016-1										42	F.11 (52016-1)				41	40	39 (copy)
degrees	degrees	-	m	m	m	m	m	m	m	m	m	m	-	-	-	-	W/m²	W/m²
158,7	0,0	8,0	0,0	0,0	0,0	0,0	3,0	2,0	0,0	0,0	1,0		0,0	0,00	1,00	0,00	0,0	0,0
125,5	0,0	7,0	0,0	0,0	0,0	0,0	3,0	2,0	0,0	0,0	1,0		0,0	0,00	1,00	0,00	0,0	0,0
107,1	0,0	7,0	0,0	0,0	0,0	0,0	3,0	2,0	0,0	0,0	1,0		0,0	0,00	1,00	0,00	0,0	0,0
94,9	0,0	7,0	0,0	0,0	0,0	0,0	3,0	2,0	0,0	0,0	1,0		0,0	0,00	1,00	0,00	0,0	0,0
85,3	0,0	6,0	100,0	30,0	60,0	8,0	3,0	2,0	0,0	0,0	29,0		1,0	0,00	1,00	0,00	0,0	0,0
76,5	0,0	6,0	100,0	30,0	60,0	8,0	3,0	2,0	0,0	0,0	29,0		1,0	0,00	1,00	0,00	0,0	0,0
67,9	0,0	6,0	100,0	30,0	60,0	8,0	3,0	2,0	0,0	0,0	29,0		1,0	0,00	1,00	0,00	0,0	0,0
58,6	0,7	6,0	100,0	30,0	60,0	8,0	3,0	2,0	0,0	0,0	27,7		1,0	0,00	1,00	0,00	4,0	7,4
48,4	10,0	6,0	100,0	30,0	60,0	8,0	3,0	2,0	0,0	0,0	11,3		1,0	0,00	1,00	0,00	46,8	164,1
36,6	17,8	5,0	100,0	10,0	50,0	6,0	0,0	0,0	2,0	3,5	0,0	1,9	1,0	1,00	0,62	0,62	85,5	102,8
23,2	23,6	5,0	100,0	10,0	50,0	6,0	0,0	0,0	2,0	3,5	0,0	1,6	1,0	1,00	0,54	0,54	464,7	781,4
8,4	26,7	5,0	100,0	10,0	50,0	6,0	0,0	0,0	2,0	3,5	0,0	1,5	1,0	1,00	0,50	0,50	521,9	959,6
-7,1	26,8	4,0	100,0	15,0	40,0	4,0	0,0	0,0	2,0	4,0	0,0	2,0	1,0	1,00	0,66	0,66	644,0	934,9
-22,0	23,9	4,0	100,0	15,0	40,0	4,0	0,0	0,0	2,0	4,0	0,0	2,1	1,0	1,00	0,70	0,70	620,3	859,0
-35,6	18,4	4,0	100,0	15,0	40,0	4,0	0,0	0,0	2,0	4,0	0,0	2,3	1,0	1,00	0,78	0,78	528,7	670,7
-47,4	10,7	3,0	0,0	0,0	30,0	6,0	0,0	0,0	2,0	4,5	0,0	3,1	1,0	1,00	1,00	1,00	458,3	458,3
-57,8	1,6	3,0	0,0	0,0	30,0	6,0	0,0	0,0	2,0	4,5	4,2	3,4	1,0	0,00	1,00	0,00	10,0	69,9
-67,1	0,0	3,0	0,0	0,0	30,0	6,0	0,0	0,0	2,0	4,5	5,0	3,5	1,0	0,00	1,00	0,00	0,0	0,0

Table F.4 — Sample output of calculated monthly data (South, vertical)

South is 0, East pos; in CAD conventions North = 0
0 = horizontal up , 90 vertical, 180 facing down

Monthly average (W/m²)

Calculated Plane (azim, tilt):	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)	(0,90)		Calculated (0,90)	(0,90)
(*)	$H_{dir;m}$	$H_{dif;m}$	$H_{dif;grnd;m}$	$H_{circum;m}$	$H_{dif;tot;m}$	$H_{dir;tot;m}$	$H_{tot;m}$		$H_{tot;sh;m}$	$F_{sh;m}$		$I_{tot;m}$	$I_{tot;sh;m}$
	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²		kWh/m²	-		W/m²	W/m²
	134	18	8	9	17	143	160		98	0,61		214,9	131,9
	102	21	10	9	21	112	133		83	0,62		197,5	123,0
	103	33	16	13	35	116	151		91	0,60		203,5	122,9
	62	34	18	11	41	73	114		67	0,58		158,8	92,6
	41	35	22	8	49	48	97		67	0,70		130,5	90,7
	30	30	22	5	47	36	83		60	0,73		114,9	83,6
	39	30	23	6	47	45	92		64	0,69		123,5	85,8
	57	32	20	9	42	67	109		67	0,61		146,5	89,7
	93	29	17	11	35	104	139		81	0,58		192,5	112,3
	128	24	13	11	26	139	166		99	0,60		222,5	133,5
	116	23	8	12	19	128	147		92	0,62		203,6	127,2
	130	20	7	11	16	141	157		101	0,64		211,3	136,0
	1036	326	185	117	395	1152	1547		970	0,63		176,6	110,8

Table F.5 — Sample output

max.of 3 obstacles							Compare:
$h_{sh;obst}$	$h_{sh;ovh}$	$F_{dir;unsh}$	$F_{dir;sh;obst}$	$F_{dir;sh;ovh}$	$F_{dir;sh;tot}$	$I_{tot;sh}$	I_{tot}
42	F.11 (52016-1)				41	40	39 (copy)
m	m	-	-	-	-	W/m²	W/m²
1,0		0,0	0,00	1,00	0,00	0,0	0,0
1,0		0,0	0,00	1,00	0,00	0,0	0,0
1,0		0,0	0,00	1,00	0,00	0,0	0,0
1,0		0,0	0,00	1,00	0,00	0,0	0,0
29,0		1,0	0,00	1,00	0,00	0,0	0,0
29,0		1,0	0,00	1,00	0,00	0,0	0,0
29,0		1,0	0,00	1,00	0,00	0,0	0,0
27,7		1,0	0,00	1,00	0,00	4,0	7,4
11,3		1,0	0,00	1,00	0,00	46,8	164,1
0,0	1,9	1,0	1,00	0,62	0,62	85,5	102,8
0,0	1,6	1,0	1,00	0,54	0,54	464,7	781,4
0,0	1,5	1,0	1,00	0,50	0,50	521,9	959,6
0,0	2,0	1,0	1,00	0,66	0,66	644,0	934,9
0,0	2,1	1,0	1,00	0,70	0,70	620,3	859,0
0,0	2,3	1,0	1,00	0,78	0,78	528,7	670,7
0,0	3,1	1,0	1,00	1,00	1,00	458,3	458,3
4,2	3,4	1,0	0,00	1,00	0,00	10,0	69,9
5,0	3,5	1,0	0,00	1,00	0,00	0,0	0,0
5,0	3,5	1,0	0,00	1,00	0,00	0,0	0,0

F.5.1.2 Explanation and examples of the more detailed (general) method, monthly

The general method for monthly calculations is, with respect to the geometrical data of the objects the same as for hourly calculations. With respect to the solar irradiation and the position of the sun it is obvious that there is a difference, because only monthly mean data are available. These are replaced by correlation factors.

The correlation factors are a function of orientation and latitude and month or season. The correlation factors consist of a weighting factor plus the mean solar altitude angle per segment (each segment is a 45 degrees view of the skyline).

The correlation factors are derived from calculations using the hourly calculation procedures introduced above. A spreadsheet is available for the derivation.

The monthly method also requires the monthly or seasonal mean fraction of direct versus direct plus diffuse solar irradiation. These are presented in ISO 52016-1:2017, Table B.48. The values were derived for a moderate sea climate (The Netherlands).

F.5.1.3 Explanation and examples of the correlation based method for simple shaped obstacles (overhangs, side fins, rebates), hourly

Examples of the method for simple shaped obstacles for façade elements, such as (window) rebates, overhangs with infinite length and side fins with infinite height, or other geometrically similar shading objects, such as other building parts (e.g. walls) or balconies:

F.5.1.4 Explanation and examples of the correlation based method for simple shaped obstacles (overhangs, side fins, rebates), monthly

The coefficients A1, A2, B1, B2 were calculated by simulation of a number of cases followed by a correlation analysis to minimize the errors (see [45]). The coefficients have purely correlation coefficients without physical meaning. This is also the reason why, after the application of the formulae, the result has to be limited between the values 0 and 1.

The original correlation coefficients were already presented in an Annex to EN 832, the predecessor of ISO 13790[5].

Originally these coefficients were obtained to be applicable for all European latitudes. Notice that the latitude is a variable in the formulae.

Examples:

Table F.6 — Sample input

Window	height (H):	1,5
	width (W):	1,2

Overhang	OD (D):	0,3
	OB (L):	0
	OW	infinite
	$P1 = D/H$	0,2
	$P2 = L/H$	0

Fin	LD or RD (D):	0,3
	LA or RA (L):	0
	LH or RH:	infinite
	$P1 = D/W$	0,25
	$P2 = L/W$	0

Rebates	OD & LD & RD:	0,3
	$P1$	0,25
	$P2$	0,2

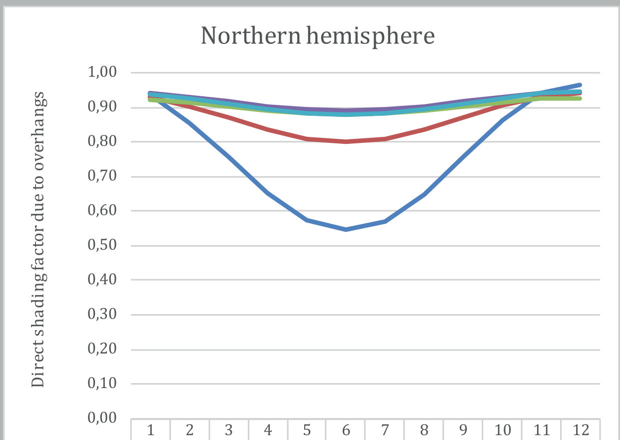
NOTE Symbols are subject to updating to ISO 52016-1 symbols.

Results:

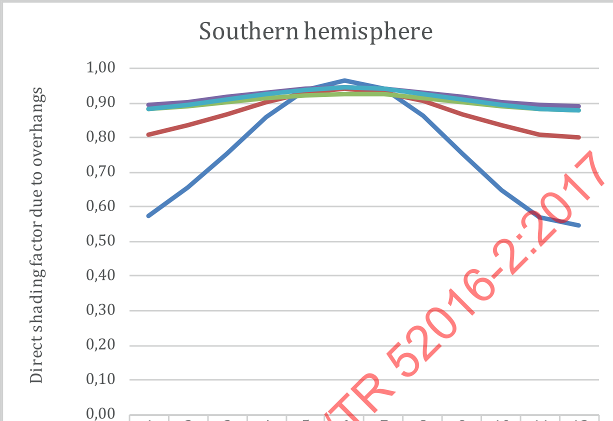
Left: latitude 40 degrees (Northern hemisphere). Right -40 degrees (Southern hemisphere)

	S	SE-SW	E-W	NE-NW	N
A1	-3,023	-1,255	-0,684	-0,654	-0,726
B1	0,045	0,015	0,005	0,006	0,007
A2	1,285	0,905	0,61	0,616	0,616
B2	-0,006	-0,008	-0,004	-0,006	-0,007

	N	NE-NW	E-W	SE-SW	S
A1	-3,023	-1,255	-0,684	-0,654	-0,726
B1	0,045	0,015	0,005	0,006	0,007
A2	1,285	0,905	0,61	0,616	0,616
B2	-0,006	-0,008	-0,004	-0,006	-0,007



	1	2	3	4	5	6	7	8	9	10	11	12
S	0,94	0,86	0,76	0,65	0,57	0,54	0,57	0,65	0,76	0,86	0,94	0,97
SE-SW	0,93	0,90	0,87	0,83	0,81	0,80	0,81	0,83	0,87	0,90	0,93	0,94
E-W	0,92	0,91	0,90	0,89	0,88	0,88	0,88	0,89	0,90	0,91	0,92	0,93
NE-NW	0,94	0,93	0,92	0,90	0,89	0,89	0,89	0,90	0,92	0,93	0,94	0,95
N	0,94	0,93	0,91	0,89	0,88	0,88	0,88	0,89	0,91	0,93	0,94	0,94

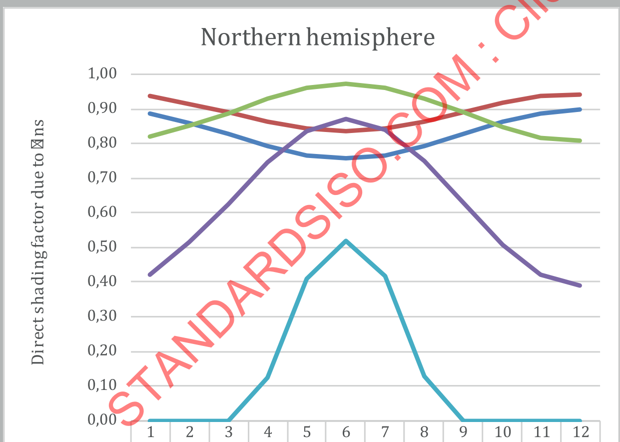


	1	2	3	4	5	6	7	8	9	10	11	12
N	0,57	0,65	0,75	0,86	0,94	0,97	0,94	0,86	0,75	0,65	0,57	0,54
NE-NW	0,81	0,84	0,87	0,90	0,93	0,94	0,93	0,90	0,87	0,83	0,81	0,80
E-W	0,88	0,89	0,90	0,91	0,92	0,93	0,92	0,91	0,90	0,89	0,88	0,88
SE-SW	0,89	0,90	0,92	0,93	0,94	0,95	0,94	0,93	0,92	0,90	0,89	0,89
S	0,88	0,90	0,91	0,93	0,94	0,94	0,94	0,93	0,91	0,89	0,88	0,88

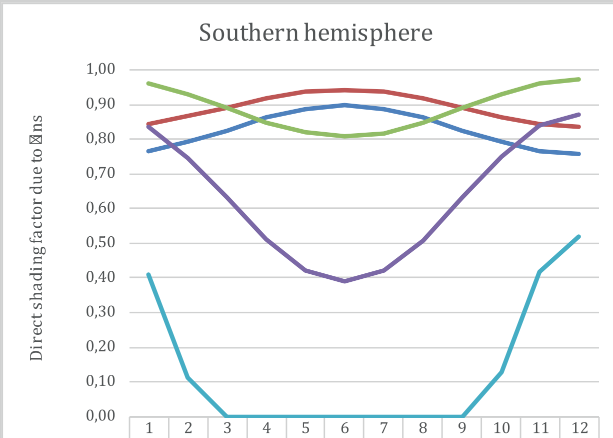
Figure F.1 — Overhang

	S	SE-SW	E-W	NE-NW	N
A1	-1,175	-0,799	0,118	0,155	0,275
B1	0,012	0,009	-0,014	-0,041	-0,133
A2	0,86	0,684	0,005	-0,68	0,641
B2	-0,008	-0,006	0,01	0,009	0,039

	N	NE-NW	E-W	SE-SW	S
A1	-1,175	-0,799	0,118	0,155	0,275
B1	0,012	0,009	-0,014	-0,041	-0,133
A2	0,86	0,684	0,005	-0,68	0,641
B2	-0,008	-0,006	0,01	0,009	0,039



	1	2	3	4	5	6	7	8	9	10	11	12
S	0,89	0,86	0,83	0,79	0,77	0,76	0,76	0,79	0,83	0,86	0,89	0,90
SE-SW	0,94	0,92	0,89	0,86	0,84	0,84	0,84	0,86	0,89	0,92	0,94	0,94
E-W	0,82	0,85	0,89	0,93	0,96	0,97	0,96	0,93	0,89	0,85	0,82	0,81
NE-NW	0,42	0,51	0,62	0,75	0,84	0,87	0,84	0,75	0,63	0,51	0,42	0,39
N	0,00	0,00	0,00	0,12	0,41	0,52	0,42	0,13	0,00	0,00	0,00	0,00

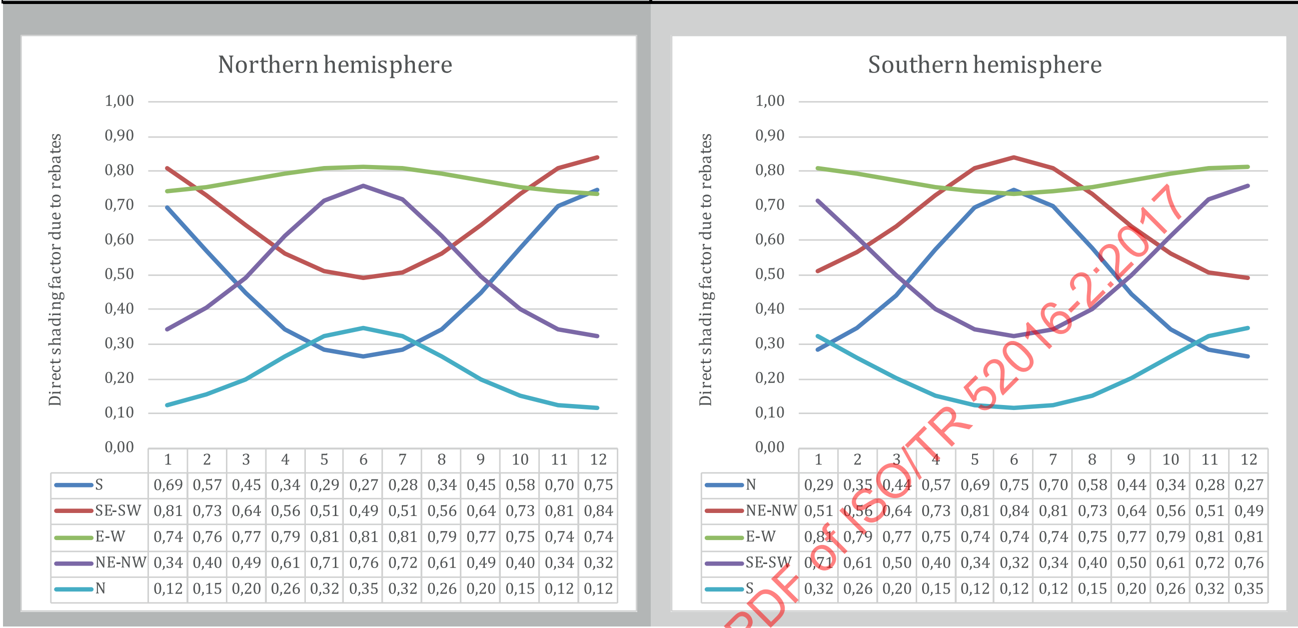


	1	2	3	4	5	6	7	8	9	10	11	12
N	0,77	0,79	0,83	0,86	0,89	0,90	0,89	0,86	0,83	0,79	0,76	0,76
NE-NW	0,84	0,86	0,89	0,92	0,94	0,94	0,94	0,92	0,89	0,86	0,84	0,84
E-W	0,96	0,93	0,89	0,85	0,82	0,81	0,82	0,85	0,89	0,93	0,96	0,97
SE-SW	0,84	0,74	0,63	0,51	0,42	0,39	0,42	0,51	0,63	0,75	0,84	0,87
S	0,41	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,13	0,42	0,52

Figure F.2 — Side fins

	S	SE-SW	E-W	NE-NW	N
A1	-5,695	-2,418	-0,868	0,336	-1,193
B1	0,081	0,032	0,009	-0,013	0,036
A2	-1,342	-1,479	0,232	-0,32	-1,825
B2	0,009	0,017	-0,022	-0,074	-0,163

	N	NE-NW	E-W	SE-SW	S
A1	-5,695	-2,418	-0,868	0,336	-1,193
B1	0,081	0,032	0,009	-0,013	0,036
A2	-1,342	-1,479	0,232	-0,32	-1,825
B2	0,009	0,017	-0,022	-0,074	-0,163



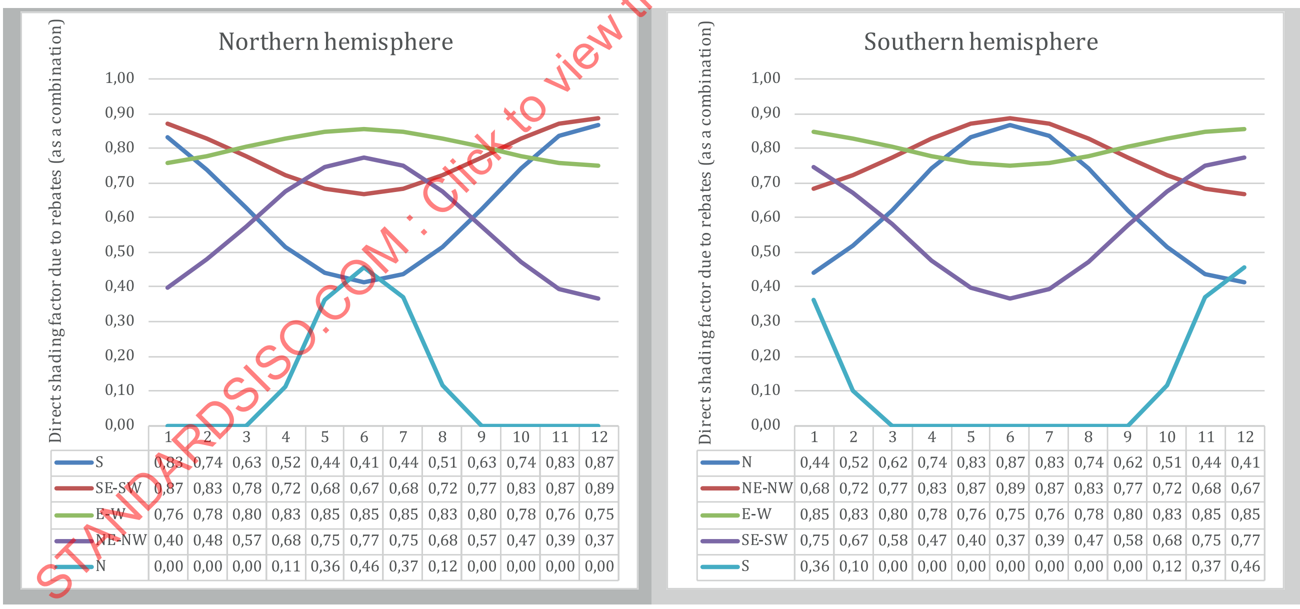
Northern hemisphere

	1	2	3	4	5	6	7	8	9	10	11	12
S	0,69	0,57	0,45	0,34	0,29	0,27	0,28	0,34	0,45	0,58	0,70	0,75
SE-SW	0,81	0,73	0,64	0,56	0,51	0,49	0,51	0,56	0,64	0,73	0,81	0,84
E-W	0,74	0,76	0,77	0,79	0,81	0,81	0,81	0,79	0,77	0,75	0,74	0,74
NE-NW	0,34	0,40	0,49	0,61	0,71	0,76	0,72	0,61	0,49	0,40	0,34	0,32
N	0,12	0,15	0,20	0,26	0,32	0,35	0,32	0,26	0,20	0,15	0,12	0,12

Southern hemisphere

	1	2	3	4	5	6	7	8	9	10	11	12
N	0,29	0,35	0,44	0,57	0,69	0,75	0,70	0,58	0,44	0,34	0,28	0,27
NE-NW	0,51	0,56	0,64	0,73	0,81	0,84	0,81	0,73	0,64	0,56	0,51	0,49
E-W	0,81	0,79	0,77	0,75	0,74	0,74	0,74	0,75	0,77	0,79	0,81	0,81
SE-SW	0,71	0,61	0,50	0,40	0,34	0,32	0,34	0,40	0,50	0,61	0,72	0,76
S	0,32	0,26	0,20	0,15	0,12	0,12	0,12	0,15	0,20	0,26	0,32	0,35

Figure F.3 — Rebate



Northern hemisphere

	1	2	3	4	5	6	7	8	9	10	11	12
S	0,83	0,74	0,63	0,52	0,44	0,41	0,44	0,51	0,63	0,74	0,83	0,87
SE-SW	0,87	0,83	0,78	0,72	0,68	0,67	0,68	0,72	0,77	0,83	0,87	0,89
E-W	0,76	0,78	0,80	0,83	0,85	0,85	0,85	0,83	0,80	0,78	0,76	0,75
NE-NW	0,40	0,48	0,57	0,68	0,75	0,77	0,75	0,68	0,57	0,47	0,39	0,37
N	0,00	0,00	0,00	0,11	0,36	0,46	0,37	0,12	0,00	0,00	0,00	0,00

Southern hemisphere

	1	2	3	4	5	6	7	8	9	10	11	12
N	0,44	0,52	0,62	0,74	0,83	0,87	0,83	0,74	0,62	0,51	0,44	0,41
NE-NW	0,68	0,72	0,77	0,83	0,87	0,89	0,87	0,83	0,77	0,72	0,68	0,67
E-W	0,85	0,83	0,80	0,78	0,76	0,75	0,76	0,78	0,80	0,83	0,85	0,85
SE-SW	0,75	0,67	0,58	0,47	0,40	0,37	0,39	0,47	0,58	0,68	0,75	0,77
S	0,36	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,12	0,37	0,46

Figure F.4 — Rebate (modelled as combination of side fins and overhang)

The difference between Figure F.3 and Figure F.4 is due to the correlations factor. Result 3) is more precise, because the correlation factors are optimized for rebates, while 4) is a combination of correlation factors optimized for side fins and for overhang respectively.

F.6 Method 2: Shading of direct and diffuse radiation

F.6.1 General

In this method shading by diffuse solar radiation is also taken into account.

The diffuse shading reduction factor, F_{dif}, is determined in addition to the direct shading reduction factor, F_{dir}.

For this method sky view factors are calculated. This can be simplified by dividing the skyline in a number of segments, $n_{sh;segm}$, as in step 1 of ISO 52016-1:2017, F.2.2.2, and calculate the sky view factors for each segment separately assuming an equal skyline height over the segment.

First of all the direct, circumsolar-diffuse, sky-diffuse, horizon-diffuse and with all of them the reflected-diffuse radiation will be calculated according to the relevant standard under EPB module M1-13 (ISO 52010-1).

From this information the following is calculated:

a) Sky-diffuse irradiance given by the view factor between the building element and the sky, taking into account the obstacles.

   This view factor will be multiplied by the sky-diffuse solar irradiance;

b) Horizon-diffuse irradiance given by the view factor between the building element and the horizon elevation given by the method for non-isotropic diffuse irradiance according to the relevant standard under EPB module M1-13 (ISO 52010-1).

   This view factor will be multiplied by the horizon-diffuse solar irradiance.

c) The rest of the view factor to 1 will be considered to increment to the reflected irradiance.

As a result of these calculations, the amount of solar irradiance for the plane of the building element is split in direct, circumsolar-diffuse, sky-diffuse, horizon-diffuse and reflected-diffuse.

$$I_{tot} = F_{dir} \cdot I_{dir} + \sum_{i=1}^{n} \left(F_{dif,i} \cdot I_{dif,i} \right) + \sum_{i=1}^{n} I_{ref,i} \qquad \text{(F.1)}$$

where

I	is the solar irradiance in its different components;
F	is the shading correction factor for each solar radiation component;
n	is the number of divisions made.

and the subscripts refers to:

dir	is the total direct radiation;
dif	is the total diffuse radiation;
ref	is the reflected radiation.

F.6.2 Diffuse radiation

The diffuse radiation has to be calculated taken into account three different components according to the relevant standard under EPB module M1-13 (ISO 52010-1).

NOTE 1 Components according to Perez diffuse model, see ISO/TR 52010-2.

NOTE 2 Some symbols are subject to updating to be in line with ISO 52016-1.

Each of these components can have its own shading correction factor.

$$F_{\text{dif}} \cdot I_{\text{dif}} = \frac{1}{n} \cdot \sum_{i=1}^{n} \left(F_{\text{dif;sky};i} \cdot I_{\text{dif;sky}} \right) + \frac{1}{n} \cdot \sum_{i=1}^{n} \left(F_{\text{dif;hor};i} \cdot I_{\text{dif;hor}} \right) + F_{\text{dif;cir}} \cdot I_{\text{dif;cir}} \qquad \text{(F.2)}$$

The shading correction factor corresponding to the circumsolar region is equal to the direct (beam) radiation.

$$F_{\text{dif;cir}} = F_{\text{dif}} \qquad \text{(F.3)}$$

On the other hand, the shading correction factors related to the diffuse from sky and from horizon has to be calculated as follows, using the same divisions as made for the direct radiation calculation, each of them with an area of $\frac{1}{2 \cdot n}$ the area of a hemisphere:

$$^{3} = \arctan\left[\frac{\max(0, H2 - H0 - H1/2}{L} \right] \qquad \text{(F.4)}$$

$$\begin{aligned} & if\, \gamma < \xi \Rightarrow \begin{cases} F_{\text{dif;sky};i} = 0,5 \\ F_{\text{dif;hor};i} = 0,5 \left(1 - \dfrac{\sin\gamma}{\sin\xi} \right) \end{cases} \\ & if\, \gamma > \xi \Rightarrow \begin{cases} F_{\text{dif;sky};i} = \left(1 - \dfrac{\sin\gamma}{\sin\xi} \right) \\ F_{\text{dif;hor};i} = 0,5 \end{cases} \end{aligned} \qquad \text{(F.5)}$$

Then, finally:

$$\begin{aligned} F_{\text{dif;sky}} &= \frac{1}{n} \cdot \sum_{i=1}^{n} F_{\text{dif;sky};i} \\ F_{\text{dif;hor}} &= \frac{1}{n} \cdot \sum_{i=1}^{n} F_{\text{dif;hor};i} \end{aligned} \qquad \text{(F.6)}$$

F.6.3 Simple method for façade elements and own-building shading

For the diffuse parts, it is suggested to use the same corrections for the sky-diffuse and horizon-diffuse. In that case the view factor with the sky becomes:

NOTE 2 Some symbols are subject to updating to be in line with ISO 52016-1.

$$F_{\text{v;sky;sh}} = \min\left(F_{\text{v;W}} - F_{\text{v;B}}, F_{\text{v;W}} - F_{\text{v;FO}}, F_{\text{v;W}} - F_{\text{v;WS}} \right) \qquad \text{(F.7)}$$

where

$F_{\text{v;W}}$ is the view factor between the window and the sky without obstacles;

$F_{\text{v;B}}$ is the view factor between the window and the building;

$F_{\text{v;FO}}$ is the view factor with the façade obstacles;

$F_{\text{v;WS}}$ is the view factor with the window sill.

NOTE These view factors can be calculated as it was shown in ISO 13790:2008, Annex G. More detailed formulae than 0,5 for vertical elements or 1 for roofs may be included.

$$F_{v;surr;sh} = 1 - F_{v;sky;sh} \tag{F.8}$$

can be used as the view factor with the surroundings when calculating the reflected-diffuse part of the radiation.

The diffuse and reflected shading reduction factors are due to remote obstacles, as well as the own building and shading devices (setbacks, fins, overhangs).

The smallest of these 3 shading reduction factors is then kept as the diffuse or reflected shading reduction factor due to remote obstacles and shading devices.

Setback and remote obstacles:

$$F_{sh;dif;setback} = \frac{(1 - F_{w-r}) \cdot F_{w-sky}}{(1 + \cos\beta)/2} \tag{F.9}$$

$$F_{sh;ref;setback} = \frac{\left(1 - F_{w-r}\right) \cdot \left(1 - F_{w-sky}\right)}{\left(1 - \cos\beta\right)/2} \tag{F.10}$$

Fins and remote obstacles:

$$F_{sh;dif;fins} = \frac{\left(1 - F_{w-s}\right) \cdot F_{w-sky}}{\left(1 + \cos\beta\right)/2} \tag{F.11}$$

$$F_{sh;dif;fins} = \frac{\left(1 - F_{w-s}\right) \cdot \left(1 - F_{w-sky}\right)}{\left(1 - \cos\beta\right)/2} \tag{F.12}$$

Overhangs and remote obstacles:

$$F_{sh;dif;overhangs} = \frac{F_{w-sky} - F_{w-o}}{\left(1 + \cos\beta\right)/2} \tag{F.13}$$

$$F_{sh;ref;overhangs} = \frac{1 - F_{w-sky}}{\left(1 - \cos\beta\right)/2} \tag{F.14}$$

where

$$F_{w-r} = 1 - \exp\left[-0{,}8632 \times \left(P_1 + P_2\right)\right] \tag{F.15}$$

$$F_{w-s} = 0{,}6514 \times \left(1 - \frac{P_2}{\sqrt{{P_1}^2 + {P_2}^2}}\right) \tag{F.16}$$

$$F_{w-o} = 0{,}3282 \times \left(1 - \frac{P_2}{\sqrt{{P_1}^2 + {P_2}^2}}\right) \tag{F.17}$$

$$F_{w-sky} = \frac{1 - \sin(\alpha + \beta - 90)}{2} \tag{F.18}$$

P_1 and P_2 are the geometrical parameters calculated in ISO 52016-1:2017, F.5.5.1.6, for the shading of direct solar radiation.

Annex G
(informative)

ISO 52016-1: Dynamic transparent building elements

No additional information beyond the accompanying document.

Annex H
(informative)

Rationale behind reorganization of suite of standards

H.1 General

This Annex provides the rationale behind the reorganization of the cluster of strongly related and partly overlapping ISO[2] and CEN standards. This concerns the standards listed in Table H.1.

Table H.1 — Related standards

Number	Title	Responsible committee
ISO 13790:2008	*Energy performance of buildings - Calculation of energy use for space heating and cooling*	ISO/TC 163/SC 2
EN 15265:2007	*Thermal performance of buildings - Calculation of energy use for space heating and cooling- General criteria and validation procedures*	CEN/TC 89
ISO 13791:2012	*Thermal performance of buildings – Calculation of internal temperatures of a room in summer without mechanical cooling – General criteria and validation procedures*	ISO/TC 163/SC 2
ISO 13792:2012	*Thermal performance of buildings – Calculation of internal temperatures of a room in summer without mechanical cooling – Simplified methods*	ISO/TC 163/SC 2
EN 15255:2007	*Thermal performance of buildings – Sensible room cooling load calculation – General criteria and validation procedures*	CEN/TC 89

These standards all have a different purpose, but there is a large overlap between them, in input data, boundary conditions, assumptions, calculation procedures and validation procedures.

Therefore a restructuring of these standards was proposed and agreed in ISO/TC 163/SC 2 and CEN/TC 89.

These standards are replaced by ISO 52017-1, ISO 52016-1 and the accompanying Technical Report ISO/TR 52016-2.

H.2 Calculation procedures in the standards that are being superseded

H.2.1 Overview

As the overview shows, one standard focuses on the calculation of the internal temperature without heating or cooling under typical or design conditions, another on the calculation of the energy needs for heating and cooling. However, the method is basically the same; the input data and boundary conditions can be different and some simplifications can be different.

Some differences and similarities:

— ISO 13790:2008: a simple hourly dynamic calculation method for calculation of the internal temperature and the required heating and cooling power (full set of formulae in normative annex);

2) Also published as EN ISO standards.

— ISO 13791:2012: a detailed hourly calculation method to calculate the internal temperature (without mechanical cooling; each building element consists of a number of layers) (solution technique in informative annex);

— ISO 13792:2012: a simplified hourly calculation method to calculate the internal temperature (without mechanical cooling; no layers per building element). In an informative annex two calculation methods are given:

— RC three-nodes model (similar to the simple hourly calculation method in ISO 13790:2008;

— Admittance procedure;

— EN 15255:2007: no normative calculation procedure, only an informative example of a calculation method based on a simplified model to calculate the sensible room cooling load (same model as in ISO 13790 and ISO 13792);

— EN 15265:2007: no calculation procedure given.

H.2.2 Input data, boundary conditions and assumptions in the current standards

H.2.2.1 Energy need for heating and cooling

In ISO 13790:2008 input data, boundary conditions and assumptions are given for the calculation of the energy need for heating and cooling for all variables in the energy balance:

— definition of boundaries and zones;

— internal conditions;

— climate conditions;

— heat transfer by transmission;

— heat transfer by ventilation;

— internal heat gains;

— solar heat gains;

— dynamic parameters; and

— also includes calculation of energy use for heating and cooling.

EN 15265:2007 contains only general assumptions and data requirements for the calculation of the energy need for heating and cooling, with limited input data (only for surface heat transfer coefficients and solar distribution).

H.2.2.2 Cooling load

In EN 15255:2007 only general assumptions and data requirements are given for the calculation of the cooling load and limited input data (only for surface heat transfer coefficients and solar distribution).

H.2.2.3 Internal temperature

ISO 13791:2012 contains general assumptions, boundary conditions and input data for all variables in the energy balance.

NOTE There is a large overlap between the assumptions, boundary conditions and input data in ISO 13791 and ISO 13792.

H.2.3 Validation procedures in the current standards

ISO 13790:2008 contains no validation *procedures*; the *results* of the test cases of EN 15265 are used.

ISO 13791:2012 contains different types of validation cases:

— for heat transfer processes:

— for heat conduction through opaque elements (4 test cases),

— for internal long-wave radiation heat exchanges (4 test cases);

— for evaluation of short-wave radiation heat transfer (calculation of shaded area of a window due to external obstructions) (6 test cases).

NOTE 1 The internal *air* temperature (at several time intervals) are compared with the reference results.

— validation procedure for the whole calculation method (2 x 9 test cases).

NOTE 2 The *operative* temperature (daily maximum, average, minimum) is compared with the reference results (calculation period is 1 day).

ISO 13792:2012 contains different types of validation cases:

— validation procedure for the whole calculation method (2 x 9 test cases).

NOTE 3 The *operative* temperature (daily maximum, average, minimum) is compared with the reference results (calculation period is 1 day).

— validation procedure for the sunlit factor due to external obstructions (3 test cases, similar to the test cases in ISO 13791).

EN 15255:2007:

— EN 15255:2007:15 test cases are defined for the whole calculation method. The required test cases depend on the class of the calculation method (which is determined by the type of cooling system).

NOTE 4 only the maximum hourly operative temperature during occupancy, the maximum hourly cooling power and the average cooling power for the 24 h cycle is compared with the reference results (calculation period is 1 day).

EN 15265:2007:

— initial tests (to check basic operation of a calculation method);

— validation tests for the energy requirements for room heating and cooling and the internal temperatures.

NOTE 5 Only the yearly values for the heating and cooling energy needs and the total sum of both are compared with the reference results (no check on monthly or hourly results) (calculation period is 1 year).

Conclusion: there is a large overlap between the validation cases in the different standards. The validation cases in ISO 13791 and ISO 13792 are almost identical (same boundary conditions, calculation period and input data). Test case B in these standards has a large overlap with the test cases in EN 15255 and EN 15265 (same geometry and material properties). However, the boundary conditions, calculation period and input data are different.

As explained elsewhere in this document, in the new structure for these standards, the validation or verification procedures have been rationalized.

H.2.4 New structure for the standards

H.2.4.1 General

In Figure 1 the proposed structure for the standards is shown.

More details are given in the next subclauses.

H.2.4.2 Analysis of ISO 13791:2012

The existing document ISO 13791 contains different types of content:

— the generic hourly calculation procedures including the assumptions behind the generic procedures;

— ingredients to be added to increase the application range of the generic calculation procedures;

— assumptions, specific procedures or simplifications and input data **for the validation cases**; and

— assumptions, specific procedures or simplifications and input data **for specific applications**.

In the process of restructuring the standards, this was considered very confusing.

H.2.4.3 Generic versus specific calculation procedures

A clear distinction has been made between:

— ISO 52017-1: the **generic** (hourly) calculation procedures, with the assumptions behind the generic procedures;

— ISO 52016-1: the **specific** (hourly) calculation procedures, with the specific assumptions, specific procedures or simplifications and input data, depending on the type of **application**.

H.2.4.4 Specific details

ISO 13791 contains many specific details, as the simplifications for surface heat transfer coefficients, assumptions on the ground floor heat transfer, simplification for a ceiling below attic, assumptions for the heat exchange with adjacent spaces, specific ventilation flows and internal gain sources, specific assumptions on occupant behaviour, effect of solar shading by side fins and overhangs, long-wave radiation exchanges in buildings, external radiative long-wave heat transfer coefficients, solar factors. and also: (design) climatic data.

All these data are irrelevant for the generic calculation procedures and therefore left out from ISO 52017-1. These specific details are part of the specific calculation procedures, in ISO 52016-1 or in other EPB standards.

H.2.4.5 Energy need for heating and cooling and (de-)humidification

On the other hand, because ISO 13791 aims at the calculation of the internal temperatures and moisture content and not at the calculation of the energy load or need for heating and cooling, the formulae in ISO 13791 do not contain a term for energy load for heating and cooling.

By simply adding such terms (equivalent to the term for internal heat gains), the application range of the calculation procedures becomes much wider. And, again, the solution technique to calculate how much heat is to be supplied or extracted in a time interval to reach or maintain a given temperature set-point is not part of the generic calculation procedures (in casu: ISO 52017-1), but part of the specific calculation procedures (in casu: ISO 52016-1).

The same is true for the latent energy: ISO 52017-1 contains the formulae for the hourly calculation of the moisture balance. ISO 52016-1 contains the specific assumptions on the moisture set-points, the procedures in case of local control and central control, absorption and desorption in materials (such as walls, furniture, carpets, books), etc.

H.2.4.6 Validation cases

In order to set up the validation test cases, specific assumptions are needed and specific requirements with respect to the accuracy. Therefore, the validation test cases have not been put in the standard with the generic calculation procedures (ISO 52017-1), but in the standard with the specific calculation procedures (ISO 52016-1).

If the formulae for the hourly calculation procedures of ISO 52016-1 are strictly followed, the test cases function not so much as validation, but as **verification** cases: to verify the proper implementation of the calculation procedures. However, a few specific deviations are allowed from the given formulae. In those cases the test cases function as **validation** cases. This is explained in ISO 52016-1 at the proper places.

Annex I
(informative)

Discussion on the hourly versus the monthly calculation methods in ISO 52016-1

I.1 General

In ISO 52016-1 an hourly calculation method has been introduced, to avoid a number of limitations of the monthly calculation method, without adding significant complexities for the user. This hourly method is an improved version compared to the simple hourly method described in ISO 13790:2008.

ISO 52016-1 also contains a monthly calculation methods, based on the method in ISO 13790:2008.

The first question is:

Why a specific hourly method and not a full dynamic simulation or – even better – measured energy use as a suitable standard reference method?

The second question is:

Why an hourly method instead of a monthly method; and vice versa?

A standard reference method for the calculation of the energy performance of buildings should be realistic, sufficiently sensitive (=discriminating between technologies and their performance), fair and robust. But a standard calculation method should also be affordable, reliable, verifiable, transparent, reproducible and affordable.

I.2 Suitable reference method to assess the energy performance

The best reference, of course, would be the actual, real energy consumption, but:

— Real energy consumption, unless covering a statistically reliable number of buildings and operating conditions (variations in practice) and conditions, does not represent standard user behaviour and standard (weather and other) conditions.

— Real energy consumption includes situations with bad quality of building, bad installing, bad equipment tuning and (energy-wise) careless occupant behaviour. It is one of the current issues within CEN: to what extent to include or exclude these situations in the standard conditions.

— Reliable, understandable and comparable data on real energy consumption are very hard to get and take a long time to acquire.

Typically a detailed full dynamic simulation tool is regarded as a suitable alternative reference approach, provided that sufficient information is available on all the input data (including operating conditions) and their variations.

In practice, however, a detailed full dynamic simulation tool introduces a lot of choices, details and complexities that makes it quite a job to use it as a reference tool for a standard method to calculate the energy performance of buildings, for use in the context of building regulations where reproducibility and transparency are key quality aspects of the standard method.

EXAMPLE For instance: which <detailed> reference buildings to take? And which <detailed> indoor conditions and use? How do these relate to real buildings? How to determine the heat losses if the thermal properties are temperature dependent and if the indoor temperature is complex (e.g. a window heated by a heat emitter below or in floor)? How to split the heat losses and gains in case of non-linear properties (losses influenced by gains)? How to translate the heat exchange between rooms or zones by transmission and air circulation to a simplified method? How realistic is the simulated pressure hierarchy due to wind, temperature, mechanical system and air tightness; including the position of the neutral planes in door or window openings or across an open floor space)? Not even mentioning the complications if the dynamic behaviour of technical building systems, with detailed flows, temperatures and controls are involved.

Conclusion: depending on the technologies and/or physical processes a suitable reference method is a tailored choice and not necessarily measurements and not necessarily a detailed simulation tool.

In many cases a more simplified hourly calculation method like the method in ISO 52016-1 will be a suitable reference calculation method. It can be used as such, as standard calculation method, or it can serve as the reference method to derive correlation factors for a more simplified (e.g. monthly) calculation method.

NOTE The hourly method of ISO 52016-1 is for instance not a suitable reference method in cases where specific complex details are involved, such as the ones mentioned in the example above, which are not taken into account in this specific hourly method, because the main concern was to ensure that the hourly method would not add complexity for the user by requiring extra input data.

In the following, the main features of the hourly method of ISO 52016-1 are described, followed by a list of main justification for the hourly method, in comparison with the monthly calculation method. This is followed by a brief overview of pros and cons of the monthly versus the hourly method.

It is expected that the monthly method will still be used in several countries, e.g. for simple types of buildings and operation.

I.3 Main features of the hourly method in ISO 52016-1, compared to the simple hourly method from ISO 13790:2008

I.3.1 Simple hourly method (ISO 13790:2008)

The simple hourly method in ISO 13790:2008[5] is, described in a so called electric equivalent “RC” model, a “5RC1” model (see Figure I.1). All building elements are combined into two main thermal resistances (for opaque and for transparent elements) and one thermal capacity. The aggregated resistance for the opaque elements is split into two, to ‘host’ the total internal thermal capacity of the building room or zone.

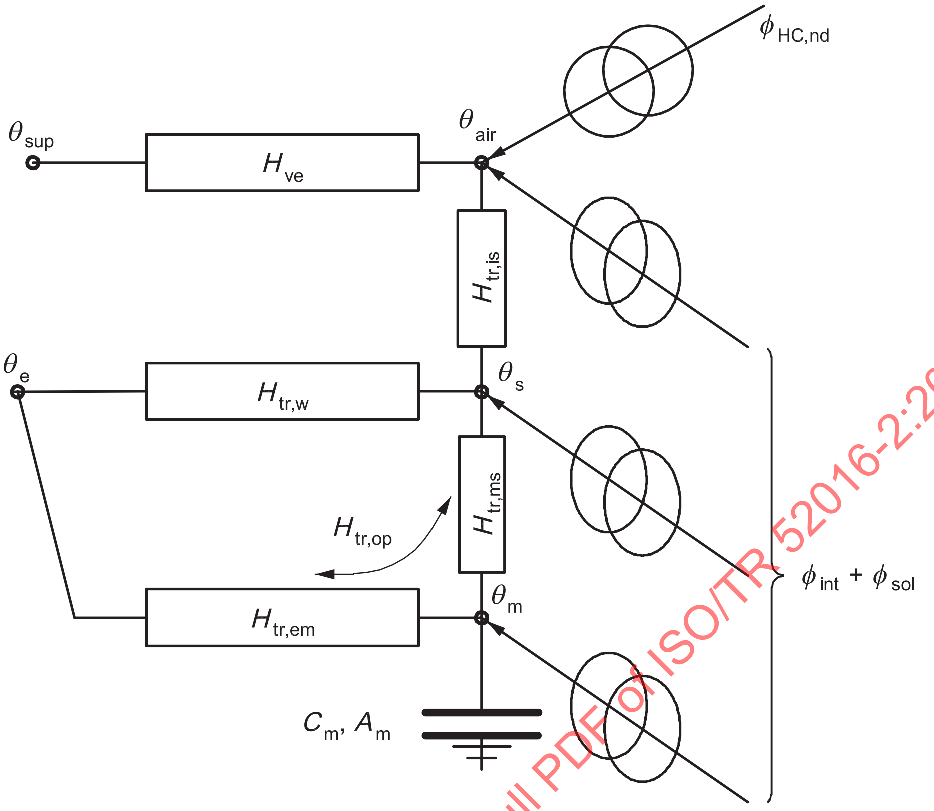


Figure I.1 — The original 5RC1 simple hourly method from ISO 13790:2008

I.3.2 Hourly method in ISO 52016-1

The core of the hourly method in ISO 52016-1 is the following (see e.g. Figure 3 and Figure 8 in the main text):

Evaluation of the internal temperature of a room or building zone solving, on an hourly basis, a system of formulae of the transient heat transfers between the external and internal environment through the opaque and transparent elements bounding the room or zone's envelope. The calculation result is the hourly temperature of each component, including the internal air and (if any) the hourly heating or cooling loads. Each construction element (e.g. floor, window, wall) is modelled as a series of a few nodes (thermal capacities and resistances).

The **same simplifications as in many full dynamic simulation methods** apply, such as:

—– time step fixed to one hour;

— the air temperature is uniform throughout the room or zone;

— the various surfaces of the room or zone elements are isothermal;

— the thermo-physical properties of the materials composing the room/zone elements are time independent;

— the heat conduction through the room/zone elements is assumed to be one-dimensional;

— the external radiant environment (sky excluded) is at the external air temperature;

— the solar radiation within the room is evenly distributed and time-independent; and

– the operative temperature is the average between the internal air temperature and the mean surface temperature.

The main additional simplifications compared with full dynamic heat balance calculations are:

— Mass and thermal resistance, per construction, are evenly distributed in the construction. Consequently: no need for input per construction layer. However, a choice is offered to make a distinction between a few simple classes with respect to the distribution of the mass in each construction.

— Solar properties of windows are not solar angle dependent; total solar energy transmittance is assumed to be direct transmittance into the zone. Consequently: no need for input per layer of glass or solar shading.

— The mean radiant temperature is calculated by weighting the various internal surface temperatures according to the relevant areas. Consequently: no need for input of the precise positions of each construction element, other than orientation and tilt (for solar irradiance and radiation to the sky).

With these simplifications the **input data to be supplied by the user** are the same as for the monthly method.

Only **the standard writers will introduce extra data**: hourly operation schedules and weather data. On the other hand, the standard writers do not need to prepare tables with pre-calculated factors (e.g. on operation of blinds, effect of solar shading, etc.). Moreover, these hourly data are available anyway, e.g. for applying the principle of equivalence for novel technologies. The hourly method brings these data to the visible foreground of the method.

In **comparison to the simple hourly method from** ISO 13790:2008 (the three node “5RC1” model with the lumped capacity):

— The new model uses the same input data as the three node (5RC1) model, but does not need “obscure” assumptions and approximations with respect to the position of the mean radiant temperature and the position of ‘the mass’ in the model: these are now transparent, because they are modelled explicitly.

— Due to the much higher number of nodes a robust numerical solution method is required. But this can be simply implemented in software.

A **Microsoft Excel[3]TM spreadsheet** for testing and development is also acceptable, but the setup of the matrix calculation requires specific Microsoft ExcelTM expertise. Also, using Microsoft ExcelTM, a higher calculation time compared to the monthly method or the 5RC1-model can appear in cases involving many runs due to lengthy iterations, sensitivity studies and/or in case of several calculation zones.

I.3.3 Summary of main differences between the simple hourly method from ISO 13790:2008 and the hourly method in ISO 52016-1

Summary of main differences between the simple hourly method in ISO 13790:2008 and the new hourly method in ISO 52016-1:

I.3.3.1 Simple hourly method ISO 13790:2008

— All construction elements combined into one combined ‘windows’ element.

— One combined ‘opaque’ element (incl. even the ground floor).

— One overall thermal capacity.

— As a consequence: a fuzzy factor is needed to find the location for the thermal capacity and for the mean surface temperature.

3) Microsoft Excel is the trademark of a product supplied by Microsoft Corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

I.3.3.2 New hourly method in ISO 52016-1

— Each construction element is known anyway.

— As a consequence: these can be used directly, without aggregation, as separate elements (windows, walls, roof, floor, etc.) without asking for more input data from the user.

— Each building element keeps its own category of thermal capacity (light <-> heavy).

— Each building element keeps its own external environment conditions (outdoor air, ground, adjacent heated space, etc.).

— Each building element keeps its own solar absorption, orientation and area (e.g. important for large sunlit roofs).

— Special elements can be added easily and in a transparent way (e.g. passive solar elements; see Annex E).

I.4 Justification of the monthly method compared to dynamic calculation methods

The main justification for choosing the monthly method for the calculation of the monthly energy needs for heating and cooling is, in short, the following:

- History: the monthly method is widespread and was well understood.
- Transparency: the monthly heat balance between transmission and ventilation heat losses and solar and internal heat gains is simple and easy to follow. The utilization factor is a simple correction factor for the dynamic situation.
- Reproducible and robust: the monthly heat balance can fairly easily be followed or checked in a spreadsheet.
- Verifiable: the monthly calculation method can be easily tested because it is simple and transparent.
- The monthly method has been validated against the three node simplified hourly (5RC1) method from ISO 13790:2008 (see ISO 13790:2008, Annex H.4).

I.5 Justification of the hourly method compared to monthly method in ISO 52016-1

The main justification for the hourly method is, in short, the following:

- The building elements, climate, environment, technical building systems, user behaviour and operating conditions and controls have a dynamic influence on the indoor conditions and heat balance in a building zone (see I.6, including Figure I.2).
- An increased accuracy by a more detailed model is not the goal. The main goal of using hourly time intervals is to be able to take into account the influence of hourly and daily variations in weather, operation (solar blinds, thermostats, heating and cooling needs, occupation, accumulation, heat recovery, free ventilation cooling, etc.) and their dynamic interactions in a transparent way. In the monthly method these influences are taken into account by monthly correlation factors, such as the utilization factors for heating and for cooling.
- For low energy buildings and buildings with dynamically (inter-)acting technologies, the monthly method is no longer the simple transparent method that it used to be for more conventional buildings and technologies, in buildings with high energy losses. Due to the necessity to introduce several correction or adjustment factors, the original transparency and robustness of the monthly method has been lost.

— The more of the above mentioned dynamic technologies and processes are included in the monthly calculation method, the less transparent the monthly calculation method becomes, and the more an hourly method becomes transparent.

— The input data are kept the same as for a monthly calculation method.

— The output from the hourly calculation method will also contain the key monthly values, to maintain the same transparency and clarity in checking the output as in case of a monthly method, with the possibility of additional illustrative output, such as the hourly values of the main parameters during a typical week per season and the "energy signature" (e.g. heating and cooling needs per week as function of external temperature). Examples of such kind of output are given in Annex L.

I.6 Examples of relevant dynamic technologies or processes

— nocturnal set back and operation (internal gains, ventilation, shutters/blinds);

— weekend set back and operation (internal gains, ventilation);

— solar shading (cooling needs);

— solar shading (lighting needs);

— nocturnal ventilation (free cooling);

— heat recovery unit (ventilation), bypass;

— thermal zoning and exchange, e.g. with VRF and/or room wise local heat pumps;

— limited cooling capacity (Comfort cooling);

— Thermal Active Building Systems; and

— air handling unit for precooling/preheating.

Most of these technologies are characterized by the fact that they require assumptions with respect to the **control**: hourly, and/or daily and/or seasonally. The control can be manual, or automated (or mixed), local or central (or mixed (e.g. BACS), with or without feedback (e.g. from room conditions).

Whether control options are or should be differentiated in the standard calculation procedures depends on whether they are robust, verifiable and are expected to lead to real energy saving.

EXAMPLE If common practice is to keep radiator valves in a bed room closed, then a thermostatic radiator valve will not lead to energy saving, but probably to more energy use (more than compensated for by higher thermal comfort).

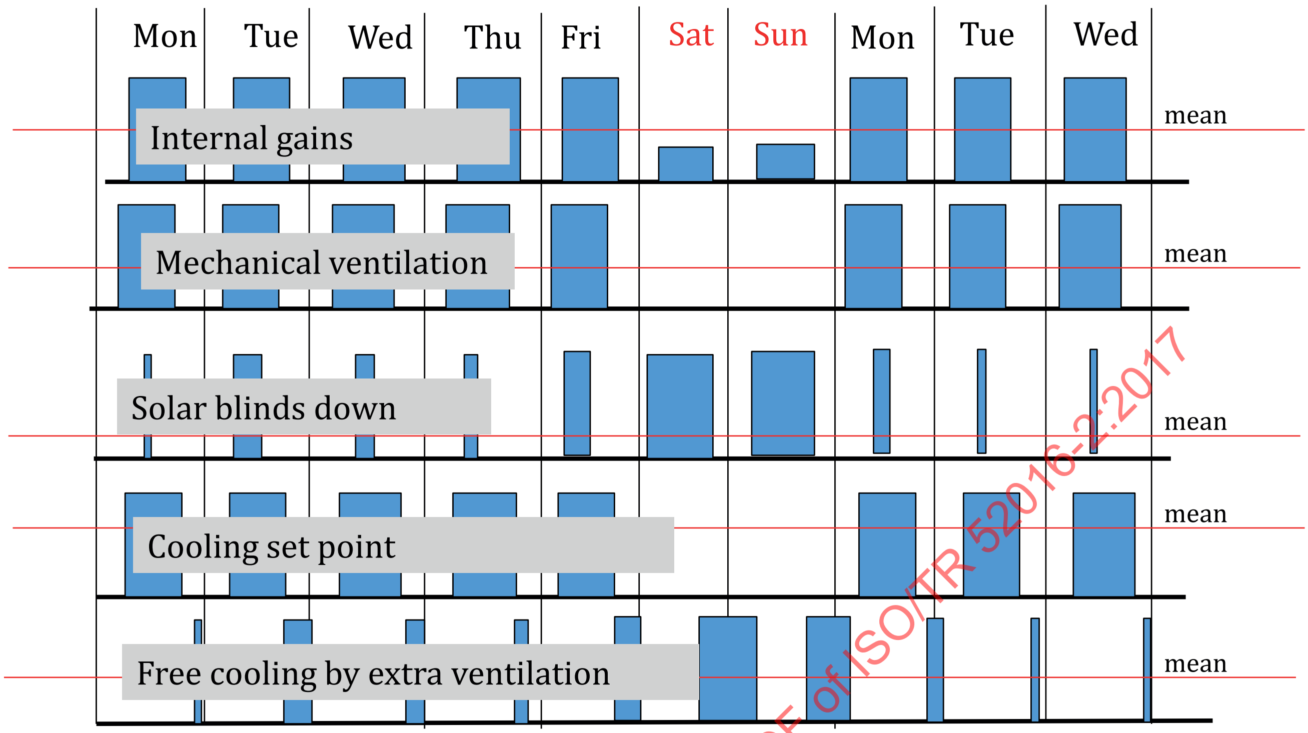


Figure I.2 — Illustration that the use of monthly mean values can be problematic, in particular in case of hourly patterns that have a dominant influence on the thermal balance

Another drawback of the monthly method is the following:

Because there are possibly months with both heating and cooling needs, and because this cannot be predicted without doing the actual calculation, for each month two independent calculations are performed:

1) Calculation of the heating needs, with assumptions for the heating mode (e.g. on the use of solar blinds, ventilation, etc.)

2) Calculation of the cooling needs, with assumptions for the cooling mode (e.g. on the use of solar blinds, ventilation, etc.)

Evidently this is a simplification for the dynamic alternations during the month.

I.7 Pros and cons of the hourly method compared to monthly method in ISO 52016-1

The main pros and cons for the hourly method in ISO 52016-1 compared to the monthly method in the same standard are presented in the form of the following dialogue:

— Pro hourly: With the hourly method the designer's choice for e.g. applying external movable solar shading, or the quality of the heat recovery unit, or the choice for a by-pass in the heat recovery unit, or for comfort cooling, is based on the impact in the **specific** situation, because of the **direct calculation** of the influence of (and interactions between) the specifically chosen processes/technologies and the hourly varying environment and operational conditions.

— Pro hourly: The hourly method enables to take into account the influence of hourly and daily variations in weather, operation (solar blinds, thermostats, heating and cooling needs, occupation, accumulation, heat recovery, free ventilation cooling, etc.) and their dynamic interactions in a direct, transparent way, without extra input for the user and without the correlation factors that are needed in a monthly method to take into account such dynamic effects. The impact of certain