



Technical Report

ISO/TR 52016-4

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

Part 4: Explanation and justification of ISO 52016-3

*Performance énergétique des bâtiments — Besoins d'énergie
pour le chauffage et le refroidissement, les températures
intérieures et les chaleurs sensible et latente —*

Partie 4: Explication et justification de l'ISO 52016-3

**First edition
2024-10**



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Published in Switzerland

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Foreword

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

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by ISO Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods* in collaboration 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 the parts in the ISO 52016 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

0.1 Set of EPB standards and supporting tools

This document gives guidance to a set of international standards that is used to collectively assess the overall energy performance of buildings (EPB). Throughout this document, this group of standards is referred to as the “set of EPB standards”.

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency (see ISO 52000-1, CEN/TS 16628 and CEN/TS 16629).

All EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in [Annex A](#) and [Annex B](#) with informative default choices.

One of the main purposes of the set of EPB standards is to enable laws and regulations to 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 (see [Annex B](#)).

0.2 Rationale behind the set of 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 set of EPB standards.

If this explanation were attempted in the standards themselves, the result is likely to be confusing, 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, e.g. this document, where all informative content is collected, to ensure a clear separation between normative and informative content (see CEN/TS 16629 for a more detailed explanation):

- to underscore the difference between the normative and informative content;
- to reduce the page count of the actual standard;
- to facilitate understanding of the set of EPB standards.

0.3 This document

This document gives guidance on ISO 52016-3. The role and the positioning of ISO 52016-3 in the set of EPB standards is defined in the introduction of ISO 52016-3. A brief article on the subject can be found in the REHVA Journal [\[21\]](#).

To fully understand this document, it is intended to be read in close conjunction, clause by clause, with ISO 52016-3. Essential information provided in ISO 52016-3 is not repeated in this document. References to a clause can refer to the combined content of that clause in both ISO 52016-3 and this document.

0.4 Accompanying spreadsheet

An extensive spreadsheet [\[35\]](#) has been prepared to test and demonstrate ISO 52016-1. For the purpose of testing and demonstrating ISO 52016-3, this spreadsheet has been extended with an (optional) sheet to cover adaptive building envelope elements with different states and different control scenarios according to ISO 52016-3.

Examples of calculations with adaptive building envelope elements are found in this document.

0.5 Background of this document and ISO 52016-3

ISO 52016-3 and the supporting technical report (this document) have been developed to respond to a strong need to include adaptive building envelope elements in the assessment of the energy performance of buildings. This inclusion aims to create a level playing field for conventional and promising techniques.

More extensive background information and history of the whole set of EPB standards is given in the introduction to ISO/TR 52000-2, the technical report accompanying the overarching EPB standard. Up-to-date information on the set of EPB standards can be found in the "public material" section of the ISO/TC 163 page on the ISO website.¹⁾

0.6 Application area of ISO 52016-3

ISO 52016-3 specifies procedures for the calculation of the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads of a building according to ISO 52016-1, with additions or modifications that are needed to incorporate adaptive building envelope elements in the calculation.

The main use of ISO 52016-3 is the assessment of the energy performance of buildings (energy performance labels and certificates), including comparison between buildings and for checking compliance with minimum energy performance criteria.

ISO 52016-3 is applicable to buildings at the design stage, to new buildings after construction and to existing buildings in the use phase.

1) <https://www.iso.org/committee/53476.html>.

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

Part 4: Explanation and justification of ISO 52016-3

1 Scope

This document provides explanation and justification to support the correct understanding and use of ISO 52016-3.

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.

ISO 7345, *Thermal performance of buildings and building components — Physical quantities and definitions*

ISO 9488, *Solar energy — Vocabulary*

ISO 52000-1, *Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures*

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

ISO 52016-3:2023, *Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 3: Calculation procedures regarding adaptive building envelope elements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345, ISO 9488, ISO 52000-1, ISO 52016-1 and ISO 52016-3:2023 apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Symbols, subscripts and abbreviations

4.1 Symbols

For the purposes of this document, the symbols given in ISO 52000-1, ISO 52016-1 and ISO 52016-3:2023 apply.

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

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52000-1, ISO 52016-1 and ISO 52016-3:2023 apply.

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

NOTE 1 ISO 52016-1 uses 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 used for both "glazing" and for "ground".

NOTE 2 In ISO 52016-3 the subscript w (origin: "window"), used in ISO 52016-1 for transparent construction elements is also used for the adaptive building envelope element.

NOTE 3 For the solar and daylight properties the subscript gl (origin: "glazing"), is used as a rule to specifically refer to the projected area of the transparent part of the element.

4.3 Abbreviated terms

For the purposes of this document, the abbreviated terms given in ISO 52016-1 and ISO 52016-3:2023 apply.

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

5 Description of the method

5.1 Output of the method

The structure of ISO 52016-3:2023, Clause 5 conforms to the common template for the set of EPB standards. ISO 52016-3:2023, Clause 5 contains a brief (qualitative) description of the method, starting with the main output from the standard.

ISO 52016-3 covers the calculation of the energy need for heating and cooling and the internal temperature in case of a building or building zone with one or more adaptive building envelope elements.

The method covers also, as product information, the calculation of some energy performance characteristics of adaptive building envelope elements, applied in a specific (e.g. reference) building.

NOTE Compare e.g. ISO 18292, that also uses a reference building for comparing the energy performance of windows.

This includes information on whether the building is smart ready in terms of adaptive building envelope elements.

5.2 General description of the method

5.2.1 General

The calculation procedures in ISO 52016-3 are an extension of the hourly calculation procedures specified in ISO 52016-1. ISO 52016-3 contains the additions and modifications that are needed to incorporate adaptive building envelope elements. Therefore, ISO 52016-1 is referenced accordingly throughout ISO 52016-3.

ISO 52016-1:2017 contains a normative Annex G that provides a framework for calculation procedures involving adaptive building envelope elements. ISO 52016-3 provides calculation procedures.

ISO 52016-3 fills a gap in the set of EPB standards.

The reasons for choosing an hourly calculation time interval are given in 6.2.

5.2.2 Distinction between ISO 52016-3 and ISO 52016-1

The calculation procedures of ISO 52016-3 can be seen as an extension of the procedures given in ISO 52016-1. The reasons for providing these in two separate documents are:

- If ISO 52016-3 was combined into ISO 52016-1, it can harm the acceptance and roll-out of ISO 52016-1, e.g. if a legal authority wants to adopt the calculation procedures of the current ISO 52016-1, but has hesitations to adopt ISO 52016-3.
- Maintenance of ISO 52016-1 would be more difficult and costly if combined with the content of ISO 52016-3. With a separate ISO 52016-3 it is easier to plan revisions, e.g. based on experiences by users or developing technologies.
- ISO 52016-3 requires specific expertise on the technologies and control scenarios involved.
- The parties interested in the details of ISO 52016-3 are quite specific. Combining all in one document would not be efficient from the user perspective.

5.2.3 Successive steps in the calculation procedures

In ISO 52016-3:2023, the actual calculation procedures are given in [6.9](#). However, that subclause is just one sentence:

"Apply the hourly calculation procedures according to ISO 52016-1:2017, 6.5, with the additions and adaptations specified in the previous clauses of this document."

ISO 52016-3:2023, 6.4 to 6.8 contain the procedures needed to prepare the calculation. In ISO 52016-3:2023, 5.4, these preparatory steps are introduced as six successive steps.

5.3 Technologies covered in ISO 52016-3

5.3.1 General

The technologies covered in ISO 52016-3 are selected on the basis of current or promising market share and distinction in functionality and control scenarios or passive response. Some technologies can be quite different in appearance but very similar in functionality and in options for control. For the purpose of ISO 52016-3 these are not categorized separately.

For example, for the purpose of ISO 52016-3 the physical model of a closed (unvented) cavity double skin façade is quite similar to a multiple glazing unit with integrated solar blinds.

Three main categories of technologies are covered in ISO 52016-3:

- Building envelope elements with dynamic solar shading (see [5.3.2](#)).
- Building envelope elements with chromogenic glazing (see [5.3.3](#)).
- Building envelope elements with an actively ventilated cavity (see [5.3.4](#)).

For the sources used in the selection of technologies, see References [35](#), [28](#), [17](#), [18](#), [27](#), [34](#) and [38](#).

Examples of types of adaptive building envelope elements that are not covered in ISO 52016-3 are presented in [5.3.5](#).

5.3.2 Building envelope elements with dynamic solar shading

A building envelope element with dynamic solar shading can be described as a façade element (usually fitted to a window, door, curtain walling or façade, with one or more actively operated mobile parts) defined as the curtain that can (partially) obstruct solar radiation or sunlight. The aim of dynamic solar shading is to control solar radiation and daylight, to contribute to the thermal insulation, thermal comfort, cooling savings and visual comfort when combined to glazing.

Dynamic solar shading can be positioned at the internal or external side of the façade element or integrated in between two or more façade elements. These façade elements may form a sealed multiple glazing unit, or consist of an assembly of multiple glazings, or assembly of partly transparent and partly opaque elements.

If a single façade is doubled inside or outside by a second, essentially glazed façade, it is usually defined as a double skin façade. The width of the cavity between these two skins can range from several centimetres at the narrowest to several metres for the widest accessible cavities. As long as such a façade has no intentional ventilation provisions (“closed cavity façade”) it fits into the description of the dynamic solar shading.

This contrasts with the third category, building envelope elements with an actively ventilated cavity.

The main technologies for the dynamic solar shading elements are:

- Venetian blind: blind where the curtain consists of horizontal slats which can be tilted and where the curtain may be retracted by accumulating the slats. The slat angle can be tilted in various positions. They are usually opaque, but can also be partly transparent or translucent.
- Roller blind: blind where the curtain consists of material (e.g. fabric) which is retracted by rolling. The curtain can be semi-transparent, semi-translucent or opaque, and sometimes thermally insulated (multilayer).
- Roller shutter: shutter where the curtain is retracted by rolling and consists of interconnected horizontal laths, that can be tilted or not, which run inside channels.

Examples are shown in [Figure 1](#):



a) Windows with internal roller blinds



b) Windows with external venetian blinds.
(Colour) photo by Samuel Zeller, CC0 1.0 DEED²⁾



c) Closed cavity façade with integrated venetian blinds



d) External folding-sliding shutters, Gerrit Rietveld Academie / Sandberg Instituut, Amsterdam

Figure 1 — Four examples of building envelope elements with dynamic solar shading

For movable blinds or shutters, a specific terminology is used to avoid confusion between the blind or shutter movement and other movements, such as slats and louvers:

- Extended/retracted: movement of the blind resulting in an increase/decrease in the surface area covered (see EN 12216:2018, 5.1)

2) No permission required. Credit: <https://creativecommons.org/publicdomain/zero/1.0/>

- Open/closed: terms used to describe the increase in light (opening) or reduction of light (closing) in an extended position for products with laths, slats or louvres which can be tilted or adjusted (see EN 12216:2018, 5.1).

See also examples in EN 12216.

5.3.3 Building envelope elements with chromogenic glazing

Chromogenic glazing can be described as an adaptive technology directly integrated in the glazing itself. The physical properties can reversibly change according to a specific active or passive trigger, changing the appearance of the glazing itself: making it more or less transparent, absorbing or reflecting for solar radiation and daylight.

The main technologies currently available on the market are:

- Thermochromic and thermotropic glazing (passive; based on the glazing temperature changing);
- Photochromic glazing (passive; based on the level of incident solar irradiance changing);
- Electrochromic glazing (active; based on the level of electric power changing);
- Gasochromic glazing (active, based on changing gas mixture in cavity);
- Liquid crystal chromogenic glazing (active; based on the level of electric power changing);
- Suspended particle devices.

However, other smart glazing technologies are being, or may be developed, that can be simulated in the same way, e.g. electrophoretic, fluidic glass, microshades and micromirror arrays.

Examples are shown in [Figure 2](#):



a) High transmittance



b) Low transmittance

Key

SOURCE: Project Hamilton Bonaduz, Switzerland. Electrochromic Glass (SageGlass). Pictures by Ingo Rasp.

Figure 2 — Examples of building envelope with chromogenic glazing

5.3.4 Building envelope elements with an actively ventilated cavity

5.3.4.1 Distinctive feature

A building envelope element with an actively ventilated cavity is similar to a building envelope element with dynamic solar shading, except for the intentional and possibly controlled (i.e. natural, hybrid or mechanical) ventilation of the cavity or air circulation via the cavity.

In many cases it is a ventilated double skin façade, but also a ventilated window with the intention to capture heat from the cavity fits into this category.

In addition to achieving thermal and solar control as in the previous two categories, the technologies under this category have in common that air is deliberately circulated through the cavity, to gain solar either heat, increase thermal comfort, or both, when heating is required and to enhance thermal comfort and reject surplus solar load during warm periods. If this is not the case, then, for the purpose of this document, the adaptive building envelope element does not belong to this category.

The difference with operable solar shading in [5.3.2](#) is that the air circulation and ventilation is controlled, either mechanically or by operable vents, thus adding a dimension to the control strategy.

5.3.4.2 Variety of technologies

A wide variety of technologies exist. Typical examples are:

- Double skin façade
 - with integrated solar shading;
 - mechanically or naturally ventilated;
 - with fixed or adjustable vent openings;
 - with narrow or wide cavity.
- Ventilated windows
 - with integrated blinds;
 - to either harvest or reject solar heat, recover heat from ventilation air, or both.

See more examples below in this subclause such as a simplified façade with air extracted behind an internal screen instead of glazing.

Active ventilative cooling is outside the scope of ISO 52016-3 if there is no thermal interaction with the components of the façade, or if it is achieved by other air inlets than the air inlet via (and with thermal interaction with) the façades.

5.3.4.3 Ventilation modes

Several ventilation modes can coexist within a single ventilated double façade [\[34\]](#):

- a) Outdoor air curtain:
In this ventilation mode, the air introduced into the cavity comes from the outside and is immediately rejected towards the outside. The ventilation of the cavity therefore forms an air curtain enveloping the outside façade.
- b) Indoor air curtain:
The air comes from the inside of the room and is returned to the inside of the room or via the ventilation system. The ventilation of the cavity therefore forms an air curtain enveloping the indoor façade.
- c) Air supply:
The ventilation of the façade is created with outdoor air. This air is then brought to the inside of the room or into the ventilation system. The ventilation of the façade thus makes it possible to supply the building with air.
- d) Air exhaust:
The air comes from the inside of the room and is evacuated towards the outside. The ventilation of the façade thus makes it possible to evacuate the air from the building.

e) Buffer zone:

This ventilation mode is distinctive inasmuch as each of the skins of the double façade is made airtight. The cavity thus forms a buffer zone between the inside and the outside, with no ventilation of the cavity being possible.

Several ventilation modes can coexist within a single ventilated double façade.

Generally, naturally ventilated double façades are those which present several ventilation modes, the shift from one ventilation mode to the other being done by motorized ventilation openings [34]. With motorized openings it is possible to shift from one ventilation mode to another as a function of their position (in this case, from a scenario of outdoor air curtain, when the openings are open, to a buffer zone scenario, when they are in closed position).

The ventilation makes use of openings in either the inner or outer skin, or both, and can be mechanical or natural.

In general, mechanically ventilated double façades are not equipped with operable ventilation openings and are characterized by well-defined ventilation modes. In case of natural ventilation, the operation is (as a rule: actively) controlled by openable vents in either the inner or outer skin, or both, allowing a shift from one ventilation mode to another as a function of their position. In that case, determining the precise mode of ventilation is not always self-evident. Indeed, when an opening is placed in open position, the ventilation phenomena which take place depend on the pressure conditions inside the cavity. The latter in turn depends on a multitude of factors, including the climatic conditions, e.g. speed and direction of the wind, temperature difference, sunshine, mode of working of the building's mechanical ventilation system or opening of the inside doors.

5.3.4.4 Façades or windows

The term "ventilated double façades" also covers the concepts of ventilated double windows. The distinction between these two terms (façade and window) is only made when a proper understanding of the text makes it imperative.

The ventilation air flow rates are provided by the relevant standard(s) under EPB module M5-5 (ventilation).

5.3.4.5 Double skin façades

A double skin façade can be defined as a traditional single façade doubled inside or outside by a second, essentially glazed façade [34]. Each of these two façades is commonly called a skin. A ventilated cavity, having a width which can range from several centimetres at the narrowest to several metres for the widest accessible cavities, is located between these two skins.

The main difference between a double skin façade and an airtight multiple glazing, whether or not it integrates a shading device in the cavity separating the glazings, lies in the intentional and possibly controlled ventilation of the cavity of the double skin façade.

For that reason, and to be clear in the distinction, in the context of ISO 52016-3 the term "building envelope element" is used with an actively ventilated cavity, thus expressing the key distinctive physical feature.

There are façade concepts where the ventilation of the cavity is controllable, by either fans or openings or both, and other façade concepts where this ventilation is not controllable. The indoor and outdoor skins are not necessarily airtight (see, for example, the "louver" type façades). Automated equipment, such as shading devices, motorized openings or fans, are most often integrated into the façade.

If the cavity is extended over multiple rooms (horizontally) or floors (vertically) it becomes a more complicated variant, due to the mixing of the cavity air temperatures and air pressures. For the purpose of ISO 52016-3, the complication has no significant effect, because it requires "only" that, for each state, the correct spatially "mixed" thermal and optical properties of the façade are obtained from the appropriate standards that have to provide the façade properties.

Examples of building envelope elements with actively ventilated cavities are shown in [Figure 3](#):



a) Antwerp Court House, Belgium, double skin façade with integrated ventilation system



b) ING House Amsterdam, The Netherlands, double skin façade with controlled natural ventilation

Figure 3 — Examples of building envelope elements with an actively ventilated cavity

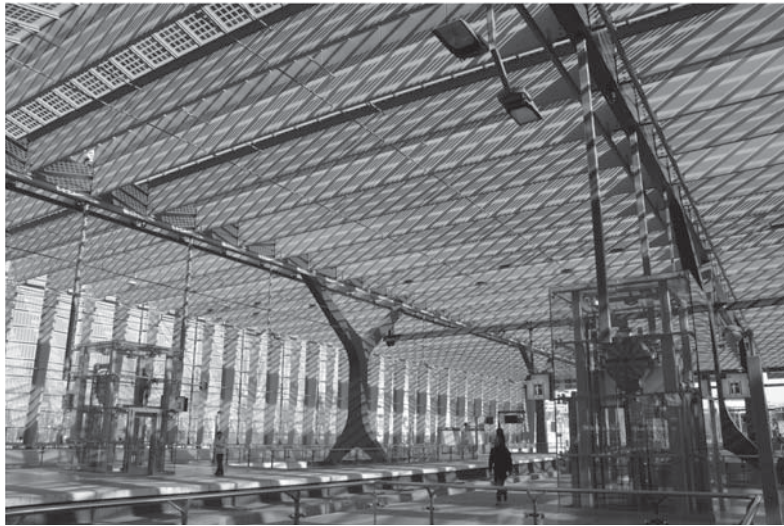
5.3.5 Types of adaptive building envelope elements not covered in ISO 52016-3

Types of adaptive building envelope elements that are not covered in ISO 52016-3 comprise, for example:

- Building integrated PV (BIPV): If integrated in or added to the glazing, the PV elements permanently change the optical properties of the glazing as any other material integrated in or fixed to the glazing (e.g. screenprint, film). The only difference is that a percentage of the absorbed solar radiation is ("passively"; based on pre-programmed optimizers) converted into electricity instead of converted to heat.
- Building integrated solar thermal systems (BIST): Similar to BIPV, the only difference with a conventional building envelope element is that a percentage of the absorbed solar radiation is converted into heat that is extracted based on the control of the solar thermal system; the control does not intend to optimize the heat transfer through the building envelope element for the sake of the energy balance and comfort for the room behind.

- Green façade and roof: These (passive) technologies also obstruct sunlight; thus, they also achieve sunlight control and summer and winter comfort goals. However, their market share and potential is still limited, while the physical description would require special knowledge.
- Phase change materials: These (passive) technologies aim to solar gain control, reduce cooling needs, winter and summer comfort, heat and solar energy store. However, their market share and potential are still limited, while the physical description and integration in the thermal balance calculation of the building would requires extra effort.

An example of a type of adaptive building envelope element that is not covered in ISO 52016-3 is shown in [Figure 4](#):



Key

SOURCE: (Colour) photo Steven Lek, CC BY-SA 4.0 DEED.

Figure 4 — Glazed roof with building integrated PV cells, Central Railway Station, Rotterdam, Netherlands

5.4 Control scenarios

When the work on ISO 52016-3 started, the high and increasing number of adaptive façade elements could not be assessed properly by using existing international standards.

No ready-to-use international standards exist for the assumptions on the control scenario. ISO 52120-1 is the key EPB standard on building automation and control. It provides a framework that needs to be worked out in each EPB calculation standard, for each controlled service or object separately. ISO 52016-3 fills this gap for what is called in ISO 52120-1 “blind control” (identifier: BLIND_CNTRL): “solar protection to avoid overheating and to avoid glaring”.

However, there were several challenges and limitations to the work:

- There was a lack of information on optimized control scenarios and on the real use in practice. Nevertheless, wherever simulations are performed in which adaptive building envelope elements are involved, certain assumptions are needed and are made anyway. The advantage of ISO 52016-3 is that the assumptions are transparent and common, thus facilitating product comparison. Moreover, recent studies provided increasingly useful information.
- For more complex façades, with their wide diversity in approaches, there is a limit to what extent harmonization of the description and the assumed operation is feasible. Consequently, ISO 52016-3 concentrates on the most commonly used technologies.

- More complex control scenarios, with for instance either predictive algorithms or combined with control of heating, ventilation and air conditioning (HVAC) and lighting, or both, pose a number of additional challenges. For this level no reference control scenario is specified in ISO 52016-3. This means that for such applications, ISO 52016-3 can be used, but only in a customized way. In that case ISO 52016-3 requires that the customization is clearly reported (see ISO 52016-3:2023, 6.8.1). Otherwise there is no transparency on the grounds for comparing products or the energy performance of buildings.

Consequently, reference control scenarios are specified in ISO 52016-3, at different levels of either automation or integration, or both (see ISO 52016-3:2023, 6.8). These reference choices aim to create a level playing field as much as possible for different technologies without becoming over-simplified, or over-optimistic.

Customized control scenarios may be used instead. Again, in that case ISO 52016-3 requires that the customization is clearly reported. Otherwise there is no transparency on the grounds for comparing products or the energy performance of buildings.

The studies that have been used for the development of the reference control scenarios are introduced in [6.8.7.2](#).

6 Calculation method

6.1 Output data

This clause in ISO 52016-3 conforms to the common template for the set of EPB standards. It allows input-output relations to be checked between the EPB standards and availability of output data.

Further explanation is given in ISO/TR 52000-2.

6.2 Calculation time intervals

For all calculations, the time interval is hourly, because the control scenarios are hourly or sub-hourly. Sub-hourly calculations are possible, but for ISO 52016-3 hourly calculations are chosen, because the calculations in ISO 52016-1 are hourly and because all standard environmental conditions are hourly: For climatic conditions see ISO 52010-1 and for indoor environment conditions see ISO 17772-1 or EN 16798-1.

ISO 52016-1:2017, G.2.2.2 gives procedures to derive monthly average values and correction factors, if needed for a monthly calculation method.

However, a monthly calculation method is not provided in ISO 52016-3, because:

- A monthly calculation method cannot take into account the dynamics of the indoor and outdoor conditions and interactions. With a monthly method it is, for example, not possible to assess the impact of absent or undersized systems on energy and thermal comfort or to assess how much solar energy gained on-site is utilized on-site and how much is surplus or to assess the impact of source temperature and energy need on the performance of a heat pump system or to assess the impact of weekend interruption (office) or night-time temperature setback (dwellings).
- A work-around, as for example applied in the monthly method of ISO 52016-1, is to introduce correction or correlation factors. However, these correction factors are highly generic and are incapable to show and value the impact of specific measures and technologies that do take into account these dynamics.
- This is even more problematic, because, as demonstrated in ISO 52016-1, the amount of input data requested from the user are for the hourly method in ISO 52016-1 not more than for the monthly method: they are the same.
- For many technologies, the hourly calculation procedures are much more transparent and simpler.

For example, in an hourly method, extending or retracting a movable solar shading device on the basis of solar irradiance on the given window requires only two IF statements: one for extension and one for retraction to provide for each hour in the year the total solar energy transmittance for the given window, based on the hourly solar irradiance for the given orientation and tilt angle, available from the weather

file. For the monthly method, many tables are needed to provide pre-calculated weighted average total solar transmittance values for various orientations, per month or season, for a specific climate. It is more complicated, less transparent, requires a pre-calculation using an hourly calculation method anyway and produces a monthly average value that does not reflect the actual dynamics over the various hours and days and cannot be used to check the impact on, e.g. hourly indoor temperatures (comfort). This is clearly shown in ISO 52016-1 by comparing ISO 52016-1:2017, Table B.24 on parameters for movable solar shading devices for the hourly method against ISO 52016-1:2017, Table B.44 on parameters for movable solar shading devices for the monthly method.

6.3 Input data

6.3.1 General

This clause in ISO 52016-3 conforms to the common template for each EPB standard. It allows input-output relations to be checked between the EPB standards and availability of input data from other sources.

It provides the overview of all input data. The tables in ISO 52016-3:2023, 6.3 are just a listing, the actual specification of the input is given further on in [Clause 6](#), as part of the description of the calculation procedures.

The input data for the calculation are the thermal, solar and daylight properties of the building element for the different states (e.g. from open to closed, from dark to light and combinations of these). In case of gradually varying properties: for a number of representative discrete states.

The thermal, solar and daylight properties of the building element are the thermal transmittance (U -value), solar transmittance (g -value) and daylight transmittance (τ_v).

In order to be able to use these properties for energy and internal temperature calculations, the details of the (passive or active) control scenario are used as input for ISO 52016-3.

6.3.2 Input data of a simplified adaptive building envelope element

See [6.4.2.1](#) and [6.4.2.2](#) for explanation of the input data in case of a simplified adaptive building envelope element.

6.3.3 Input data of a detailed adaptive building envelope element

See [6.4.2.2](#) for explanation of the input data in case of a detailed adaptive building envelope element.

6.3.4 Control related input data

6.3.4.1 Applied control type

For the use of software tools, the introduction of harmonized identifiers adds to the transparency of the assessment procedures. This applies in particular to typologies, e.g. to distinct categories of technologies and control options.

6.3.4.2 Number and description of states

If an adaptive building envelope element can be adapted in different dimensions (e.g. venetian blinds can be extended/retracted, but also the slats can be tilted), then for the understanding it is convenient to distinguish these dimensions in the listing of the possible states. See ISO 52016-3:2023, Table 13. However, for listing the properties for the various states and making the link to the control scenarios a one-dimensional numbering system is more convenient, especially when it comes to look-up tables in software.

See [6.4.3](#) for specific explanation of the control related input data per category of adaptive building envelope element.

6.3.4.3 List of sensors

The list of sensors is directly related to the applied methods to identify the conditions or events that can lead to a change of state.

See [6.8.3](#) for the options. In many cases, different types of sensors can have the same effect.

6.3.4.4 Applied methods to identify the conditions or events

See [6.8.4](#) for the options.

6.3.5 Climatic input data

No additional information beyond ISO 52016-3.

6.3.6 Constants and physical data

No additional information beyond ISO 52016-3.

6.3.7 Input data from [Annex A](#) and [Annex B](#)

See [Annex B](#) for explanation and justification of specific choices.

6.4 Properties of the adaptive building envelope element

6.4.1 General

The term adaptive building envelope element (see [Clause 3](#)) is used for the product or assembly that comprises the adaptive component(s). Usually, the adaptive building envelope element is a product or assembly consisting of multiple layers. When possible, the properties used as input for the calculation according to ISO 52016-1, for each state of the adaptive element, are the properties for the whole product or assembly that are invariable for a given state. In that case it is defined in ISO 52016-3 as a simplified adaptive building envelope element.

If the properties are variable, because they depend on environmental conditions (for environmentally activated elements: other than the conditions that trigger the state changes), then it is defined as a "detailed adaptive building envelope element". In that case a more detailed model of the adaptive building envelope element is needed in ISO 52016-3. For example, if the U -value or g -value strongly depends on local temperatures. This can be specifically the case for layers between glazing and solar shading provisions that are naturally ventilated.

However, if the variable properties can be described as a (pre-determined) function of specific conditions, the simplified model can still be used, in combination with the pre-determined function to be applied at each hour of the calculation. For example: the g -value of a windows with venetian blinds, at certain slat angle, as function of the solar angle above horizon and ratio direct-diffuse solar irradiance. See examples in [6.4.3.1](#).

On the other hand, if one or more of the component properties of the adaptive building envelope element are needed as input for the control scenario in ISO 52016-3, it also requires the use of a detailed model of the adaptive building envelope element. This is described in ISO 52016-3:2023, 6.4.2.

The input data for the calculation are the thermal, solar and daylight properties of the adaptive building element for the different states (e.g. from extended to retracted, from open to closed, from dark to light and combinations of these); and in case of gradually varying properties: for a number of representative discrete states.

These properties are the thermal transmittance (U -value), (optional) air permeability (L -value), solar transmittance (g -value) and daylight transmittance (τ_V).

These properties can be determined according to the relevant standards listed in ISO 52016-3:2023, Table B.1:

- for EPB module M2-5 (thermal transmission): ISO 10077-1 or ISO 15099;
- for EPB module M2-8 (solar and daylight properties): ISO 9050, EN 410, ISO 52022-3 or ISO 15099.

Each of these standards covers a specific application area, as described in the third column of ISO 52016-3:2023, Table B.1.

As much as possible input data from all types of construction elements are collected in ISO 13789 to enable ISO 52016-1 to refer for these input data to this single EPB standard, ISO 13789. For example, the properties from ground floor and windows. However, when dealing with less conventional adaptive building envelope elements, it can be more efficient to get the data directly from the appropriate standards on thermal and solar window properties listed above.

The standards that provide the solar and daylight properties can, in turn, require as input detailed (e.g. spectral or detailed directional) component properties.

In any case, if (only) detailed (e.g. spectral or detailed directional) properties are available as output from these standards, ISO 52016-3 requires that these are aggregated to become suited as input for ISO 52016-3.

In some cases, ISO 52016-3 requires more detailed information, for instance the properties per component, e.g. thermal resistance and air permeability per component, solar absorptance and solar and daylight transmittance and reflectance per component. In this case the simple model used in ISO 52016-1 for the transparent building envelope element (typically: the window) is not suited. A more detailed model is needed to describe the adaptive building envelope element. This is described in the next clause (6.4.2).

Figure 5 illustrates the different paths of linking a simple and a detailed adaptive building envelope element to the ISO 52016-1 calculation of heating and cooling load and internal temperatures.

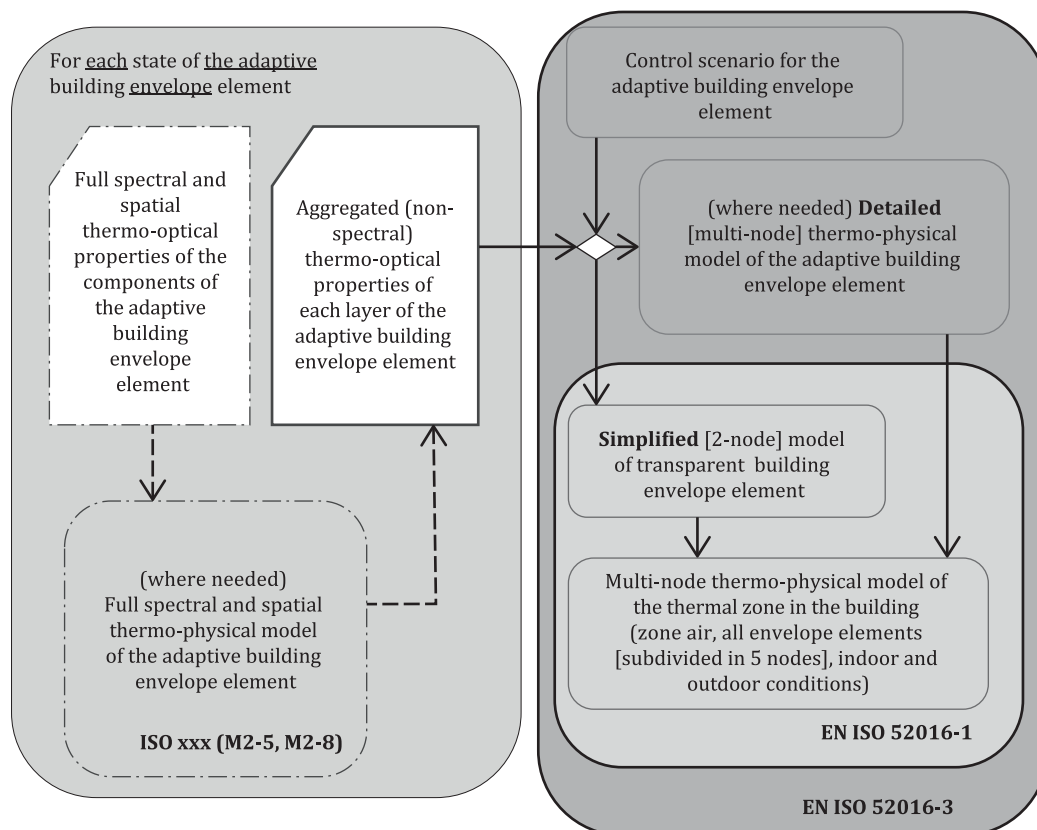


Figure 5 — Illustration of a simple and a detailed adaptive building envelope element linked to ISO 52016-1 calculation procedures

6.4.2 Simplified or detailed adaptive building envelope element

6.4.2.1 Simplified adaptive building envelope element

In case the solar or daylight properties are angle dependent, but approximated by fixed properties for representative conditions (e.g. angle of solar incidence and ratio direct: diffuse), the procedures as described for windows in ISO 52016-1:2017, E.2.2.1 are taken into account.

ISO 52016-1:2017, E.2.2.2 gives procedures in case of movable parts (e.g. shading, shutters), but those procedures are overruled by the more detailed procedures in ISO 52016-3.

6.4.2.2 Detailed adaptive building envelope element

No additional general information beyond ISO 52016-3.

Explanation on the multi-node model for the adaptive building envelope element is given in [6.4.4](#).

6.4.3 Properties of a simplified adaptive building envelope element

6.4.3.1 Adaptive building envelope element with dynamic solar shading

6.4.3.1.1 Direct and secondary solar energy transmission; simplification in ISO 52016-1

The total solar energy transmission consists of four parts (see ISO 52022-3 or ISO 15099):

- the direct part, τ_{sol} : the short wave solar radiation passing through the adaptive building envelope element to the internal environment (thermal zone), including the portions that enter the internal environment after re-reflection in one or more layers of the element;
- the secondary part, consisting of heat from solar radiation absorbed in one or more layers of the element that enters the internal environment by a) conduction), b) thermal radiation or c) ventilation.

In ISO 52016-1 the secondary solar energy transmission is approximated as a contribution to the direct solar energy transmission to the internal environment (thermal zone).

This approximation leads to an error in the surface temperature of the internal layer of the adaptive building envelope element. The error is small if the secondary solar heat gain is only a small portion of the total solar energy transmission (g -value) as is the case for windows without solar shading provision in place.

The reason for simplification in ISO 52016-1 was to avoid that for the hourly calculation method more input data are needed than for the monthly calculation method. Without this simplification the threshold to use the hourly calculation method would be higher, while the main purpose of going from monthly to hourly calculations was to catch the dynamic effects and interactions, as explained briefly in [6.2](#).

6.4.3.1.2 Variable properties

Within a specific state, the thermal and solar properties are often assumed to be constant, but this may not always be the case, as already stated in [6.4.1](#). The amplitude of variations strongly depends on the configuration and type of components: venetian blinds have a higher directional variation of solar and daylight transmittance than roller blinds. Building elements with naturally vented cavities (stack effect) have a g -value (or even U -value, depending on the configuration) that can be more strongly temperature dependent than in case of unvented cavities.

Whether or not to take this variability into account depends on the balance between the overall accuracy of the calculations on the one hand and the uncertainty in the physical process and uncertainty in the use in practice on the other.

The extreme is to use only a fixed value for the whole year, which is for instance common practice for the total solar energy transmittance (g -value) in case of a window with venetian blinds fully extended, while actually the natural air circulation along the blinds is a function of the temperatures of the blinds and

adjacent glazing (in turn: function of solar irradiation), environment temperature and e.g. wind. The ratio between direct and diffuse solar irradiance and the solar incidence angle has a significant effect on the g -value of a building envelope element (window) with venetian blinds.

A research result that is very relevant in this respect is the study by Zweifel [43] providing a new model (approximating formulae) for the optical properties (transmittance, reflectance) of venetian blinds as function of the sun position and slat angle. In this way, the simplified model for the adaptive building envelope element as used in ISO 52016-1 can be kept, with such function applied each hourly calculation interval to take the variability of the properties into account.

6.4.3.2 Adaptive building envelope elements with chromogenic glazing

6.4.3.2.1 Environmentally activated chromogenic glazing

The value of the total solar energy transmittance of the adaptive building envelope element changes as a result of a change of the optical property of the glazing laminate where the functional smart layer is integrated. Usually this is the solar absorption of the outer laminate of an insulated glazing unit, so: $a_{\text{sol;gl;1}}$. This component property is not an input parameter for ISO 52016-3, as described in 6.4.2, unless for specific reasons, such as to determine the conditions that set the state of the adaptive building envelope element. In that case ISO 52016-3 requires a detailed model of the adaptive building envelope element (see 6.4.4).

For information on properties of thermochromic glazing, see Reference [31]. For information on commercial materials, see Reference [29].

6.4.3.2.2 Actively controlled chromogenic glazing

No additional information beyond ISO 52016-3.

6.4.3.3 Adaptive building envelope elements with actively ventilated cavity

6.4.3.3.1 Ventilation properties and modes

No additional general information beyond ISO 52016-3.

One specific issue concerns the terms "cavity" versus "gap". The term cavity is usually reserved for the space between two parallel impermeable components (layers), such as a cavity wall, a double window, double skin façade or a sealed double-glazing unit. The cavity is filled with air or a gas-mix. In a closed cavity, the air or gas-mix can circulate, depending on the geometry, temperature and temperature difference between the surfaces of the planes ("Nusselt-Raileigh relations"). In a cavity with openings, air can move in and out, as result of forced ventilation, or naturally, as function of wind or stack effect, or both.

If a blind (e.g. roller blind or venetian blind) is placed inside a cavity, it is, as a rule, modelled as a layer similar to glazing, but with specific air permeability. In this case the cavity is split in two gaps, with air exchange depending on the conditions. See ISO 15099 or ISO 52022-3 for all details of the modelling of vented cavities. ISO 52022-3 uses the term gas spaces instead of cavities or gaps. ISO 15099 uses the terms cavity and gap also for the space between a glazing and a solar shading layer, without discrimination.

See 5.3.4 for a detailed description. See 6.8.5.5 for the various control modes.

6.4.3.3.2 Thermal and solar properties

No additional information beyond ISO 52016-3.

6.4.4 Model and properties of a detailed adaptive building envelope element

In order to understand the model and properties of a detailed adaptive building envelope element, it is necessary to understand the thermal balance model in ISO 52016-1.

See [Annex E](#) for relevant details on:

- the thermal balance model in ISO 52016-1;
- the simplified model of a transparent building element in ISO 52016-1, used for the simplified adaptive building envelope element;
- examples of the detailed adaptive building envelope element, including the formulae needed in ISO 52016-3 for making the connection to the thermal balance model of ISO 52016-1.

6.5 Connection of the model of the adaptive building envelope element to the model of the thermal zone of ISO 52016-1

See also [Annex E](#) for relevant details on:

- building envelope element, including the formulae needed in ISO 52016-3 for making the connection to the thermal balance model of ISO 52016-1.

6.6 Selection of control type

No additional information beyond ISO 52016-3.

6.7 Modelling of the control of the environmentally activated adaptive building envelope element

Discretization of a continuous range of states

For environmentally activated building envelope elements the function $Y = f(X)$ can be used directly at each hourly time interval. Consequently, discretization of a continuous range of states is not needed in ISO 52016-3, which makes the calculation procedure less complex.

For actively controlled building envelope elements the discretization can be "programmed" and is not a linear function of environmental conditions anyway.

Just in case discretization is needed in ISO 52016-3 for specific situations, the discretization procedures are given anyway.

The following is the procedure to calculate the property $Y_{gl,t}$ of the adaptive building envelope element at environment condition $X_{st,t}$, using a discrete number of states, N_{st} , assuming a linear relation:

Step 1: Define the number of discrete states, N_{st} :

N_{st} is the number of states of the adaptive building envelope element covering the range of variations in properties;

Minimum value: $N_{st} = 2$

Maximum value: ISO 52016-3 states that the number of states shall not exceed the technical possibility to operate at intermediate states. Under this condition, the default number is $N_{st} = 4$ and, for practical reasons, the maximum value is:
 $N_{st} = ([Y_{w,stmax} - Y_{w,stmin}] * 100 + 1)$

Step 2: Determine the discrete values of the environment condition and the property:

$$\Delta X_{st} = \frac{X_{stmax} - X_{stmin}}{N_{st}}, \Delta Y_w = \frac{Y_{w,max} - Y_{w,min}}{N_{st} + 1} \quad (1)$$

Step 3: Search the discrete value of $X_{st;i}$ ($i=1,...,N_{st}$) that is the closest to $X_{st;t}$ and determine the corresponding discrete value of $Y_{w;i}$:

$$\text{For } i = 1, ..., N_{st} \quad \text{find } X_{st;i} \quad \text{until } \left| X_{st;t} - X_{st;i} + \left(\frac{\pm \Delta X_{st,hyst}}{2} \right) \right| < \Delta X_{st} \quad (2)$$

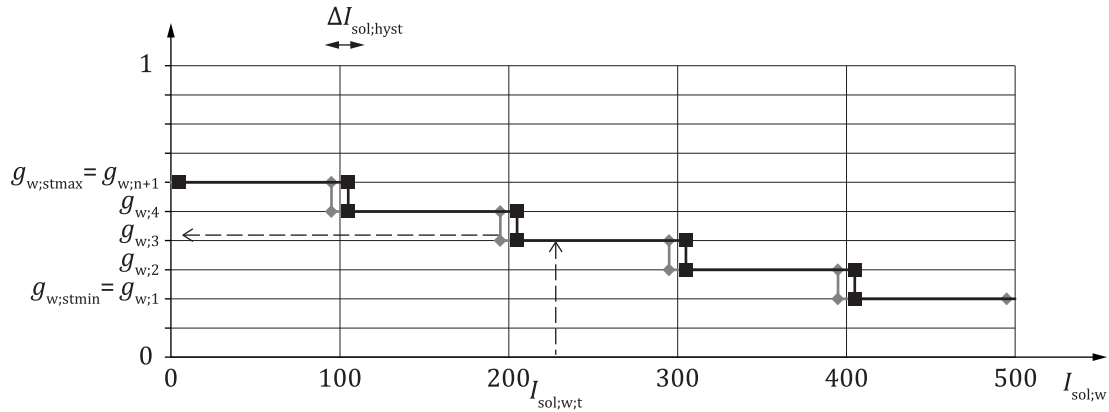
$$\text{If } X_{st;t} - X_{st;i} \left(\frac{\pm \Delta X_{st,hyst}}{2} \right) \geq 0 \quad \text{then } Y_{w;i} = Y_{w,max} - N_{st;i} \cdot (\Delta Y_w) \quad (3)$$

$$\text{if } X_{st;t} - X_{st;i} \left(\frac{\pm \Delta X_{st,hyst}}{2} \right) < 0 \quad \text{then } Y_{w;i} = -(N_{st;i} - 1) \cdot (Y) \quad (4)$$

with $\left(\frac{\pm \Delta X_{st,hyst}}{2} \right)$: is

$+\left(\frac{\Delta X_{st,hyst}}{2} \right)$ if $X_{st;t}$ is higher than the value at the previous time interval, or
 $-\left(\frac{-\Delta X_{st,hyst}}{2} \right)$ if $X_{st;t}$ is lower than the value at the previous time interval.

In [Figure 6](#) the procedure is illustrated for $Y_{gl;t} = g_{w;t}$ and $X_{st;t} = I_{sol,w;t}$. Compare with the continuous function as illustrated in ISO 52016-3:2023, Figure 1.



Key

$I_{sol,w,min} = 0 \text{ W/m}^2$, $I_{sol,w,max} = 400 \text{ W/m}^2$, $\Delta I_{sol,w} = 10 \text{ W/m}^2$

$g_{w,stm,max} = 0,6$, $g_{w,stm,min} = 0,2$

Figure 6 — Example of application of the discretization procedure (normally not needed)

6.8 Modelling of the control scenario for the actively controlled adaptive building envelope element

6.8.1 General

No additional information beyond ISO 52016-3.

6.8.2 Selection of conditions and events

No additional information beyond ISO 52016-3.

6.8.3 Selection of sensors

No additional information beyond ISO 52016-3.

6.8.4 Selection of methods to identify the conditions or events

6.8.4.1 General

No additional information beyond ISO 52016-3.

The following is additional information on specific topics:

6.8.4.2 Glare (ISO 52016-3:2023, Table 29):

6.8.4.2.1 General

There is a multitude of methods to assess glare risk, ranging from simple to detailed. The choice between the methods depends on the situation, such as availability and reliability of detailed data of the external and internal environment plus the occupants and the available equipment. Three typical methods are presented in ISO 52016-3.

6.8.4.2.2 Glare method MM1, AM1 (=AC1)

For many aspects, relatively simple and reliable tools and descriptors are available, but not for discomfort glare from windows. Several different equations describing the subjective sensation of discomfort glare experienced by an observer have been published (see Reference [41]). In general, all these equations draw upon four physical quantities: the luminance and solid angle of the source, background luminance (adaptation) and position (line of sight).

The majority of existing glare equations were developed for the evaluation of discomfort glare from small (artificial) light sources and cannot be used for the assessment of discomfort glare from windows, because of the mostly large source size and sometimes complex nonuniform glare sources.

An approach to overcome the difficulties of how to treat individual differences in perceived glare was to use the probability that a person was disturbed instead of using the glare magnitude itself. For that reason, the glare scale was reduced to two categories: a category “disturbed” was used if the subject rated the glare source to be “disturbing” or “intolerable”. The new probability function was called “daylight glare probability, DGP”.

Based on comprehensive user assessment studies in test rooms, Wienold [42] suggests using an upper limit value of DGP = 0,45 to avoid disturbance by glare.

In Wienold and Christoffersen,[41] it is shown that the most simple formula gives already a reasonable correlation between DGP and the glare perception. This simplified DGP (named DGPs) can be derived as a linear equation with the vertical illuminance at eye level, $E_{v,e}$.

In ISO 52016-3 DGP had to be renamed. The following symbol and subscript was chosen instead of DGP: P_{dglare} : probability of daylight glare.

$$P_{\text{dglare}} = 6,22 \cdot 10^{-5} E_{v,e;w} + 0,184 \quad (5)$$

However, this equation formula omits the influence of individual glare sources. Therefore, the DGPs can be applied only if no direct sun or specular reflection of it hits the eye of the observer. Enhanced DGP formulae were developed, (see References [30] and [31]) based on vertical eye illuminance and the other parameters mentioned above, allowing individual glare sources to be identified and quantified.

But without knowledge on the details of the space (e.g. geometry, material properties) and position of the occupants, these enhanced models are not applicable as default choice for the calculations in ISO 52016-3.

Moreover, for ISO 52016-3, the vertical illuminance at eye level itself had to be obtained, somehow, from the illuminance on the external surface of the façade, $E_{v;e;w}$

NOTE This is also true for assessing the DAYL-mode, but for that mode it is less critical for the comfort of the occupants.

In a conservative estimation, the vertical illuminance at eye level can be estimated to be not more than 0,25 of the illuminance on the external surface of the façade. In that case, the formula for DGPs would reach the limit value to avoid glare disturbance ($DGP = 0,45$), at external illuminance of 17 100 lx. This is equivalent to an irradiance of 150 W/m².

In building simulations, this irradiance level is also often used as an indicator that blinds should be closed to avoid or decrease the disturbance of direct solar (beam) radiation.

Consequently, in ISO 52016-3:2023, Formula (6) the external irradiance level of 150 W/m², converted into illuminance level of 17 250 lx is used as default limit value for glare:

$$P_{\text{dglare}} = 0,25 \times 6,22 \cdot 10^{-5} E_{v;e;w} + 0,184 \quad (6)$$

In any case this limit value should be regarded as a rough indication for a first preliminary evaluation and to demonstrate that the control procedures work correctly. Other, more precise methods are listed in ISO 52016-3. Those are applicable if more detailed information is used, see [6.8.4.2.3](#) (Glare method AC2).

6.8.4.2.3 Glare Method AM2 (=AC2)

This concerns a (simplified) geometric approach, estimating the vertical illuminance on the occupant, using the estimated hourly solar illuminance level and direction, the position and view direction of the occupant, combined with the geometrical data, daylight transmittance of the adaptive building envelope element and background luminance (walls, floor, ceiling), using formulae (rule based control) or separate tools (model based control). See References [\[42\]](#) and [\[30\]](#).

6.8.4.2.4 Optimized position of blind

The rules or models mentioned above can also be complemented with calculation of the optimum position of the adaptive element. For instance, the level of retraction of roller blinds to interrupt the line between the eyes and the sun, or the slat angle in case of Venetian blinds, or the window sections that need to be darkened in case of chromogenic glazing.

Recent studies provide algorithms to adjust the position (state) of a solar blind to avoid glare, while maintaining as much as possible incoming daylight and view out, for example:

- Angelina Katsifaraki et al,[\[33\]](#) with a daylight optimized simulation-based shading controller for venetian blinds;
- Zweifel[\[43\]](#),[\[44\]](#) providing formulae and scenarios for the control of the slat angle of venetian blinds;
- de Vries and Loonen[\[40\]](#) on optimization of the level of retraction of roller blinds.

6.8.4.2.5 Glare method AM3 (=AC3)

Estimation of the glare risk by direct measurement (e.g. indoor CCD camera into direction of the window).

6.8.4.3 Low daylight (ISO 52016-3:2023, Table 30)

6.8.4.3.1 Low daylight method MM1, AM1 (=AC1)

As default approach, the internal illuminance at desk level, $E_{v;int;desk}$ is roughly estimated with a simplified linear formula involving the external daylight illuminance on the adaptive building envelope element, the

daylight transmittance of the transparent part of the adaptive building envelope element and the height of the transparent area of the adaptive building envelope element above 1 m from the floor.

$$E_{V;\text{int};\text{desk}} = a_{\text{dayl}} \cdot \tau_{V;\text{gl}} \cdot H_{\text{gl};1\text{m}} \cdot E_{V;\text{e};\text{w}} + b_{\text{dayl}} \quad (7)$$

With the two coefficients a_{dayl} and b_{dayl} the result can be adapted to the type of sky and sun angle, geometry and material properties of the room.

As default parameter values are chosen: $a_{\text{dayl}} = 0,02 \text{ m}^{-1}$, $b_{\text{dayl}} = 30 \text{ lx}$ and $H_{\text{gl};1\text{m}} = 1,4 \text{ m}$.

Taking the limit value of 300 lx (see 6.8.7.1), the limit is reached, for example according to [Table 1](#).

Table 1 — Daylight mode default criteria

	With the default parameters: Low daylight mode if illuminance or irradiance lower than:	
$\tau_{V;\text{gl}}$ (-)	$E_{V;\text{e};\text{w}}$ (lx)	$I_{\text{sol};\text{w}}$ (W/m ²)
0,8	12 000	105
0,4	24 000	210
0,1	96 000	840

6.8.5 Basic rules for the reference control scenario

6.8.5.1 General

For the reference control scenarios, the following basic assumptions and rules apply.

6.8.5.2 Individual modes

No additional information beyond ISO 52016-3.

6.8.5.3 Combinations of choices

No additional information beyond ISO 52016-3.

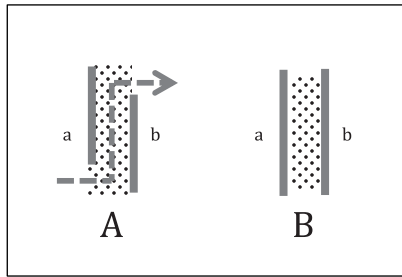
6.8.5.4 Limit values of the control parameters

No additional information beyond ISO 52016-3.

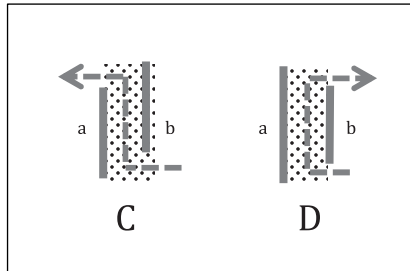
6.8.5.5 Adaptive building envelope elements with actively ventilated cavity

For active ventilative façades, the ventilation through the façade is controlled.

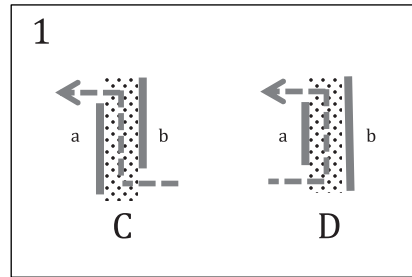
This is illustrated in [Figure 7](#).



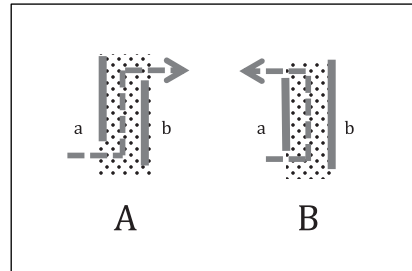
To harvest solar heat
Typical for natural ventilation only



To warm up internal glazing
For natural or mechanical ventilation
a) Heating mode



To cool down internal glazing
For natural or mechanical ventilation



To cool down cavity (ventilative cooling)
Typical for natural ventilation only
b) Cooling mode

Key

- a External.
- b Internal.
- 1 if possible

- A if air supply wanted
- B if no air supply wanted
- C if air exhaust wanted
- D if no air exhaust wanted

Figure 7 — Illustration of additional basic reference control scenario for active ventilated façades (applicable only if technically possible)

6.8.6 Modelling of the user behaviour

One of the key simplifications in the control scenarios in ISO 52016-3 is, that for manual and motorized operation the different behaviour of different possible occupants with regard to the position of the blind is averaged (see also [Annex D](#)). Ideally, a high number of hourly calculations would be chosen, each with different occupant types (= different blind positions), together leading to a statistically representative set. However, this is currently not feasible.

See [6.8.7](#) for more explanation of the reference control scenarios, including the modelling of the user behaviour.

6.8.7 Reference control scenarios

6.8.7.1 General parameter values

The reference control scenarios provide the actual state as function of a number of conditions.

The options for the conditions are (see [Table C.1](#) for explanation of all identifiers):

DAY-mode: DA, NI

HC-mode: HE, NE, CO

TINT-mode: TN, TH, TV

RAD-mode: RL, RH

DAYL-mode: LN, LL

GLARE-mode: GN, GY

In total this gives 144 combinations.

However, not each combination is physically possible (e.g. NI with RH) or relevant. In the latter case, these are clustered together (e.g.: GX means that it applies to both GN and to GY).

In the end 23 relevant combinations remained, as shown in the flow chart in ISO 52016-3:2023, 6.8.7.

For a specific combination of type of adaptive element, control type and space type, the corresponding state properties are specified. This is done in ISO 52016-3:2023, Annex C.

The generic control scenario, illustrated with the flow chart in ISO 52016-3:2023, 6.8.7, with its 23 possible states looks complicated. However, not all choices are always applicable, and the resulting states are not necessarily all different. In [Annex C](#) of this document flow charts are presented for specific combinations of adaptive element type, space category and control type. These flow charts show that the actual number of states for a specific combination is sometimes much less than 23.

The obvious question is then: why use this generic scenario instead of directly introducing the specific scenarios for each combination? The answer is that using the generic scenario as starting point, the specific scenarios can be modified and expanded to other combinations by just changing the input data: the thermal, solar and visual transmittance of the adaptive element for each of the 23 states. There is no need for any re-programming of software or spreadsheet and consequently no risk of introducing programming errors, ambiguities or conflicts.

6.8.7.2 Parameter values specified for the reference control scenarios

6.8.7.2.1 General

In ISO 52016-3:2023, Table 33, parameter values are specified for the reference control scenarios, as far as not dependent on the space type or adaptive element type (these latter parameters are provided in [Annex C](#) of the standard). This applies to:

6.8.7.2.2 HC-mode

In case of absence of heating or cooling system or in case of longer than 24 h zero heating or cooling needs due to holidays or weekend interruption (e.g. in an office), the 24 h average value of the heating or cooling needs is not available to decide on the HC-mode. In that case the internal operative temperature or the external air temperature is used as criterion, see [Table 2](#).

Table 2 — HC-mode parameters

MM1, AM1	$\theta_{\text{int;op;24;limHE}}$	20	°C
	$\theta_{\text{int;op;24;limCO}}$	23	°C
AM2 ^b	$\theta_{\text{e;a;24;limHE}}$	12	°C
	$\theta_{\text{e;a;24;limCO}}$	16	°C

The MM1, AM1 methods are the default choice; the indoor operative temperature needed for this method is available and therefore this method is a better choice than the method AM2 that uses the external air temperature as criterion for the HC-mode.

The AM2 method is not the default choice in the standard; the limit values for the external air temperature are based on the study described in [Annex D](#).

6.8.7.2.3 TINT-mode

See [Table 3](#).

Table 3 — TINT-mode parameters

MM1, AM1	$\theta_{\text{int;op;limTN}}$	22	°C
	$\theta_{\text{int;op;limTV}}$	24	°C

These values are based on the study described in [Annex D](#).

6.8.7.2.4 GLARE-mode

See [Table 4](#).

Table 4 — GLARE-mode parameters

MM1	$P_{\text{DGP;limGY}}$	0,45	--
AM1	$P_{\text{DGP;limGY}}$	0,45	--

The $P_{\text{DGP;limGY}}$ limit of 0,45 is based on Wienold 2009^[42] as the threshold for disturbing glare (see [6.8.4](#), explanation of the methods MM1, AM1).

6.8.7.2.5 DAYL-mode

See [Table 5](#).

Table 5 — DAYL-mode parameters

MM1	$E_{\text{V;int;desk;limLL}}$	300	lx
AM1	$E_{\text{V;int;desk;limLL}}$	300	lx

These values are based on the study described in [Annex D](#). See [6.8.4](#) for the explanation of the methods MM1, AM1.

6.8.7.3 Reference control scenarios for adaptive building envelope elements with dynamic solar shading or chromogenic glazing

The detailed specification of states are based on recent studies.

In particular, the European Solar Shading Organisation (ES-SO) has conducted a study to analyse the results from recent international research on the use of solar shading devices. The analyses led to control schedules for manual versus motorized versus automated control. These control schedules were then tested in series of building simulation, to obtain insight in the sensitivity of the choices on the calculated energy and comfort.

Adjustments were made to find a balance between simplicity and sensitivity, taking into account the uncertainty and large variation that exist on the actual user behaviours in practice.

Details of the ES-SO study are presented in [Annex D](#).

First draft control scenarios were also evaluated as part of a study led by TNO to develop an innovative adaptive climate façade (See Reference [\[32\]](#)).

As follow-up and partly in parallel with the ES-SO study, simulations have been performed to test and evaluate control scenarios e.g. as described in the draft of ISO 52016-3 that was published for enquiry in 2022, by:

— Department of Architecture and Design, Politecnico di Torino, Turin, Italy.