PUBLIC DOCUMENT

Report on Case Study to EN ISO 52016-3, Impact of adaptive building envelope elements on heating and cooling needs and internal temperatures

September 30, 2023

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Abbreviations and acronyms in this document:

CEN	**European standards organization**
EN	**European standard**
EPBD	**Energy Performance of Buildings Directive**
EPB standard	**Standard for the calculation of energy performance of buildings, that complies with the requirements given in ISO 52000-1, CEN/TS 16628 and CEN/TS 16629 or later updates**
ISO	**International organization for standardization**
TR	**Technical report (of CEN and/or ISO)**

1 Introduction

This document presents the case study with example calculations using EN 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* [1].

This case study makes use of the spreadsheet tool that has been developed to demonstrate the calculation procedures and to perform example calculations on EN ISO 52016-1 [3], with a special (optional) addition to enable calculations including the procedures of EN ISO 52016-3.

The aim of the study is to test and demonstrate the EN ISO 52016-3 calculation procedures including the control scenarios.

This case study makes use of the common choices with respect to climatic data, example buildings and conditions of use as for the earlier series of case studies (see bibliography), with some details revised, due to new findings or specific needs.

A summary of these example calculations can be found in CEN ISO/TR 52016-4 [2], the technical report accompanying EN ISO 52016-3.

2 Executive summary

This document presents the case study with example calculations using EN 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* [1].

The aim of this study was to test and demonstrate the EN ISO 52016-3 [1] calculation procedures including the control scenarios.

This case study makes use of the spreadsheet tool that has been developed to demonstrate the calculation procedures and to perform example calculations on EN ISO 52016-1 [3], with a special (optional) addition to enable calculations including the procedures of EN ISO 52016-3.

The spreadsheets developed to support the individual EPB standards have been and are primarily intended to validate and demonstrate the associated standard in a **transparent** way. In the spreadsheet, each step in the calculation can be followed. As a result, the spreadsheet is not suited (but also not intended) for use in daily practice.

In any case, for use in the daily practice of EPB assessment, **a software tool** will be needed, with user-friendly interface and connecting the different modules for the overall EPB calculation. The spreadsheet is very suitable for software developers to check the calculation algorithms in their programs.

The new features of the spreadsheet tool on EN ISO 52016-1 are extensively introduced and illustrated in this report:

The focus is -of course- on the **additional sheet** (“AdaptW”) to enable **calculations according to EN ISO 52016-3**, coupled -on an hourly basis- to the core calculation of the spreadsheet: calculation according to EN ISO 52016-1, the calculation of the energy needs for heating and cooling, internal temperatures and sensible and latent heat loads.

But two other new features in the spreadsheet on EN ISO 52016-1 are also extensively introduced, because these are relevant for this case study:

- **Adaptive comfort criteria** according to EN 16798-1 have been included as an option. (although for specific reasons not used in this case study).
- A (seasonal and total) **thermal comfort score** has been developed within the European ALDREN project [16], as a key indicator next to the energy performance indicators and the energy class. The idea behind this score is similar to the idea behind the adaptive comfort

criteria.

This thermal comfort score has been added to the spreadsheet tool to enrich the evaluation of results from the spreadsheet on EN ISO 52016-1 in general. As first application it has been used in the evaluation of the example cases in this case study.

The calculations have been performed for the single-family house and on a simple office room, in order to demonstrate the impact of different patterns of use, like optional night or day time temperature set back (residential), office hours and weekend interruption (office), but also the differences in control scenarios between residential and office spaces.

The calculations were performed for the three selected climates, with evidently quite different balance between heating and cooling needs.

The results of the example cases show that the updated spreadsheet on EN ISO 52016-1 [3] with the added sheet for (optional) application of EN ISO 52016-3 [1] enabled to check and demonstrate the functionalities of EN ISO 52016-3 and the interaction with the calculation procedures of EN ISO 52016-1.

The spreadsheet works well to demonstrate, validate and illustrate the calculation procedure of EN ISO 52016-3. In particular because each step of the calculation is visible and can be tracked and traced, as has been demonstrated with the example cases.

All data and the updated **spreadsheet tool** will be made **publicly available** at the EPB Center website for additional exercises.

Link: https://epb.center/support/documents/demo-en-iso-52016-1/

Main limitations of this case study:

– As the spreadsheet tools on other EPB standards, this **spreadsheet tool is not suited for application in daily practice**. It has not been developed for that purpose. It has been developed to test and demonstrate the calculation procedures of a specific EPB standard, in a transparent way, step-by-step.
– For daily use in practice, software tools can be used that have a user-friendly interface and that make the connections to other parts of the overall EPB calculation.
– **Conclusions on** the difference between **the example cases shall not be extrapolated** to other cases, because there is a multitude of combined effects (climate, orientation, window size, space type, insulation level, building mass, …) that lead to the final result, in terms of energy and comfort. That is why the set of EPB standards adopted the holistic approach: the performance of a component or product can only be properly appreciated in the full and dynamic context of the specific building.
– The spreadsheet contains some simplifications regarding the assessment of **lighting and visual comfort** conditions (to avoid the need for more detailed information on room, occupants and sky), but for the testing and demonstration this is no problem. A software tool covering all key EPB standards is more suited to integrate all aspects in full detail.
– For the same reason building envelope elements with an **actively ventilated cavity** have not been included in this case study.

3 The context of the case study

EN ISO 52016-3:2023 [1] specifies procedures for the calculation of the sensible and latent energy needs for heating and cooling and the internal temperatures and humidity of a thermal zone in a building using the hourly procedures given in EN ISO 52016-1 [3], with the additional procedures given in EN ISO 52016-3.

Note that it is not the intention of this case study to give an explanation and justification of the calculation procedure of the standard in full detail. This is extensively done in the technical report that accompanies the standard: CEN ISO/TR 52016-4 [2].

4 Coverage of the scope

4.1 Introduction

4.1.1 Scope of the standard

EN 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 the hourly calculation methodology in ISO 52016-1. Additions or modifications of the calculations are provided in EN ISO 52016-3 if the building envelope contains one or more adaptive building envelope elements: building envelope elements with adaptive components that are either environmentally or actively controlled as a function of specific conditions. The adaptive building envelope element replaces the transparent building element in the calculation according to ISO 52016-1.

The three types of adaptive building envelope elements covered in this document are:

- Building envelope elements with dynamic solar shading
- Building envelope elements with chromogenic glazing
- Building envelope elements with an actively ventilated cavity

Environmentally activated control is described in EN ISO 52016-3 for building envelope elements with chromogenic glazing, but can also occur for other types of adaptive building envelope elements. In that case the same approach applies as for environmentally activated chromogenic glazing.

EN ISO 52016-3 is applicable to the assessment of the energy performance of buildings (energy performance labels and certificates), including comparison between buildings and checking conformity with minimum energy performance criteria.

It is also applicable to assess the contribution of the adaptive building envelope element to the smart readiness of a building.

In addition, EN ISO 52016-3 provides indicators for the impact of the adaptive building envelope element on the performance of the building compared to a reference building envelope element. It is applicable to buildings at the design stage, to new buildings after construction and to existing buildings in the use phase.

EN ISO 52016-3 is not applicable to geometrically complex adaptive building envelope elements that can only be modelled as multiple coupled thermal zones.

4.1.2 Scope of this case study

This case study is focussed on testing and demonstrating the procedures for the calculation of the energy needs for heating and cooling and internal temperatures according to the hourly calculation methodology in ISO 52016-1 with the additions or modifications of the calculations given in EN ISO 52016-3[1] in case the building envelope contains one or more adaptive building envelope elements: building envelope elements with adaptive components that are either environmentally or actively controlled as a function of specific conditions.

[1] Including proposed amendment 2023 regarding Annex C

Limitations:

The spreadsheet tool, and consequently the calculations in this case study do not include cases with **environmentally controlled (also known as 'passive') adaptive building envelope elements**, because the calculation procedures for these elements are very simple compared to the procedures for actively controlled elements.

The calculations do also not include "**different" adaptive building envelope elements** in the same space: if their properties or their control scenarios are different, or if they are identical but behave differently due to different ambient conditions (e.g. if positioned at different orientations). This limitation, however, does not hinder the demonstration of the various types of elements and control scenarios.

Building envelope elements with an **actively ventilated cavity** are also not included in this case study. The main reason is the high variety in products and assemblies, but mainly because it would not be complete without hourly coupling with the air flow calculations according to EN 16798-7 [14] and it would add a dimension to the degrees of freedom in the control scenarios and consequently complicate the specification of input data and the calculation procedures significantly.

Spreadsheet:

The spreadsheet developed to demonstrate EN ISO 52016-1 (with the EN ISO 52016-3 addition for optional use) is primarily intended to validate and demonstrate the standard(s) in a **transparent** way. In the spreadsheet, each step in the calculation can be followed.

As a result, the spreadsheet is not suited (but also not intended) for use in daily practice.

In any case, for use in the daily practice of EPB assessment, **a software tool** will be needed, with user-friendly interface and connecting the different modules for the overall EPB calculation. The spreadsheet is very suitable for software developers to check the calculation algorithms in their programs.

4.2 Coupling and complementing spreadsheets

4.2.1 Introduction

To facilitate the use of the spreadsheet and to test specific links with other EPB standards, links have been created with the most relevant other spreadsheets in the series.

Some links are straightforward, **one-directional input-output relations**. These are introduced in 4.2.2.

Other couplings are a little **bit more complex**, because they involve hourly interactions. In some cases the hourly interactions can be dealt with by adding the relevant equations from another module into the spreadsheet tool for EN ISO 52016-1. See 4.2.3

If there are hourly interactions with other modules that are **more complex**, then two spreadsheets need to be run as a couple, exchanging input and output on an hourly basis. See 4.2.4. Spreadsheets are not the most appropriate type of tools for such dynamic coupling, in particular in case of hourly calculations covering a full year.

One should keep in mind, though, that such couplings **do not intend to replace a software tool**. The sole intention is to illustrate and demonstrate the calculation procedures and to lay a basis for reference calculation cases e.g. to validate software tools.

4.2.2 Straightforward input-output links

Simple, one-directional links have been created with the spreadsheet that generates **climatic datasets** (see case study on EN ISO 52010-1 [10], [5], [6]) and the spreadsheet that generates a full year of **hourly operation schedules and conditions of use** (see case study on EN 16798-1 [13]).

Both links are important, because they contribute to the overall consistency and transparency of the EP calculations.

4.2.3 Add on calculations

One example of an "add on" calculation is the calculation of the **heat transmission through a ground floor** according to EN ISO 13370:2017.

Another example is the (simplified) calculation of **ventilative cooling**. A special sheet has been added to the spreadsheet of EN ISO 52016-1 with rules that can overrule the assumed air flow rate in case the conditions are favourable for applying ventilative cooling.

Simplified, because for assessing the actual air flow rates, a coupling with the spreadsheet with EN 16798-7 (air flow rates) is needed, in which case we are on the next level: see 4.2.4

A third important application of an 'add on' sheet is the one that is central in this case study: the sheet for **adaptive building envelope elements**, according to EN ISO 52016-3:2023. This new standard deals specifically with the integration of adaptive building envelope elements in the calculation of EN ISO 52016-1, including reference control scenario's. In this add on sheet these control scenarios can be specified and tested. The (hourly) output is a change of state of the adaptive element, so a change in thermal and solar properties, that overrules the fixed input values that are otherwise used.

More explanation and illustration is given in 5 (Calculation tools).

4.2.4 Dynamic coupling between two spreadsheets

This concerns two spreadsheets that need to be run as a couple, exchanging input and output each hour during the calculation. More details are given in the case study on EN ISO 52016-1 [11].

Such coupling is not needed for the underlying case study.

5 Calculation tools

5.1 EN ISO 52016-1 spreadsheet, with special addition for EN ISO 52016-3

5.1.1 Introduction

Under the Service Contract with DG ENERGY a new version of the spreadsheet on EN ISO 52016-1 was prepared and published in November 2019.

However, for the cases studies in 2021 the spreadsheet has again been significantly updated, including a first version of the added sheet to enable calculations for the development and testing of draft versions of EN ISO 52016-3. Following some final checking and cleaning, a preliminary test version was published at the EPB Center website in January 2023, including fully operational procedures to perform calculations according to the further developed draft of EN ISO 52016-3[2].

For this case study the spreadsheet has been further updated and corrected and published in August 2023.

Link: https://epb.center/support/documents/demo-en-iso-52016-1/

In this report the focus is on the additional sheet to enable calculations according to EN ISO 52016-3.

Extensive information on the spreadsheet on EN ISO 52016-1 *as a whole* can be found in the specific case study report on that standard [10]. More general information on EN ISO 52016-1 can also be found in EPB Center webinars [8].

[2] Including proposed amendment 2023 regarding Annex C

Two other new features in the spreadsheet on EN ISO 52016-1 deserve an explanation in this report:

- Adaptive comfort criteria (5.1.2);
- Thermal comfort score (5.1.3).

5.1.2 New in spreadsheet on EN ISO 52016-1: adaptive comfort criteria

In the new version of the EN ISO 52016-1 spreadsheet adaptive comfort criteria according to EN 16798-1 have been included as an option.

The following graph (**Figure 1**) shows an example: single family house in Strasbourg for the month June.

Without adaptive comfort criteria the setpoints for this case would be: 20°C with night time temperature setback of 16°C for heating and 26°C for cooling.

The graph shows that, with some delay and smoothing, the setpoints for heating and cooling are increased if the outdoor temperature rises above a certain level.

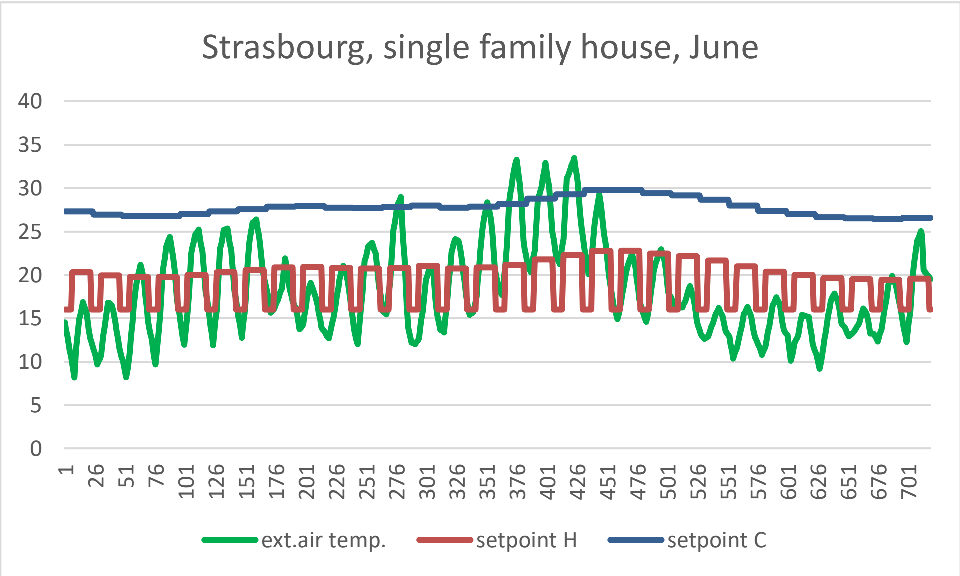


Figure 1 – Example of adaptive comfort criteria, built in as a new option in the spreadsheet on EN ISO 52016-1

However, to avoid that the this choice would complicate the analyses and conclusions, this option has not been applied in this case study.

5.1.3 New in spreadsheet on EN ISO 52016-1: thermal comfort score

The absence of a system (e.g., cooling) could lead to better energy performance with poorer indoor environment quality (IEQ). Improving IEQ by installing the system (e.g., cooling) could lead to poorer energy performance. Passive solutions leading to low energy consumption while ensuring a good thermal comfort need to be rewarded.

Therefore, a thermal comfort score has been developed within the European ALDREN project [16], to be reported together with the energy performance indicators and the energy class. This will make it possible to compare the energy performance of building with regard to IEQ.

The calculated thermal comfort score is dedicated for comparing buildings and it is not linked to a specific use or a specific room of the building.

This Thermal Comfort Score is added to the spreadsheet tool to support the evaluation of examples of the calculations according to EN ISO 52016-3

This thermal comfort score has been added to the spreadsheet tool to enrich the evaluation of results from the spreadsheet on EN ISO 52016-1 in general. As first application it has been used in the evaluation of the example cases in this case study, as presented in Clause 6.

The protocol for calculating the Thermal Comfort Score for simulated energy performance is described in full detail in Table 10 of [16]. The idea behind this score is similar to the idea behind the adaptive comfort criteria. It consists of the following steps:

Step 1:

- Extract from the calculation the hourly external air and indoor operative temperatures.

Step 2:

- Assign each hour during occupancy to one of the three seasonal periods of the year, based on the outdoor running mean temperature (as in EN 16798-1:2019 [7], but adapted): winter, summer and spring/fall.

  Note that the division into heating, cooling and intermediate season between heating and cooling is based on the **clothing**, which refers to the outdoor running mean temperature. The operation schedules of technical systems are not taken into account for division into seasons (heating, cooling, between heating and cooling).

Step 3:

- For each season and for each of the four IEQ categories as specified in EN 16798-1: divide the hours during occupancy hours in which the operative temperature is inside or outside the temperature interval for thermal comfort. These temperature intervals are defined in Table B.5 of EN 16798-1:2019, for each season, for different space categories. IEQ category I is the most stringent, category IV is the most lenient.
- Then, for each season and for each IEQ category, calculate the fraction of occupancy hours outside the temperature interval.

  The temperature setpoints adopted for our calculations are based on values given in EN 16798-1, applicable for IEQ category II, with the following effect:
  - The more stringent temperature interval of **IEQ category I** will not always be met. So even if the available heating and cooling power is enough to always meet the setpoints, the thermal comfort score will not be ideal.
  - The setpoints in EN 16798-1, Annex C are the same for each of **the three seasons** (e.g. 20-26°C), while for the thermal comfort score they are more refined, because they take into account the clothing (ergo: the season). See examples below.
    For calculations that use the setpoints from EN 16798-1 Annex C this implies that we need to ignore the thermal comfort score during spring/fall.
  - There is no rule defined for **occupied hours with night time temperature setback**. One solution could be to ignore these hours, ergo: to regard these night time hours as unoccupied. However, then also too high operative temperatures during night would be ignored. This would be a bad idea, because high night time temperatures are even more harmful for health than high temperatures during daytime, as they prevent occupants to recover from the temperature stress and disturb good sleeping quality.
    As solution, it has been decided to take also the occupied hours with night time temperature setback into account for the thermal comfort score, but with a 4 Kelvin

decreased value for the lower temperature limit. The 4K decrease (as the night time temperature setback itself) is a recognition of the higher 'clothing' (clo-value) during night time due to bed cover.

Steps 4&5:

- For each season, calculate the thermal comfort score as the weighted mean -for each IEQ category- of the fractions of occupancy hours outside the interval.

Step 6:

- Calculate the overall thermal comfort score as a weighted average using the hours during occupancy for each season period as a weighting factor.

A worked example is shown below in **Tables 1 - 3**:

Table 1 - Lower and higher operative temperature limits per IEQ category and per season, for residential and office spaces

Residential space	**IEQ cat I**	**IEQ cat II**	**IEQ cat III**	**IEQ cat IV**
Winter, lower limit [a]	21,0	20,0	18,0	17,0
Winter, higher limit	25,0	25,0	25,0	25,0
Summer, lower limit [a]	23,5	23,0	22,0	21,0
Summer, higher limit	25,5	26,0	27,0	28,0
Spring/fall, lower limit [a]	22,25	21,5	20,0	19,0
Spring/fall, higher limit	25,25	25,5	26,0	26,5
Office space	**IEQ cat 1**	**IEQ cat 2**	**IEQ cat 3I**	**IEQ cat 4**
Winter, lower limit	21,0	20,0	19,0	17,0
Winter, higher limit	23,0	24,0	25,0	25,0
Summer, lower limit	23,5	23,0	22,0	21,0
Summer, higher limit	25,5	26,0	27,0	28,0
Spring/fall, lower limit [a]	22,25	21,5	21,5	19,0
Spring/fall, higher limit	24,25	25,0	26,0	26,5
[a]: Residential: during night time temperature setback: lower limit decreased with 4 K				

Example of result (case SFHn_Sbg_InVen_MAN_HE; see 6.2.2.1.1):

Table 2 - Steps 4&5

Winter	**Hrs occupied**	3960		
IEQ Category	**Weight**	**Hrs out cat.**	**% out cat.**	**% in category (excl. all better cat.)**
IEQ I	1	2580	65,2	34,8
IEQ II	2	0	0,0	65,2
IEQ III	3	0	0,0	0,0
IEQ IV	4	0	0,0	0,0
<> IEQ IV	5			0,0

			Score	**1,7**
Summer	**Hrs occupied**	3072		
IEQ Category	**Weight**	**Hrs out cat.**	**% out cat.**	**% in category (excl. all better cat.)**
IEQ I	1	2073	67,5	32,5
IEQ II	2	1617	52,6	14,8
IEQ III	3	839	27,3	25,3
IEQ IV	4	382	12,4	14,9
<> IEQ IV	5			12,4
			Score	**2,6**
Spring/Fall	**Hrs occupied**	1728		
IEQ Category	**Weight**	**Hrs out cat.**	**% out cat.**	**% in category (excl. all better cat.)**
IEQ I	1	938	54,3	45,7
IEQ II	2	771	44,6	9,7
IEQ III	3	14	0,8	43,8
IEQ IV	4	0	0,0	0,8
<> IEQ IV	5			0,0
			Score	**2,0**

Table 3- Steps 6&7

Season	**Occup.hrs**	**Score**
Winter	3960	1,7
Summer	3072	2,6
Spring/Fall	1728	2,0
Overall thermal comfort	**8760**	2,1

The scale:
≤ 2
>2.0 ≤ 2.5
>2.5 ≤ 3
>3

5.1.4 Additional sheet for EN ISO 52016-3

The spreadsheet on EN ISO 52016-1 has been extended with a sheet called AdaptW that contains the choices, rules and calculation results for EN ISO 52016-3[3].

[3] Including proposed amendment 2023 regarding Annex C

More information on the rationale of the calculation procedures of EN ISO 52016-3 can be found in the accompanying technical report, CEN ISO/TR 52016-4 [2].

A core element of the EN ISO 52016-3 calculation procedures is the set of **reference control scenarios** for actively controlled adaptive building envelope elements (EN ISO 52016-3, Annex C). In A**nnex A** examples are given of **flow diagrams** that illustrate these reference scenarios. The full set of flow diagrams can be found in CEN ISO/TR 52016-4.

The next paragraph (5.2) successively describes:

- the input data and parameters (5.2.1);
- the hourly calculation, step-by-step (5.2.2);
- the postprocessing and output (5.2.3).

5.2 Explanation and demonstration of the additional sheet for EN ISO 52016-3

5.2.1 Input data and parameters

5.2.1.1 Input data to activate the optional calculation according to EN ISO 52016-3

As part of the input data for EN ISO 52016-1, this sheet AdaptW can be activated or ignored.

To activate it, two actions are needed:

- In the sheet Method_input: the switch to activate this option needs to be changed from 0 to 1.
- In the sheet Input_0: the class of the window(s) to which the calculation procedures for adaptive elements (sheet AdaptW) shall apply, need to changed from “F” (fixed properties) to “Wadapt1”: the properties as calculated each hour in the sheet adaptW. See **Figure 2**:

For South window:
class changed from “F” to “Wadapt1”

Eli		1	2	3	4	5	6	7	8
Name	Unit	ground floor	facade S	ternal floor	pitched roof	internal wall	window E	window S	w + door W
Subtype	-	GR	OP	AD	OP	AD	W	W	W
Class	-	I	I	D	D	D	F	Wadapt1	F
U_{eli_inp}	W/(m2K)		0,22	2,03	0,11	1,77	1,00	1,06	1,10
$R_{c;eli\_inp}$	(m2K)/W	5,30							
$\kappa_{m;eli}$	J/(m2K)	306000	306000	464000	17500	299000	0	0	0
A_{eli}	m2	91,8	32,2	85,0	61,8	70,0	4,9	12,0	8,5

Figure 2 – Sheet Input_0: select window(s) to become an adaptive element

Note that in the spreadsheet more than one window can become an adaptive element, but for this version of the spreadsheet (see limitations listed in 4.1.2) they will all behave the same, following the first one (counted from left to right). The calculation procedures in the standard, EN ISO 52016-3, do not have this limitation: different adaptive elements can be assigned to different windows, or the same adaptive elements can be assigned to different windows. In the latter case they can still behave differently at a given hour, e.g. because they are positioned on different orientations.

If activated, the resulting hourly thermal and solar properties of the adaptive transparent building element overrule the fixed values that are used as 'normal' input in the EN ISO 52016-1 spreadsheet.

All other input data and parameters related to EN ISO 52016-3 are (to be) given in the special sheet “AdaptW”. This sheet consists of several sections, as introduced in the following paragraphs.

5.2.1.2 Input of thermal, solar and visual properties of adaptive element: brief library

The sheet AdaptW contains a brief library of 12 example adaptive elements, with different glazing and adaptive component types, with the thermal, solar and visual properties for different key states (see **Figure 3**):

- Status 0 = retracted.
- Status 1 = extension status 1 (e.g. for Venetian blinds: horizontal slats = open).
- Status 2 = extension status 2 (e.g. for Venetian blinds: slats at 45°).
- Status 3 = extension status 3 (e.g. for Venetian blinds: slats at 80° = closed).

The properties are based on the relevant standards, as listed in EN ISO 52016-3.

In the spreadsheet: if the adaptive element is partly extended, the properties are linearly interpolated.

If extension status 2 or status 3 are not applicable, the properties are simply set to the same values as for status 1.

LIBRARY OF ADAPTIVE ELEMENTS (max. 12) with properties for each key state

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			Extension status 0 (retracted)				Extension status 1					Extension status 2	
Number (id)	Description	Type	$U_{w;Wadapti;sti}$	$g_{w;Wadapti;sti}$	$\tau_{e;w;Wadapti;sti}$	$\tau_{vis;w;Wadapti;sti}$	Descr.	$U_{w;Wadapti;sti}$	$g_{w;Wadapti;sti}$	$\tau_{e;w;Wadapti;sti}$	$\tau_{vis;w;Wadapti;sti}$	Descr.	$U_{w;Wa}$
1	SG-EXRBLD	ExRoChr	5,809	0,884	0,87	0,905	mply extende	3,269	0,114	0,02	0,014	as status 1	3,26
2	SG-EXVBLD	ExVen	5,809	0,884	0,87	0,905	slats 0 degr.	3,784	0,231	0,18	0,212	slats 45 degr.	3,72
3	SG-INVBLD	InVen	5,809	0,884	0,87	0,905	slats 0 degr.	4,685	0,548	0,30	0,361	slats 45 degr.	4,49
4	DG-EXRBLD	ExRoChr	1,063	0,653	0,58	0,814	mply extende	0,900	0,040	0,01	0,012	as status 1	0,9
5	DG-EXVBLD	ExVen	1,063	0,653	0,58	0,814	slats 0 degr.	0,936	0,142	0,11	0,178	slats 45 degr.	0,93
6	DG-INVBLD	InVen	1,063	0,653	0,58	0,814	slats 0 degr.	0,978	0,478	0,21	0,327	slats 45 degr.	0,96
7	SCG-EXRBLD	ExRoChr	0,984	0,332	0,31	0,699	mply extende	0,837	0,030	0,00	0,010	as status 1	0,83

Figure 3 – Partial screenshot of the spreadsheet section with input of example adaptive elements and their properties for successive key states (see also 6.1.2.4)

5.2.1.3 Parameters on scenario dependent control criteria

The following parameters are given in the sheet AdaptW:

- High and very high operational temperature threshold values, as function of control and space type, according to Table 33 of EN ISO 52016-3.
- Low and high solar radiation threshold values, as function of control type, space type, HC-mode and TINT-mode, based on Table C.1 of EN ISO 52016-3.

See **Figure 4**:

P	Q	R	S	T	U	V	W	X	Y	Z	AA
		52016-3: Table 33		52016-3, Table C1							
OVERVIEW OF SCENARIO DEPENDENT CONTROL CRITERIA											
	1	TINT-mode		RAD-mode		6	7	8	9	10	11
				NE-TH	NE-TH	NE-TV	NE-TV	CO-TH	CO-TH	CO-TV	CO-TV
Number	Description (id)	TH	TV	RL	RH	RL	RH	RL	RH	RL	RH
1	MAN-RES	22	24	37,5	72,5	37,5	72,5	37,5	72,5	22,5	47,5
2	MOT-RES	22	24	30,0	60,0	30,0	60,0	30,0	60,0	17,5	33,0
3	AUT-RES	22	24	30,0	60,0	15,0	30,0	15,0	30,0	10,0	15,0
4	MAN-OFFHE	22	24	37,5	72,5	37,5	72,5	37,5	72,5	22,5	47,5
5	MOT-OFFHE	22	24	30,0	60,0	30,0	60,0	30,0	60,0	17,5	33,0
6	AUT-OFFHE	22	24	30,0	60,0	15,0	30,0	15,0	30,0	10,0	15,0
7	MOT-OFFHECO	22	24	15,0	30,0	15,0	30,0	10,0	15,0	10,0	15,0
8	AUT-OFFHECO	22	24	10,0	15,0	10,0	15,0	10,0	15,0	10,0	15,0
9											
10											

Figure 4 – Screenshot of spreadsheet section with scenario dependent control criteria, according to Table 33 and Table C.1 of EN ISO 52016-3

5.2.1.4 Parameters on other control criteria

The following parameters are given in the sheet AdaptW:

- Parameters for HE-mode, if no heating or cooling system available or if system switched off.
- External vertical illuminance limit for glare disturbance (in the spreadsheet based on simple default formula, see CEN ISO/TR 52016-4, 6.8.4)
- External vertical illuminance limit for low daylight (in the spreadsheet calculated with simple formula, see CEN ISO/TR 52016-4, 6.8.4).
- Default value for the conversion factor from irradiance to illuminance (the luminous efficacy).

See **Figure 5**:

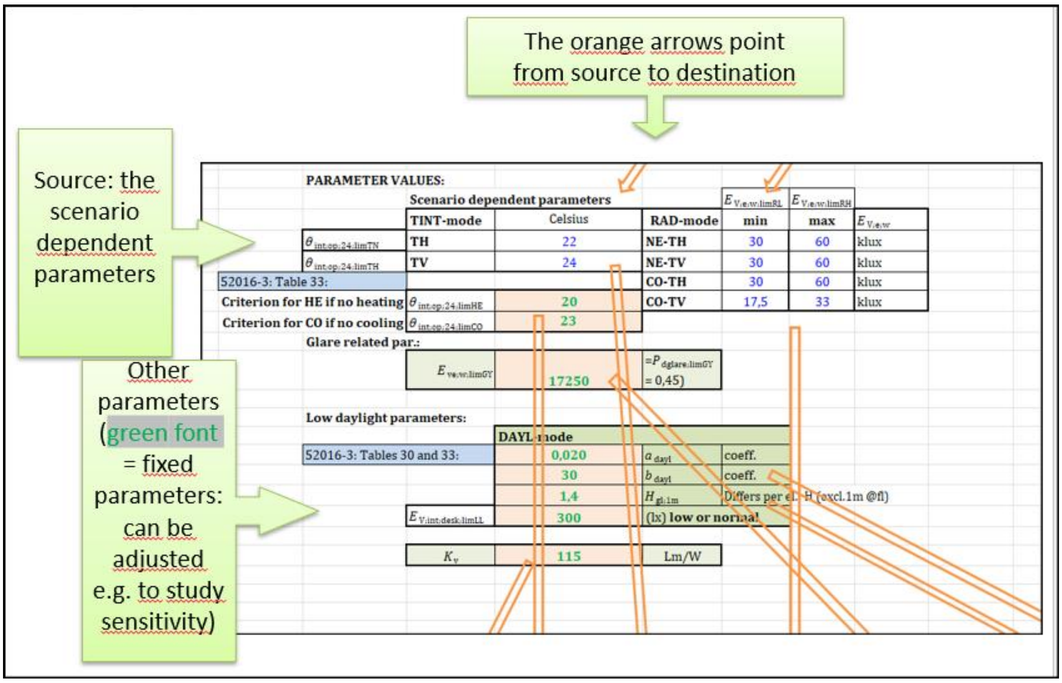


Figure 5 – Screenshot of spreadsheet section with other control criteria according to Table 30 and Table 33 of EN ISO 52016-3

5.2.1.5 Parameters on position of blinds of each state

Position of blinds of each state, for various types of adaptive elements and space types, according to Tables C.2 – C.8 of EN ISO 52016-3[4]:

- The fraction that is extended "by rule": as specified by the control scenario.
- Plus:
    - for manual control the correction due to user behaviour (EN ISO 52016-3, 6.8.6);
    - for automated control the correction due to occupant intervention (EN ISO 52016-3, 6.8.6);
- The state extension number, referring to the secondary states. In case of venetian blinds the secondary states are:
    1. slats open
    2. slats half open
    3. slats closed

    For shutters, roller blinds and chromogenic glazings there are no secondary states.

See **Figure 6**:

AP	AQ	AR	AS	AT	AU	AV	AW	AX
POSITION at each state, as function of scenari			52016-3, Tables C2-C8					
	Table C2-MM			Table C2-AUT			Table C3-MM	
	1	2	3	4	5	6	7	8
State	**Fraction extended, by rule**	**Correction for deviating occupants**	**State extension number (for the extended part)**	**Fraction extended, by rule**	**Correction for deviating occupants**	**State extension number (for the extended part)**	**Fraction extended, by rule**	**Correction for deviating occupants**
Comment:	No comments	o comment	No var.	lo comment	o comment	No var.	No comments	o commen
1	0,00	0,10	1	0,00	0,00	1	0,00	0,10
2	0,00	0,10	1	0,00	0,00	1	0,00	0,10
3	0,00	0,10	1	0,00	0,00	1	0,00	0,10
4	0,00	0,10	1	0,00	0,00	1	0,00	0,10
5	0,00	0,10	1	0,00	0,00	1	0,00	0,10
6	1,00	-0,40	1	1,00	0,00	1	1,00	-0,40
7	1,00	-0,40	1	1,00	-0,20	1	1,00	-0,40
8	0,00	0,10	1	0,00	0,00	1	0,00	0,10
9	1,00	-0,40	1	1,00	0,00	1	1,00	-0,40
10	1,00	-0,40	1	1,00	-0,20	1	1,00	-0,40
11	0,00	0,10	1	0,00	0,00	1	0,00	0,10

Figure 6 – Partial screenshot of spreadsheet section with position of adaptive element for each state (1 - 23), from Tables C.2 – C.8 of EN ISO 52016-3

[4] Including proposed amendment 2023 regarding Annex C

5.2.1.6 Input data on how to select the case

The following selections need to be made:

- Space type:
    - residential,
    - office heated,
    - office heated and cooled.
- Adaptive element: to be selected from the brief library, nº 1 - 12 (which can be customized). This includes:
    - Type of adaptive element
    - Thermal, solar and visual transmittance for each of the key states

See **Figure 7**:

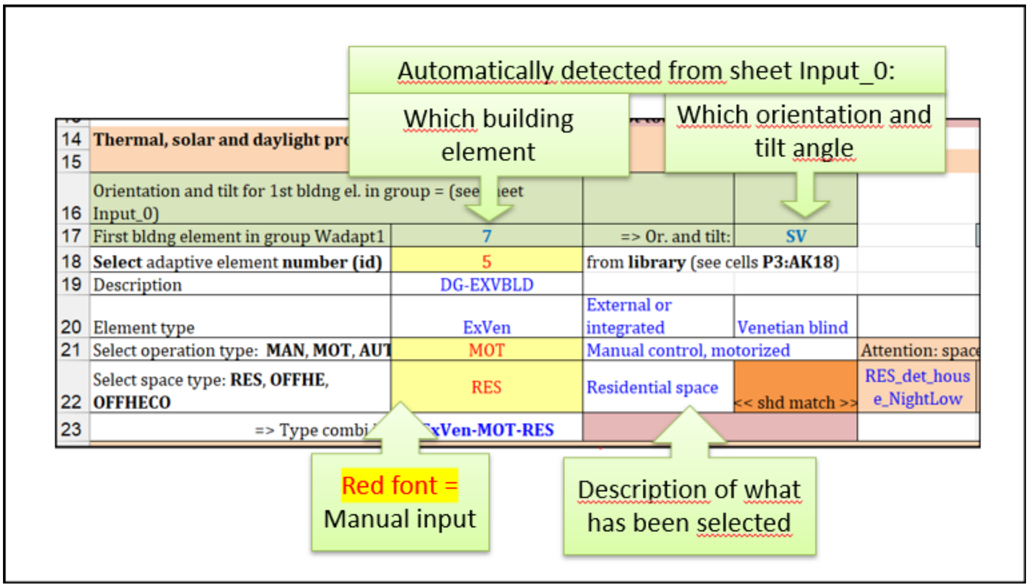


Figure 7 – Partial screenshot of spreadsheet section with selection of adaptive element, type of space and type of control

On the basis of these input data, the thermal, solar and visual properties are calculated for each of the 23 states, see **Figure 8**:

28	STATES	1	2	3	4	5	6	7	8	9	10	11
29	(relevant combinations of parameters)		Positions at each state, 52016-3:		Table C4	<- see AN6:CJ38		Properties at each state				
30						Status extension 1, 2 or 3						
31	State identifier	State number	Fraction extended, by rule	Correction for deviating occupants	=> Corrected fraction extended	Number (for the extended part)	Description (for the extended part)	$U_{w;Wadapt;i;st\,i}$	$1/R_{c;w;Wadapt;i;st\,i}$	$g_{w;Wadapt;i;st\,i}$	$\tau_{e;w;Wadapt;i;st\,i}$	$\tau_{vis;w;Wadapt;i;st\,i}$
32	X=any option; x=any but one option	0	No comments	No comments		No comments		W/(m²·K)	(m²·K)/W	-	-	-
33	DA-HE-TX-RX-GN-LX	1	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
34	DA-HE-TX-RX-GY-LX	2	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
35	DA-NE-TN-RX-GN-LX	3	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
36	DA-NE-TN-RX-GY-LX	4	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
37	DA-NE-TH-RL-GX-LX	5	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
38	DA-NE-TH-RH-GX-LN	6	1,00	-0,40	0,60	2,00	slats 45 degr.	0,98	1,18	0,31	0,27	0,38
39	DA-NE-TH-RH-GX-LL	7	1,00	-0,40	0,60	2,00	slats 45 degr.	0,98	1,18	0,31	0,27	0,38
40	DA-NE-TV-RL-GX-LX	8	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
41	DA-NE-TV-RH-GX-LN	9	1,00	-0,40	0,60	2,00	slats 45 degr.	0,98	1,18	0,31	0,27	0,38
42	DA-NE-TV-RH-GX-LL	10	1,00	-0,40	0,60	2,00	slats 45 degr.	0,98	1,18	0,31	0,27	0,38
43	DA-CO-TN-RX-GN-LX	11	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75
44	DA-CO-TN-RX-GY-LX	12	0,00	0,10	0,10	1,00	slats 0 degr.	1,05	1,28	0,60	0,53	0,75

Figure 8 – Partial screenshot of spreadsheet section with properties of adaptive element for each state (1 - 23)

5.2.2 The hourly calculation explained step-by-step

Brief description:

During the hourly calculation, at each hour of the year it is assessed which of the 23 combinations applies (e.g.: DA-HE-TN-RL-GN-LN). This does not immediately lead to the corresponding state, because:

- For automated control, if occupants present and awake, the corresponding state can *lead to* low daylight. In that case the combination changes (LN → LL).
- Some state changes are only applied after a specific delay:
  - An existing state remains unchanged if the control is manual or motorized and as long as occupants are not present or asleep.
  - "LL" (which is a manual override of the automated control) changes only back to "LN" if there is another (automatic) change requested.

When the actual state for the given hour has been assessed, the corresponding thermal, solar and visual properties of the adaptive element are determined and passed on to the overall thermal balance calculation according to EN ISO 52016-1.

Note that not each change of state results in a change of properties: the thermal, solar and visual transmittance can be the same for different states.

Detailed description:

Each hour, the following is calculated (where applicable using the relevant parameter values and formulae from EN ISO 52016-3):

1. The solar irradiance at the window plane, obtained from sheet Output_t: just to determine the **DAY-mode**.

   NOTE Duplicates with 5., but enables the use of a different parameter.

2. The average heating or cooling load of the previous day (from 7 to 7), obtained from sheet Output_t: to determine the **HE-mode**.
3. The average operating temperature of the previous day (from 7 to 7), obtained from sheet Output_t: to determine the **HE-mode** in case the average heating or cooling load of the previous day is zero (due to absence of system, or if system interrupted, e.g. office during weekend).
4. The operative temperature (of the previous hour to avoid oscillation and because the operative temperature is an output from the whole calculation for this hour), obtained from sheet Output_t: to determine the **TINT-mode**.
5. The solar irradiance at the window plane, obtained from sheet Output_t: to convert to the external illuminance at the window plane.
6. The external illuminance at the window plane: to determine the **RAD-mode** and as basis for the calculation of the GLARE-mode.
7. The external air temperature, obtained from sheet ClimDat_t: not used in the reference scenario.
8. The occupants density, obtained from sheet Input_p: to determine if occupied or not.
9. The comfort mode, obtained from the sheet Input_t, with 0 = no comfort required; 1 = temperature setback; 2 = normal: to determine the **OCC-mode** (OCC-SLP, OCC-AW, UNOCC).
10. The **GLARE-mode** is now determined. Disturbance by glare (GY) is not applicable if the OCC-mode is UNOCC or if the space type is RES.
11. Now the state (1 to 23) can be determined, except for the DAYL-mode, so for the latter LN is assumed.
12. A correction is made for **occupation**: in case of manual or motorized operation (MAN or MOT): only if occupants are present and awake (OCC-AW) the state changes; otherwise the state remains as it was.

13. The visual transmittance of the adaptive element is determined for this state (see 5.2.1.6).
14. The external illuminance at the window plane plus the visual transmittance of the adaptive element is the basis for the determination of the internal illuminance at desk level.
15. The internal illuminance at desk level is used to determine the **DAYL-mode**.
    Low level daylight (LL) is only applicable for automated control (AUT) and occupants present and awake (OCC-AW).
16. This leads to an update of the state (1 to 23).
17. Again, a correction is made for **occupation**: in case of manual or motorized operation (MAN or MOT) and if occupants are not present or not awake (not OCC-AW) the state is not changed, but remains as it was.
18. This was the final determination of the state 1-23 and now the corresponding thermal, solar and visual transmittance can be obtained from the properties at each state (see 5.2.1.6).
19. These values are written in the sheet Input_t, and -from there- read by the macro that gathers all input needed for the hourly energy balance calculation according to EN ISO 52016-1, thus overriding the fixed values given as input in the Input_0.

See **Figure 9** and **Figure 10** for some screenshots to illustrate these steps:

– **Figure 9**: from case SOff_Sbg_ExVen_AUT_HECO at an arbitrary summer day
– **Figure 10**: from different cases and at different time-intervals, to illustrate specific features

F	G	H	I	J	K	L	M	N
			I_{sol}	$\Phi_{HC;nd;24}$	$\vartheta_{int;op;24}$	$\vartheta_{int;op}$	I_{sol}	$E_{V;e;w}$
	Time interval number		W/m2	W	C	C	W/m2	klux (!!)
	6484		0,0	0,0	25,3	25,5	0,0	0,0
	6485		0,0	0,0	25,3	25,4	0,0	0,0
	6486		0,0	0,0	25,3	25,3	0,0	0,0
	6487		6,7	0,0	25,3	25,1	6,7	0,8
	6488		78,8	-275,0	25,7	24,2	78,8	9,1
	6489		120,0	-275,0	25,7	24,2	120,0	13,8
	6490		378,2	-275,0	25,7	24,7	378,2	43,5
	6491		477,1	-275,0	25,7	25,1	477,1	54,9
	6492		600,8	-275,0	25,7	25,6	600,8	69,1
	6493		630,8	-275,0	25,7	26,0	630,8	72,5
	6494		385,7	-275,0	25,7	26,0	385,7	44,4
	6495		469,1	-275,0	25,7	26,0	469,1	53,9
	6496		349,0	-275,0	25,7	26,0	349,0	40,1

a): First part of the hourly calculations in sheet AdaptW

O	P	Q	R	S	T	U	V	W	X	Y	Z
$\vartheta_{e;air}$						Init.!	>=0	0, 1 or 2			
C	DAY-mode	HC-mode	TINT-mode	Radmin	Radmax	RAD-mode	Occupants density p/m²	Comf012 ID	Occupancy	GLARE-mode	Interim State id
15,8	NI	NE	TV	10	15	RL	0,00	1	UNOCC	GN	NI-NE-TV-RL-GN-LN
15,8	NI	NE	TV	10	15	RL	0,00	1	UNOCC	GN	NI-NE-TV-RL-GN-LN
15,8	NI	NE	TV	10	15	RL	0,00	1	UNOCC	GN	NI-NE-TV-RL-GN-LN
15,8	DA	NE	TV	10	15	RL	0,00	2	UNOCC	GN	DA-NE-TV-RL-GN-LN
17,3	DA	CO	TV	10	15	RL	0,02	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN
18,7	DA	CO	TV	10	15	RL	0,06	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN
20,2	DA	CO	TV	10	15	RH	0,06	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN
21,3	DA	CO	TV	10	15	RH	0,07	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN
22,4	DA	CO	TV	10	15	RH	0,07	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN
23,5	DA	CO	TV	10	15	RH	0,04	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN
23,6	DA	CO	TV	10	15	RH	0,06	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN
23,7	DA	CO	TV	10	15	RH	0,07	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN
23,7	DA	CO	TV	10	15	RH	0,07	2	OCC-AW	GY	DA-CO-TV-RH-GY-LN

b) Second part of the hourly calculations in sheet AdaptW

AA	AB	AC	AD	AE	AF	AG	AH	AI
	If MAN/MOT: remains at state if not OCC-AW	-	lx	*Remains LL until state change*		*If MAN/MOT: ànd not OCC-AW: remains at state*	<< (again, but needed because conditions may change while state remains)	
Interim State number	State number	τ_{vis}	$E_{V;int;desk}$	DAYL-mode	State id	State number		
21	21	0,02	0	LN	NI-NE-TV-RL-GN-LN	21		
21	21	0,02	0	LN	NI-NE-TV-RL-GN-LN	21		
21	21	0,02	0	LN	NI-NE-TV-RL-GN-LN	21		
8	8	0,18	34	LN	DA-NE-TV-RL-GN-LN	8		
16	16	0,18	75	LL	DA-CO-TV-RL-GN-LL	16		
16	16	0,18	99	LL	DA-CO-TV-RL-GN-LL	16		
17	17	0,02	54	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	61	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	69	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	71	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	55	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	60	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	52	LL	DA-CO-TV-RH-GY-LL	18		

c): Third part of the hourly calculations in sheet AdaptW

AJ	AK	AL	AM	AN	AO
$1/R_{c;window}$	$g_{w;Wadapti;sti}$	τ_{vis}	**Number of changes**	**Number of changes if OCC-AW**	
W/m2K	-	-			
1,08	0,03	0,02	0	0	
1,08	0,03	0,02	0	0	
1,08	0,03	0,02	0	0	
1,12	0,14	0,18	1	0	
1,12	0,14	0,18	0	0	
1,12	0,14	0,18	0	0	
1,11	0,07	0,09	1	1	
1,11	0,07	0,09	0	0	
1,11	0,07	0,09	0	0	
1,11	0,07	0,09	0	0	
1,11	0,07	0,09	0	0	
1,11	0,07	0,09	0	0	
1,11	0,07	0,09	0	0	

d): Fourth and last part of the hourly calculations in sheet AdaptW

Figure 9 – Partial screenshots of spreadsheet section with hourly calculations; case SOff_Sbg_ExVen_AUT_HECO on an arbitrary summer day

Some observations:

- In **Figure 9 a)** note e.g.: the 24 hour average heating or cooling need at previous day ($\Phi_{HC;nd;24}$, 7 h to 7 h,) is used to determine HC-mode. If there was no heating or cooling need (either because there is no heating or cooling system, or because the system has been switched off during the 24 hours period (e.g. office during weekend), the HC-mode would be determined on the basis of the 24 hour average internal operative temperature, given in the next column ($\theta_{int;op;24}$).
- In **Figure 9 b)** note e.g. very high operative temperature (TV), occupation and comfort modes, glare, ...

– In **Figure 9 c)** note e.g. visual transmittance decreased because of disturbing glare (GY); also: the final state id and corresponding state number.
– In **Figure 9 d)** note the resulting thermal, solar and visual properties and data for the postprocessing.

$\Phi_{HC;nd;24}$	$\vartheta_{int;op;24}$	$\vartheta_{int;op}$	I_{sol}	$E_{V;e;w}$	$\vartheta_{e;air}$		
W	C	C	W/m2	klux (!!)	C	DAY-mode	HC-mode
0,0	15,9	19,2	0,0	0,0	0,6	NI	HE
0,0	15,9	18,9	0,0	0,0	0,4	NI	HE
0,0	15,9	18,7	0,0	0,0	0,3	NI	HE
0,0	15,9	18,4	0,0	0,0	0,4	NI	HE
0,0	15,9	18,2	0,0	0,0	0,6	NI	HE
0,0	15,9	17,9	0,0	0,0	0,7	NI	HE
0,0	15,9	17,7	0,0	0,0	0,7	NI	HE
0,0	15,9	17,5	0,0	0,0	0,8	NI	HE
0,0	15,9	17,2	0,0	0,0	0,8	NI	HE
252,9	18,6	20,0	0,0	0,0	2,2	NI	HE
252,9	18,6	20,0	17,7	2,0	3,5	DA	HE
252,9	18,6	20,0	91,9	10,6	4,9	DA	HE
252,9	18,6	20,0	370,7	42,6	5,9	DA	HE
252,9	18,6	20,0	294,8	33,9	6,9	DA	HE
252,9	18,6	20,0	98,6	11,3	7,9	DA	HE
252,9	18,6	20,0	103,8	11,9	7,8	DA	HE

a): Weekend interruption and HC-mode

$E_{V;e;w}$	$\vartheta_{e;air}$						Init.!	>=0	0, 1 or 2		
klux (!!)	C	DAY-mode	HC-mode	TINT-mode	Radmin	Radmax	RAD-mode	Occupants density p/m²	Comf012 ID	Occupancy	GLARE-mode
0,0	16,7	NI	CO	TV	10	15	RL	0,00	0	UNOCC	GN
0,0	17,1	NI	CO	TV	10	15	RL	0,00	0	UNOCC	GN
0,1	17,5	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
0,9	17,8	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
3,0	18,8	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
10,2	19,8	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
12,8	20,8	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
32,0	21,4	DA	CO	TV	10	15	RH	0,00	0	UNOCC	GN
7,5	22,1	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
9,1	22,7	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
9,2	22,7	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
15,7	22,7	DA	CO	TV	10	15	RH	0,00	0	UNOCC	GN
6,0	22,6	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN
4,8	21,8	DA	CO	TV	10	15	RL	0,00	0	UNOCC	GN

b): No glare while unoccupied

>=0	0, 1 or 2					If MAN/MOT: remains at state if not OCC-AW
Occupants density p/m²	Comf012 ID	Occupancy	GLARE-mode	Interim State id	Interim State number	State number
0,02	1	OCC-SLP	GN	NI-CO-TV-RL-GN-LN	23	23
0,02	1	OCC-SLP	GN	NI-CO-TV-RL-GN-LN	23	23
0,02	1	OCC-SLP	GN	NI-CO-TV-RL-GN-LN	23	23
0,02	1	OCC-SLP	GN	NI-CO-TV-RL-GN-LN	23	23
0,02	1	OCC-SLP	GN	DA-CO-TV-RL-GN-LN	16	23
0,02	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN	16	16
0,02	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN	16	16
0,02	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN	16	16
0,02	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN	16	16
0,02	2	OCC-AW	GN	DA-CO-TV-RH-GN-LN	17	17
0,02	2	OCC-AW	GN	DA-CO-TV-RH-GN-LN	17	17
0,02	2	OCC-AW	GN	DA-CO-TV-RH-GN-LN	17	17
0,02	2	OCC-AW	GN	DA-CO-TV-RL-GN-LN	16	16

c): No manual state changes while occupants not present or asleep

				If MAN/MOT: remains at state if not OCC-AW	-
Occupancy	GLARE-mode	Interim State id	Interim State number	State number	τ_{vis}
OCC-AW	GY	DA-CO-TV-RH-GY-LN	17	17	0,42
OCC-AW	GY	DA-CO-TV-RH-GY-LN	17	17	0,42
OCC-AW	GY	DA-CO-TV-RH-GY-LN	17	17	0,42
OCC-AW	GN	DA-CO-TV-RL-GN-LN	16	16	0,66
UNOCC	GN	DA-CO-TV-RL-GN-LN	16	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	16	0,66

d): No manual state changes (DA >NI) after occupants have left for the weekend

				Init.!	>=0	0, 1 or 2					If MAN/MOT: remains at state if not OCC-AW	-	lx
HC-mode	TINT-mode	Radmin	Radmax	RAD-mode	Occupants density p/m²	Comf012 ID	Occupancy	GLARE-mode	Interim State id	Interim State number	State number	τ_{vis}	$E_{V;int;desk}$
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	1	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,00	2	UNOCC	GN	NI-HE-TN-RL-GN-LN	19	2	0,45	0
HE	TN	0	999	RL	0,02	2	OCC-AW	GN	NI-HE-TN-RL-GN-LN	19	19	0,42	0
HE	TN	0	999	RL	0,06	2	OCC-AW	GY	DA-HE-TN-RL-GY-LN	2	2	0,45	402
HE	TN	0	999	RL	0,06	2	OCC-AW	GY	DA-HE-TN-RL-GY-LN	2	2	0,45	706
HE	TN	0	999	RL	0,07	2	OCC-AW	GY	DA-HE-TN-RL-GY-LN	2	2	0,45	960
HE	TN	0	999	RL	0,07	2	OCC-AW	GY	DA-HE-TN-RL-GY-LN	2	2	0,45	1158
HE	TN	0	999	RL	0,04	2	OCC-AW	GY	DA-HE-TN-RL-GY-LN	2	2	0,45	1224

e): Successive events after weekend interruption (motorized)

				If MAN/MOT: remains at state if not OCC-AW	-	lx	*Remains LL until state change*		*If MAN/MOT: à OCC-AW: rema state*
Occupancy	GLARE-mode	Interim State id	Interim State number	State number	τ_{vis}	$E_{V;int;desk}$	DAYL-mode	State id	State numb
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	23	0,02	0	LN	NI-CO-TV-RL-GN-LN	23
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	23	0,02	0	LN	NI-CO-TV-RL-GN-LN	23
UNOCC	GN	NI-CO-TV-RL-GN-LN	23	23	0,02	0	LN	NI-CO-TV-RL-GN-LN	23
UNOCC	GN	DA-CO-TV-RL-GN-LN	16	16	0,18	55	LN	DA-CO-TV-RL-GN-LN	16
UNOCC	GN	DA-CO-TV-RL-GN-LN	16	16	0,18	79	LN	DA-CO-TV-RL-GN-LN	16
UNOCC	GN	DA-CO-TV-RL-GN-LN	16	16	0,18	92	LN	DA-CO-TV-RL-GN-LN	16
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	43	LN	DA-CO-TV-RH-GN-LN	17
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	50	LN	DA-CO-TV-RH-GN-LN	17
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	54	LN	DA-CO-TV-RH-GN-LN	17
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	56	LN	DA-CO-TV-RH-GN-LN	17
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	55	LN	DA-CO-TV-RH-GN-LN	17
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	51	LN	DA-CO-TV-RH-GN-LN	17
UNOCC	GN	DA-CO-TV-RH-GN-LN	17	17	0,02	45	LN	DA-CO-TV-RH-GN-LN	17

f): Successive events during and after weekend interruption (automated)

AA	AB	AC	AD	AE	AF	AG	AH	AI
	If MAN/MOT: remains at state if not OCC-AW	-	lx	*Remains LL until state change*		*If MAN/MOT: ànd not OCC-AW: remains at state*	<< (again, but needed because conditions may change while state remains)	
Interim State number	State number	τ_{vis}	$E_{V;int;desk}$	DAYL-mode	State id	State number		
23	23	0,02	0	LN	NI-CO-TV-RL-GN-LN	23		
23	23	0,02	0	LN	NI-CO-TV-RL-GN-LN	23		
23	23	0,02	0	LN	NI-CO-TV-RL-GN-LN	23		
16	16	0,18	34	LN	DA-CO-TV-RL-GN-LN	16		
16	16	0,18	75	LL	DA-CO-TV-RL-GN-LL	16		
16	16	0,18	99	LL	DA-CO-TV-RL-GN-LL	16		
17	17	0,02	54	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	61	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	69	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	71	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	55	LL	DA-CO-TV-RH-GY-LL	18		
17	17	0,02	60	LL	DA-CO-TV-RH-GY-LL	18		

g): High solar irradiance in summer leads to (automatic) darkening of the blinds, but occupant intervenes to raise the internal illuminance

Figure 10 - Partial screenshots of spreadsheet section with hourly calculations; different cases to illustrate specific features

Observations:

- **Figure 10 a):** case Soff_Sbg_ExVen_MOT_HE, winter day:

    - Due to weekend interruption, the 24 hour average heating need is zero. Nevertheless, the HC-mode is heating (HE), because the 24 hour average operative temperature is below the limit value. After the weekend interruption the mode is still HE, because the 24 hour average heating need is no longer zero.
- **Figure 10 b):** High illuminance, but no glare (GN) because unoccupied due to weekend.
- **Figure 10 c):** residential space, manual control and operation, summer morning:
    - The state would change from night to day (state 23 → 16), but does not, because occupants are still sleeping.
- **Figure 10 d)**: case Soff_Sbg_ExVen_MOT_HE summer:
    - The state would change from day to night (state 16 → 123, but does not, because the occupants have left the office for the weekend while still daytime (residential space, manual control and motorized operation, summer evening
- **Figure 10 e)**: case Soff_Sbg_ExVen_MOT_HE, winter day, during and after weekend interruption / absence:
    - Due to manual control the state does not change during the weekend (office): the state should be 19, but remained at state 2, the last state during occupancy before the weekend.
    - After the weekend interruption: first the heating system starts up; this does not affect the state.
    - The next hour the occupant(s) enter the space and change the state to 19, because it is still dark (NI).
    - The following hour the occupant again changes the state, because of the sunrise. Because at the same time there is glare disturbance (GY), the state is set to
- **Figure 10 f)**: case Soff_Ath_ExVen_AUT_HECO, summer:
    - During weekend interruption: the automated control continues to make state changes, based on changing DAY-mode, RAD-mode, TINT-mode; but no glare (GY) and no low daylight (LL).
- **Figure 10 g)**: case Soff_Sbg_ExVen_AUT_HECO), on a summer day.
    - Due to high solar irradiation (RL->RH) while the operative temperature is very high (TV), the state changes from 16 to 17, see 2nd column.
    - The visual transmittance of the adaptive building envelope element for this state 17 (3rd column) is now needed as parameter to determine if the illuminance on the desk (4th column) does not become so low that the occupant will intervene.
    - Indeed: the illuminance on the desk is too low: DAYL-mode switches from LN->LL (5th column).
    - Consequently, the occupant intervenes: the state changes from 17 to 18, to allow more daylight, see 7th column. Note that this will lead to a higher *g*-value (similar as in **Figure 10 f)).**

5.2.3 Postprocessing and output

Postprocessing:

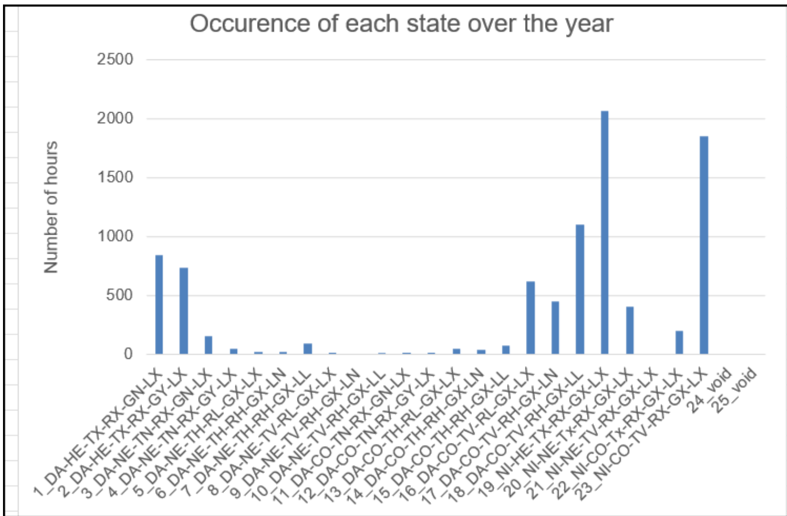
Specific postprocessing on the adaptive elements:

- The average number of hours between change of thermal or solar properties of the adaptive element (1) over the year and (2) only counted during occupation. This is an indication of the frequency of the state change: if high (during occupation), it will be considered as annoying; if very low, it could be an indication of bad control.
  Note that not each change of state results in a change of properties: the thermal, solar and visual transmittance can be the same for different states. See **Figure 11**.
- The number of hours that each state occurred over the year. See **Figure 12**.

	If MAN/MOT: ànd not OCC-AW: remains at state	<< (again, but needed because conditions may change while state remains)		$1/R_{c;window}$	$g_{w;Wadapti;sti}$	τ_{vis}	Number of changes	Number of changes if OCC-AW
	State number			W/m2K	-	-		
-GY-LL	7			1,11	0,07	0,09	1	1
-GY-LL	7			1,11	0,07	0,09	0	0
GN-LL	5			1,12	0,14	0,18	1	1
GN-LL	8			1,12	0,14	0,18	0	0
GN-LL	5			1,12	0,14	0,18	0	0
GN-LL	8			1,12	0,14	0,18	0	0
GN-LL	8			1,12	0,14	0,18	0	0
-GY-LL	10			1,11	0,07	0,09	1	1
-GN-LL	10			1,11	0,07	0,09	0	0
GN-LN	8			1,12	0,14	0,18	1	0
GN-LN	8			1,12	0,14	0,18	0	0
GN-LN	21			1,08	0,03	0,02	1	0
GN-LN	21			1,08	0,03	0,02	0	0

Figure 11 – Postprocessing in sheet AdaptW. Recording the number of changes in properties, total and only during occupants present and awake.

In **Figure 11** note e.g. that despite the state change from 5 to 8, this is not counted as a change, because in this case the properties remain the same.



Average no of hrs without change	
whole yr	during occupation, non-sleeping hours
6,4	4,5

Figure 12 – Postprocessing in sheet AdaptW. Example of frequency of occurrence of each state over full year (all hours). To the right: the average number of hours without change of state. Case: Soff_Ath_ExVen_AUT_HECO

Figure 12 shows that in this case:

- during night time the following states are dominant:
  - state 19 (HE);
  - state 23 (CO, TV).
- During daytime the following states are dominant:
  - state 18 (CO, TV, RH. LL);
  - state 1 (HE, GN);
  - state 2 (HE, GY);
  - state 16 (CO, TV, RL);
  - state 17 (CO, TV, RH).

Note that a state that combines cooling (CO) and glare disturbance (GY) does not occur. This is because the state is already dark in case of high solar irradiance (~ illuminance) in the cooling mode.

5.3 Supporting calculations

No special supporting calculations needed, other than explained above

6 Example cases

6.1 Definition of the cases

6.1.1 Rationale of the selection of cases

The calculation cases are based on the cases used for the verification and validation of ISO 52016-1 and the cases used for the demonstration presented in ISO/TR 52016-2 [4], making use of updated information obtained during the series of example case calculations by the EPB Center in the context of a Service Contract with the European Commission to support the uptake of the EPB standards ([9] – [15]).

The cases have been selected to demonstrate various effects. It is obvious that for a calculation in which so many parameters are involved, the focus needs to be on the most important factors, from the point of view of the criteria: completeness, functionality, sensitivity and usability.

Therefore the following factors are considered:

- Space type (residential, office), with different operation and use profile (e.g. temperature settings, occupancy).
- Climate (cold, moderate, warm).
- Unlimited system versus absent heating or cooling system (impact on energy needs and on thermal comfort).
- Type of adaptive transparent building elements (none, external or internal venetian blinds, external roller blinds).
- Operation of adaptive transparent building elements (manual, motorized, automated).

6.1.2 Sources of input data

6.1.2.1 Building types

As used in EPB Center case studies (see e.g. [11]);

– single-family house (SFH)
– single office space(Soff)

A difference with the cases in [11] is:

- Improved input for the night time temperature setback for the SFH case; therefore it is here renamed into SFHn.
- Different thermal and solar properties of the large South window, the candidate for the adaptive transparent building element.

The single-family house (SFHn):

A detached single family house, described as Example 1 in the Technical Report, CEN ISO/TR 52016-2 [4], accompanying EN ISO 52016-1; see **Figure 13**:

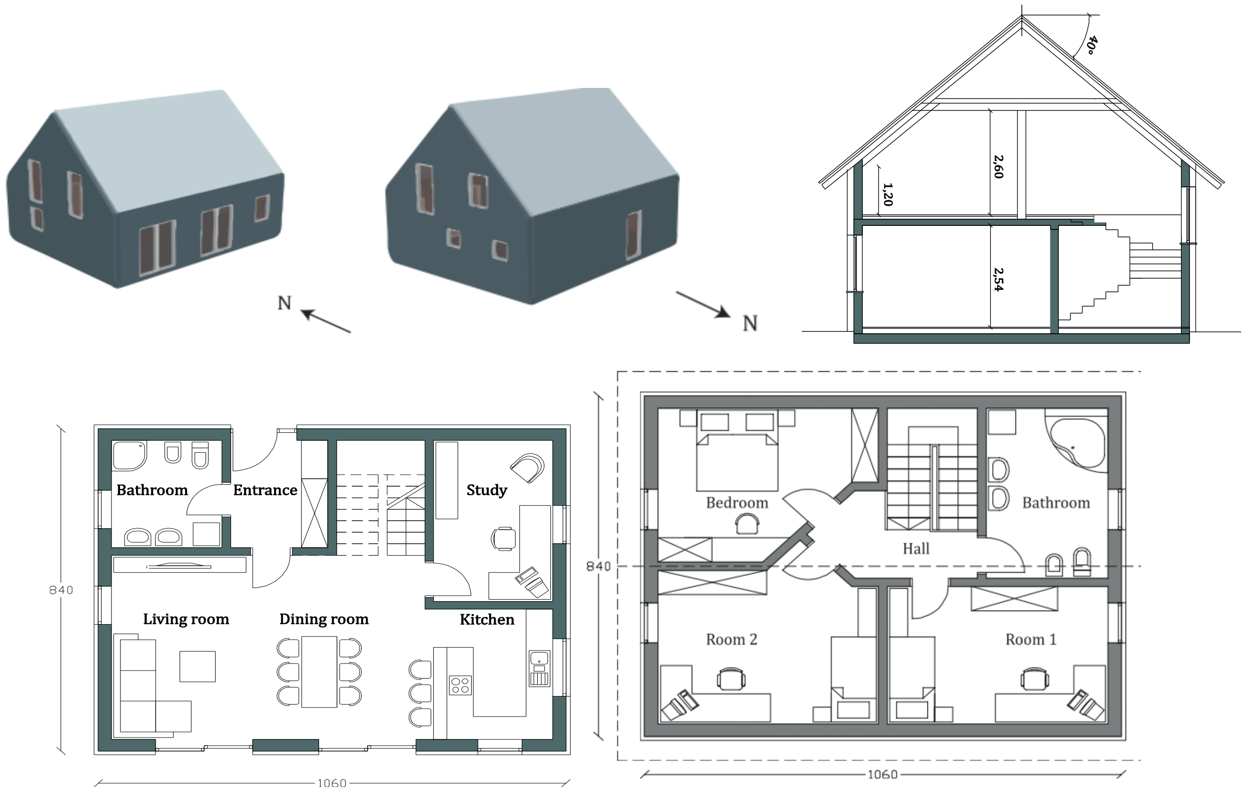


Figure 13 – The single family house

The single office space(SOoff):

An office room with geometry based on the BESTEST "shoebox" model; see **Figure 14**:

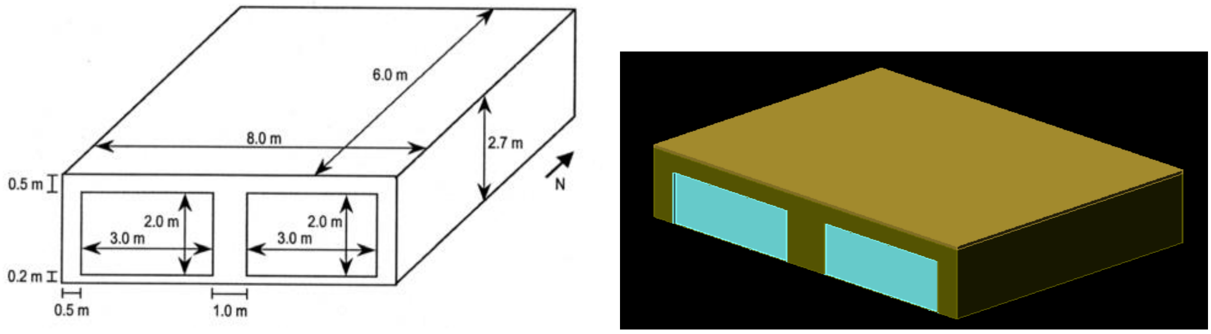


Figure 14 – The single office space

See description in the Case studies Preparatory work report [9].

6.1.2.2 Climates

- Oslo
- Strasbourg
- Athens

similar as for the other case studies (see [9] - [15]); selected because of the evidently quite different outdoor air temperatures and solar radiation intensity.

The different solar angle is also an interesting parameter in itself. For instance because:

- a higher solar angle (Athens) leads to relatively lower solar irradiance on a vertical South window;
- the length of the day can have an impact on the states of the adaptive elements: whether the occupants, for example, leave the office at the end of the day while it is still daytime or after sunset.

6.1.2.3 Operation and use profile

- Night or day time temperature set back (residential)
- Office hours and weekend interruption (office).

The pattern of use affects not only the temperature settings, but also the thermal comfort scores (only relevant during presence of occupants), and also the required and assumed ventilation, internal heat gains and operation of movable blinds.

A fully operational version of the use profile generator based on EN 16798-1 (see case study on EN 16798-1, [13]) is available since 2021. The use profile generator can produce output for various types of spaces. One of the sheets with output data is tailored to be fit as input for EN ISO 52016-1. It can be simply copied and pasted into the input data sheet of the EN ISO 52016-1 spreadsheet.

The link to the Use Profile Generator based on EN 16798-1 is important, because it contributes to the overall consistency and transparency of the calculations. Before, the operation and use profile was based on a tabulated (manual) input of a weekly schedule.

6.1.2.4 Selected adaptive building envelope elements

The adaptive building envelope element selected for this case study are a high performance double glazing with:

- No adaptive building envelope element (**UnProt**)
- External venetian blinds (**ExVen**)
- Internal venetian blinds (**InVen**)
- External roller blinds (**ExRbl**)

The specifications of these assemblies were copied from the ES-SO study, the study initiated by the European Solar Shading Organisation, that formed a major basis for the reference control strategies in EN ISO 52016-3, as explained in CEN ISO/TR 52016-4 [2].

> **Chromogenic glazings** are not explicitly covered in this case study. Actively operated chromogenic glazings follow the same reference control scenarios as roller blinds, so the roller blind variants are also applicable for active chromogenic glazings. The thermal, solar and visual properties for each state can be specified as input data. So, it is easy to run example cases with specific chromogenic glazing products.
>
> **Environmentally controlled (passive) adaptive building elements** are disregarded in this case study (and in the spreadsheet), because they are much more straightforward and quite trivial to calculate.

The adaptive building envelope elements specified and used in the ES-SO study were:

Table 4 – The adaptive elements in the ES-SO study

	Identifier	Type [a]	Description
1	SG-EXRBLD	ExRoChr	Single glazing with external roller blind
2	SG-EXVBLD	ExVen	Single glazing with external venetian blind
3	SG-INVBLD	InVen	Single glazing with internal venetian blind
4	DG-EXRBLD	ExRoChr	Double glazing with external roller blind

5	DG-EXVBLD	ExVen	Double glazing with external venetian blind
6	DG-INVBLD	InVen	Double glazing with internal venetian blind
7	SCG-EXRBLD	ExRoChr	Solar control glazing with external roller blind
8	SCG-EXVBLD	ExVen	Solar control glazing with external venetian blind
9	SCG-INVBLD	InVen	Solar control glazing with internal venetian blind
10	TRG-EXRBLD	ExRoChr	Triple glazing with external roller blind
11	TRG-EXVBLD	ExVen	Triple glazing with external venetian blind
12	TRG-INVBLD	InVen	Triple glazing with internal venetian blind
a: identifier used in the spreadsheet			

All specifications (type, thermal, solar and visual properties for each key state) of these 12 adaptive elements can be found in a small library in the spreadsheet, as successively shown in the following four screenshots (**Figure 15**):

a):

			Extension status 0 (retracted)			
Number (id)	Description	Type	$U_{w;Wadapti;sti}$	$g_{w;Wadapti;sti}$	$\tau_{e;w;Wadapti;sti}$	$\tau_{vis;w;Wadapti;sti}$
1	SG-EXRBLD	ExRoChr	5,809	0,884	0,87	0,905
2	SG-EXVBLD	ExVen	5,809	0,884	0,87	0,905
3	SG-INVBLD	InVen	5,809	0,884	0,87	0,905
4	DG-EXRBLD	ExRoChr	1,063	0,653	0,58	0,814
5	DG-EXVBLD	ExVen	1,063	0,653	0,58	0,814
6	DG-INVBLD	InVen	1,063	0,653	0,58	0,814
7	SCG-EXRBLD	ExRoChr	0,984	0,332	0,31	0,699
8	SCG-EXVBLD	ExVen	0,984	0,332	0,31	0,699
9	SCG-INVBLD	InVen	0,984	0,332	0,31	0,699
10	TRG-EXRBLD	ExRoChr	0,727	0,526	0,45	0,742
11	TRG-EXVBLD	ExVen	0,727	0,526	0,45	0,742
12	TRG-INVBLD	InVen	0,727	0,526	0,45	0,742

b):

Extension status 1				
Descr.	$U_{w;Wadapti;sti}$	$g_{w;Wadapti;sti}$	$\tau_{e;w;Wadapti;sti}$	$\tau_{vis;w;Wadapti;sti}$
mply extende	3,269	0,114	0,02	0,014
slats 0 degr.	3,784	0,231	0,18	0,212
slats 0 degr.	4,685	0,548	0,30	0,361
mply extende	0,900	0,040	0,01	0,012
slats 0 degr.	0,936	0,142	0,11	0,178
slats 0 degr.	0,978	0,478	0,21	0,327
mply extende	0,837	0,030	0,00	0,010
slats 0 degr.	0,869	0,086	0,06	0,152
slats 0 degr.	0,906	0,228	0,12	0,284
mply extende	0,645	0,029	0,01	0,010
slats 0 degr.	0,664	0,111	0,08	0,152
slats 0 degr.	0,686	0,391	0,17	0,297

c):

Extension status 2				
Descr.	$U_{w;Wadapti;sti}$	$g_{w;Wadapti;sti}$	$\tau_{e;w;Wadapti;sti}$	$\tau_{vis;w;Wadapti;sti}$
as status 1	3,269	0,114	0,02	0,014
slats 45 degr.	3,720	0,132	0,08	0,100
slats 45 degr.	4,499	0,380	0,16	0,192
as status 1	0,90	0,040	0,01	0,012
slats 45 degr.	0,931	0,074	0,06	0,085
slats 45 degr.	0,966	0,384	0,12	0,182
as status 1	0,837	0,030	0,00	0,010
slats 45 degr.	0,863	0,046	0,03	0,073
slats 45 degr.	0,895	0,171	0,07	0,161
as status 1	0,645	0,029	0,01	0,010
slats 45 degr.	0,661	0,058	0,04	0,073
slats 45 degr.	0,680	0,324	0,10	0,172

d):

Extension status 3				
Descr.	$U_{w;Wadapti;sti}$	$g_{w;Wadapti;sti}$	$\tau_{e;w;Wadapti;sti}$	$\tau_{vis;w;Wadapti;sti}$
as status 1	3,269	0,114	0,02	0,014
slats 80 degr.	3,507	0,066	0,02	0,023
slats 80 degr.	4,150	0,240	0,04	0,047
as status 1	0,90	0,04	0,01	0,01
slats 80 degr.	0,914	0,030	0,01	0,020
slats 80 degr.	0,941	0,294	0,03	0,046
as status 1	0,837	0,03	0	0,01
slats 80 degr.	0,849	0,022	0,01	0,017
slats 80 degr.	0,873	0,117	0,02	0,041
as status 1	0,645	0,029	0,01	0,01
slats 80 degr.	0,652	0,021	0,01	0,017
slats 80 degr.	0,666	0,258	0,03	0,044

Figure 15 – Screenshots (in 4 parts) of the small library of example adaptive elements

The properties for “Unprotected” are the properties of Extension status 0 (retracted).

6.1.2.5 Control of adaptive building envelope elements

The variations with respect of the control type are:

- No control scenario (**FIX)**, in absence of adaptive building envelope element.
- Adaptive building envelope element, with reference control scenarios , manual (**MAN**), motorized (**MOT**) or automated (**AUT**).

With the new feature in the spreadsheet various control scenarios can be easily modelled and tested, with impact on energy and thermal comfort.

6.1.3 List of selected cases and variants

The following cases have been specified, each with specific variants. By successively comparing two variants the effect of a single parameter change can be analysed.

Base case 1: Single family house in Strasbourg, no adaptive transparent building element, only heating (no mechanical cooling system). Case code: SFHn_Sbg_UnProt_FIX_HE

Table 5 – Single Family House Base case and variants

SFHn	Sbg	UnProt	FIX	HE
SFHn	Sbg	InVen	MAN	HE
SFHn	Sbg	ExRbl	MOT	HE
SFHn	Sbg	ExVen	MAN	HE
SFHn	Sbg	ExVen	MOT	HE
SFHn	Sbg	ExVen	AUT	HE
SFHn	Sbg	ExVen	AUT	HECO

Base case 2: Office space in Strasbourg, no adaptive transparent building element, heating and cooling. Case code: SFHn_Sbg_UnProt_FIX_HECO.

Table 6 – Single Office Space Base case and variants

Soff	Sbg	UnProt	FIX	HECO
Soff	Sbg	UnProt	FIX	FF
Soff	Sbg	UnProt	FIX	HE
Soff	Sbg	ExVen	MOT	HE
Soff	Sbg	ExVen	AUT	HE
Soff	Sbg	ExVen	MOT	HECO
Soff	Sbg	ExVen	AUT	HECO
Soff	Osl	ExVen	AUT	HE
Soff	Osl	ExVen	AUT	HECO
Soff	Ath	ExVen	AUT	CO
Soff	Ath	UnProt	FIX	HECO
Soff	Ath	ExVen	AUT	HECO

6.2 Calculations

6.2.1 Introduction

Each of the cases from **Tables 5 and 6** have been calculated with the updated spreadsheet tool for EN ISO 52016-1 including the special sheet on EN ISO 52016-3.

By successively comparing two variants the effect of a single parameter change is analysed.

To facilitate reading, **Annex A (in casu: A.1)** contains tables with an overview of all identifiers used for the control scenarios (**Table A.**1) and for the example cases (**Table A.2**).

6.2.2 Calculation results and discussion

6.2.2.1 Single Family House

6.2.2.1.1 Internal venetian blinds versus no solar shading

Base case: Strasbourg, no solar shading provision, heating only; compared against a manually operated internal Venetian blinds. See **Table 7**:

Table 7 - Main results for no solar protection versus manually operated internal venetian blinds

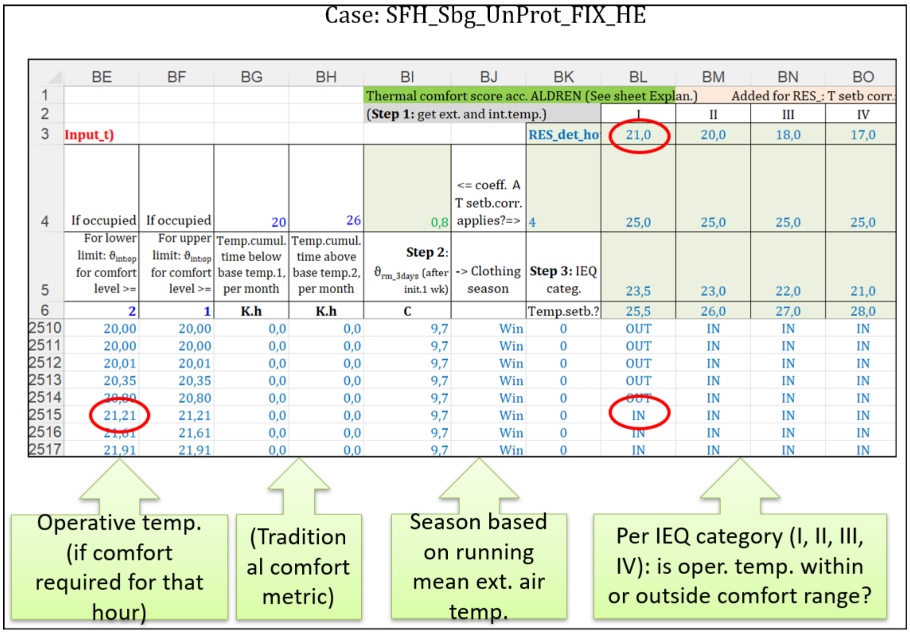
Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score a)		Avg number of hours without properties change b)
	kWh/an	kWh/an	kWh/an	Winter	Summer	
SFHn_Sbg_UnProt_FIX_HE	7911	0	7911	1,6	3,5	n.a.
SFHn_Sbg_InVen_MAN_HE	8507	0	8507	1,7	2,6	6,2

a: See explanation above; the lower the number the better
b: Average number of hours without state change during occupation, non-sleeping hours

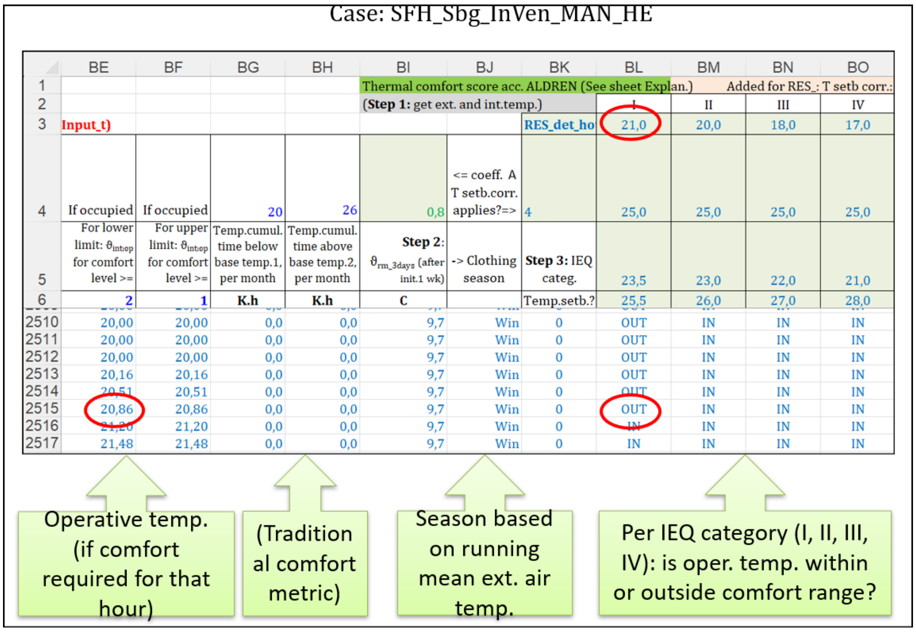
In this first comparison a few phenomena need to be explained, which leads to a longer analysis than the next comparisons.

As to be expected, with (even internal) venetian blinds, **the energy need for heating** is increased, to 'pay' for higher thermal and visual comfort.

The winter thermal comfort score without blinds is slightly better than with blinds. This is not as expected intuitively. However, this can be simply explained: the heating setpoint is based on IEQ Category II: for residential spaces this is 20°C. The thermal comfort score also appreciates if the temperature during the winter season exceeds the setpoint for the higher class, IEQ Category I (21°C). Without blinds the indoor temperature meets more often this higher threshold (1445 hours) than with blinds (1380 hours). This is illustrated in **Figure 16**.



a): without blinds



b): with manually controlled internal venetian blinds, leading to less (winter) hours with temperature above the IEQ Category I lower threshold.

Figure 16 - Screenshots to illustrate why the thermal comfort score in winter can be lower with blinds (b) compared to without blinds (a)

During **summer** the internal venetian blinds lead to a significantly better **thermal comfort**.

For the case with internal venetian blinds, the annually average **number of hours without state change** during active occupation is 6,2. This means that the frequency of state changes is quite low, as expected for manual operation.

Typically during **winter**:

- at **night**: state 19 = fully extended (with correction for 20% of occupants who keep the blinds retracted) and slats closed;
- during **daytime**: state 1 = fully extended (with correction for 20% of occupants who keep the blinds retracted) and slats open (horizontal).

Typically during **summer**:

- at **night**: state 23 = fully extended (with correction for 20% of occupants who keep the blinds retracted) and slats half open (45°);
- during **daytime**: in case of low solar irradiance: state 16 = fully extended (with correction for 20% of occupants who keep the blinds retracted) and slats open (horizontal);
  and, in case of higher solar irradiation: state 17 = the same, but with slats closed.

But also other states occur, although less frequently:

Table 8 – Number of occurrences per state over the full year. Case SFHn_Sbg_InVen_MAN_HE

State	Number of occurrences	Fraction extended	Slat position	Most frequently occuring
1_DA-HE-TX-RX-GN-LX	1980	0,80	slats 0 degr.	**2**
2_DA-HE-TX-RX-GY-LX	0	0,80	slats 0 degr.	

3_DA-NE-TN-RX-GN-LX	211	0,80	slats 0 degr.	
4_DA-NE-TN-RX-GY-LX	0	0,80	slats 0 degr.	
5_DA-NE-TH-RL-GX-LX	171	0,80	slats 0 degr.	
6_DA-NE-TH-RH-GX-LN	36	0,80	slats 45 degr.	
7_DA-NE-TH-RH-GX-LL	0	0,80	slats 45 degr.	
8_DA-NE-TV-RL-GX-LX	17	0,80	slats 0 degr.	
9_DA-NE-TV-RH-GX-LN	0	0,80	slats 45 degr.	
10_DA-NE-TV-RH-GX-LL	0	0,80	slats 45 degr.	
11_DA-CO-TN-RX-GN-LX	1	0,80	slats 0 degr.	
12_DA-CO-TN-RX-GY-LX	0	0,80	slats 0 degr.	
13_DA-CO-TH-RL-GX-LX	174	0,80	slats 0 degr.	
14_DA-CO-TH-RH-GX-LN	8	0,80	slats 45 degr.	
15_DA-CO-TH-RH-GX-LL	0	0,80	slats 45 degr.	
16_DA-CO-TV-RL-GX-LX	1105	0,80	slats 0 degr.	**4**
17_DA-CO-TV-RH-GX-LN	457	0,80	slats 80 degr.	
18_DA-CO-TV-RH-GX-LL	0	0,80	slats 80 degr.	
19_NI-HE-TX-RX-GX-LX	2916	0,80	slats 80 degr.	**1**
20_NI-NE-Tx-RX-GX-LX	404	0,80	slats 80 degr.	
21_NI-NE-TV-RX-GX-LX	1	0,80	slats 80 degr.	
22_NI-CO-Tx-RX-GX-LX	154	0,80	slats 80 degr.	
23_NI-CO-TV-RX-GX-LX	1125	0,80	slats 45 degr.	**3**

6.2.2.1.2 External venetian blinds versus internal venetian blinds

Table 9 - Main results for manually operated external versus internal venetian blinds

Identifier	**Heating need $Q_{H;nd}$**	**Cooling need $Q_{C;nd}$**	**Heating and cooling need $Q_{HC;nd}$**	**Thermal comfort score**		**Avg number of hours without properties change**
	kWh/an	kWh/an	kWh/an	**Winter**	**Summer**	
SFHn_Sbg_InVen_MAN_HE	8507	0	8507	1,7	2,6	6,2
SFHn_Sbg_ExVen_MAN_HE	8081	0	8081	1,6	1,9	6,2

The most obvious differences between these two cases are:

– the lower energy needs for heating in case of external venetian blinds. Because internal venetian blinds, when extended, lead to higher solar gains than external venetian blinds, the opposite might have been expected;

– the much better summer thermal comfort score in case of external venetian blinds.

Energy need for heating:

During the heating mode / daytime the adaptive element is always in state 1, except in glare mode (state 2, which did not occur for this climate and orientation and is ignored for residential spaces: properties for state 2 = properties for state 1). But there is a difference in assumed behaviour for state 1: it is assumed that the blinds are in case of internal blinds extended for 80% (with slats open), in case of external blinds extended for 10% (with slats open). Consequently, for state 1 the *U*-value for window with internal binds is 1,00 and with external blinds 1,05 W/(m²K)[5]. This would lead to **higher** heating needs in case of external venetian blinds.

During heating mode /night time (state 19) there is also a difference in assumed behaviour: it is assumed that the blinds are extended in case of internal blinds for 80% (with slats closed), in case of external blinds for 100% (with slats closed). So for state 19 the *U*-value for window with internal binds is 0,97 and with external blinds 0,91 W/(m²K). So during night time the heat losses with external blinds are lower.

These two effects combined is the main reason for the lower heating needs in case of external venetian blinds, in these examples.

Thermal comfort score:

The summer thermal comfort score in case of external venetian blinds is much better than in case of internal venetian blinds, as expected, due to the higher *g*-value of the latter.

This is also clear from the more traditional metric for thermal comfort: the number of hours that the operative temperature exceeded a specific upper limit, see **Figure 17**.

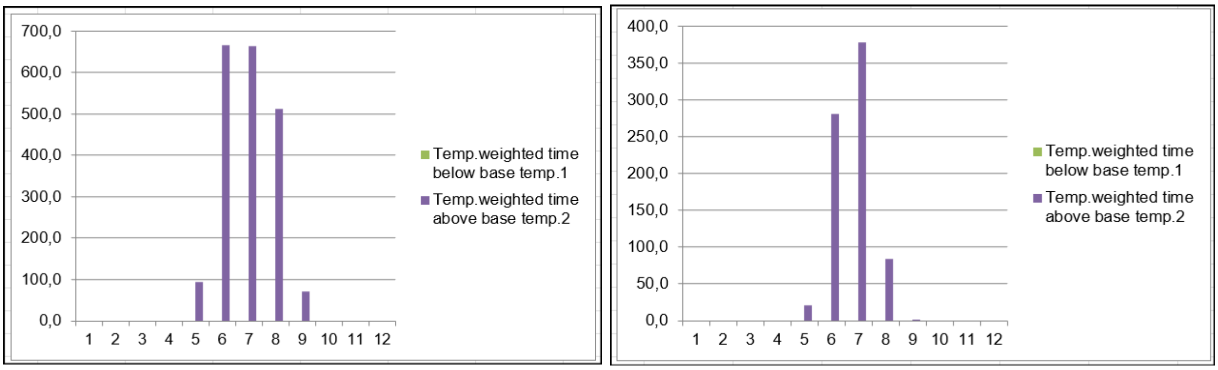


Figure 17 – Number of hours in a month that the operative temperature exceeds 26°C during hours that thermal comfort is required. Left: with internal venetian blinds; right: with external venetian blinds.

Other observations:

The average number of hours before one of the properties of the adaptive element changes during occupancy amounts 6,2. This is fine.

[5] Note that the *U*-value for the window with fully extended blinds and closed slats was calculated to be lower in case of external venetian blinds (*U* = 0,914 versus 0,941 W/(m²K), see **Table x**), due to a much wider (insulating) air gap between the blinds and the adjacent glazing.

6.2.2.1.3 External venetian blinds automated versus manual and motorized control and operation

See **Table 10:**

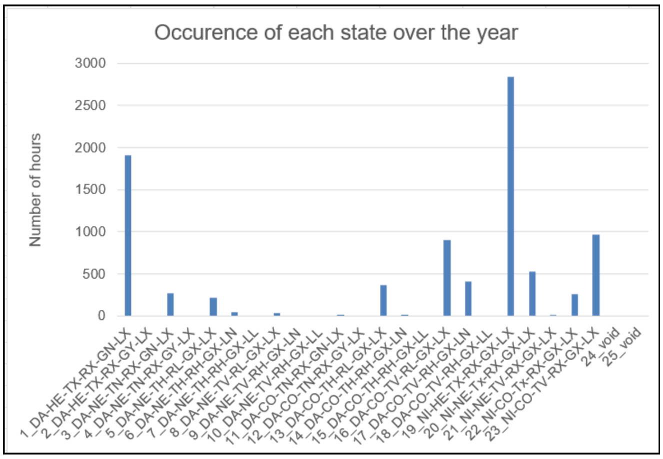
Table 10 - Main results external venetian blinds automated versus manual and motorized control and operation

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	**Winter**	**Summer**	
SFHn_Sbg_ExVen_MAN_HE	8081	0	8081	1,6	1,9	6,2
SFHn_Sbg_ExVen_MOT_HE	8084	0	8084	1,6	1,8	5,9
SFHn_Sbg_ExVen_AUT_HE	7872	0	7872	1,6	1,9	6,8

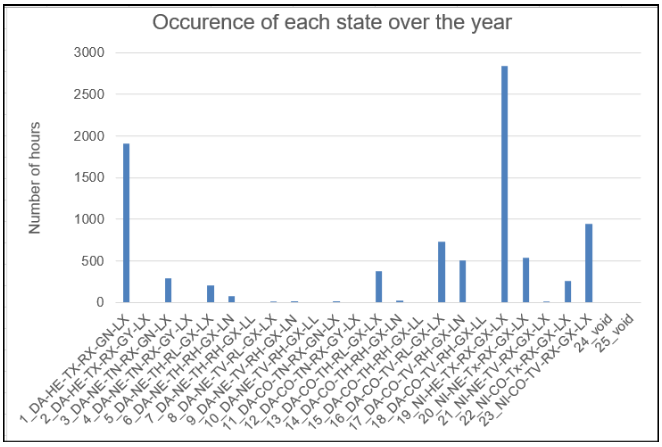
The differences in energy, thermal comfort and frequency of change in properties are quite small, except for the lower heating needs in case of automated control.

Motorized versus manual operation: motorized operation is slightly more efficient in summer thermal comfort, in this example.

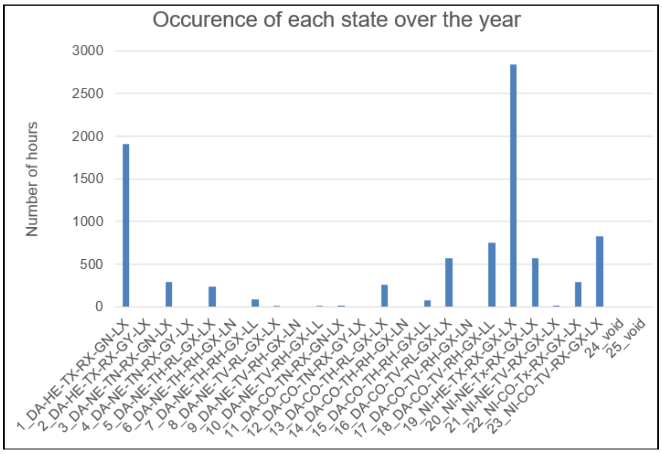
Figure 18 shows the frequency of occurrence of each state for these three variants.



a) manual



b) motorized



c) automated

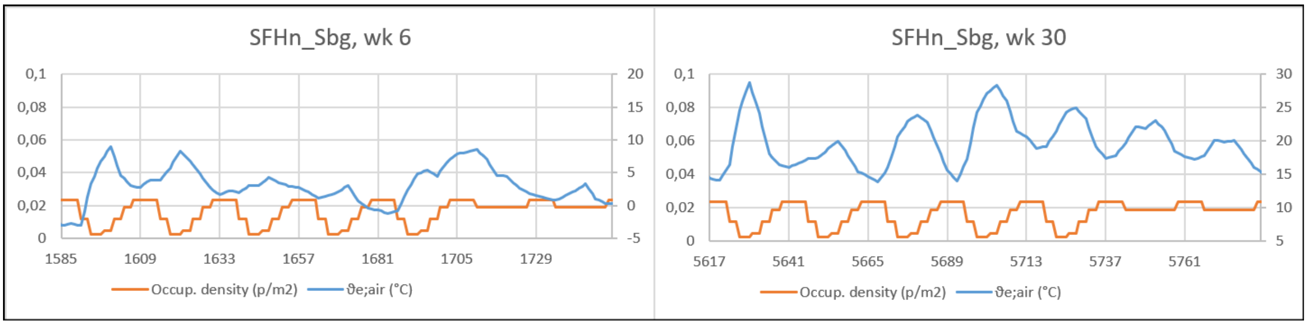
Figure 18 – Occurrence of each state over the year

The differences are small.

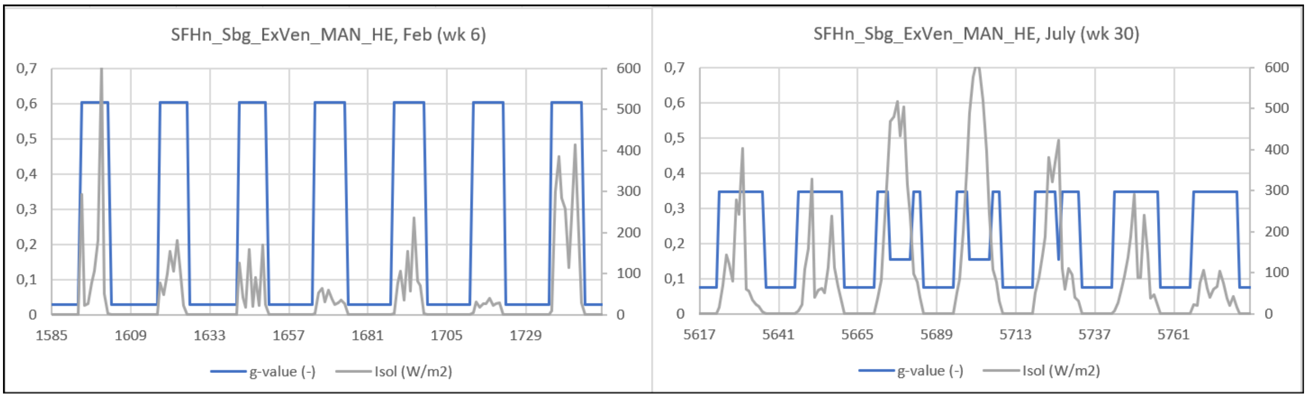
In the automated mode low daylight with occupant intervention (LL) can occur. See e.g. state number 17 instead of e.g. 16.

Note that for residential spaces it is assumed that the automated control has no occupancy sensor. In residential spaces it is also assumed that there is no glare disturbance.

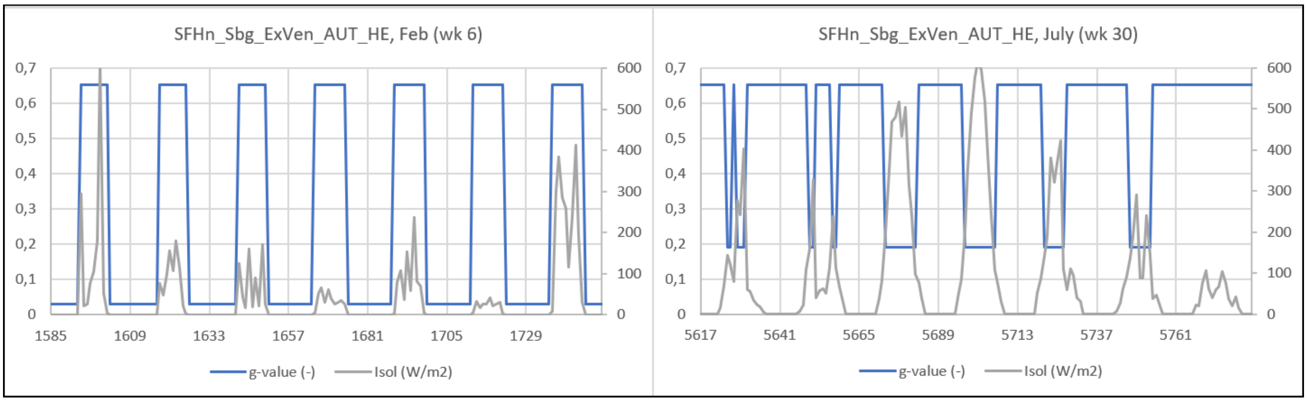
Finally, **Figure 19** shows, as an example, the time sequence for an arbitrarily selected week in winter and in summer. First, **Figure 19-a)** shows the assumed occupancy density (according to EN 16798-1) and the external air temperature. **Figure 19-b)** shows the *g*-value of the adaptive element, together with the solar irradiance on this South vertical window, for manual control and operation. **Figure 19-c)** shows the same for automated control.



a) Assumed occupancy density and the external air temperature



b) The solar irradiance and the *g*-value of the adaptive element, manual



c) The solar irradiance and the *g*-value of the adaptive element, automated

Figure 19 – Illustration of the hourly time sequence (SFHn_Sbg_ExVen_MAN/AUT_HE)

6.2.2.1.4 External roller blinds versus external venetian blinds

See **Table 11**:

Table 11 - Main results external roller blinds versus external venetian blinds

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling	Thermal comfort score	Avg number of hours

			need $Q_{HC;nd}$			without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
SFHn_Sbg_ExVen_MOT_HE	8084	0	8084	1,6	1,8	5,9
SFHn_Sbg_ExRbl_MOT_HE	8201	0	8201	1,6	2,0	23,5

The frequency of change in properties is much lower in case of roller blinds. This seems obvious, because the number of states with different thermal and solar properties is much smaller. On average the change is only once a day.

But also for the case with external venetian blinds the properties are the same for a range of state numbers:

- for states 1 -5, 8, 11 and 12: 10% extended, slats 0°;
- for states 6, 7, 9, 10, 14 and 15 (high operative temperature, high irradiance): 60% extended, slats 45°;
- states 13 and 16 (cooling mode, high operative temperature, low irradiance): 60% extended, slats 0°;
- states 17 and 18 (cooling mode, very high operative temperature, high irradiance): 80% extended, slats 80°;
- states 19-22 (night): 100% extended, slats 80°;
- state 23 (night, cooling mode, very high operative temperature): 100% extended, slats 45°.

Compare this with the roller blinds:

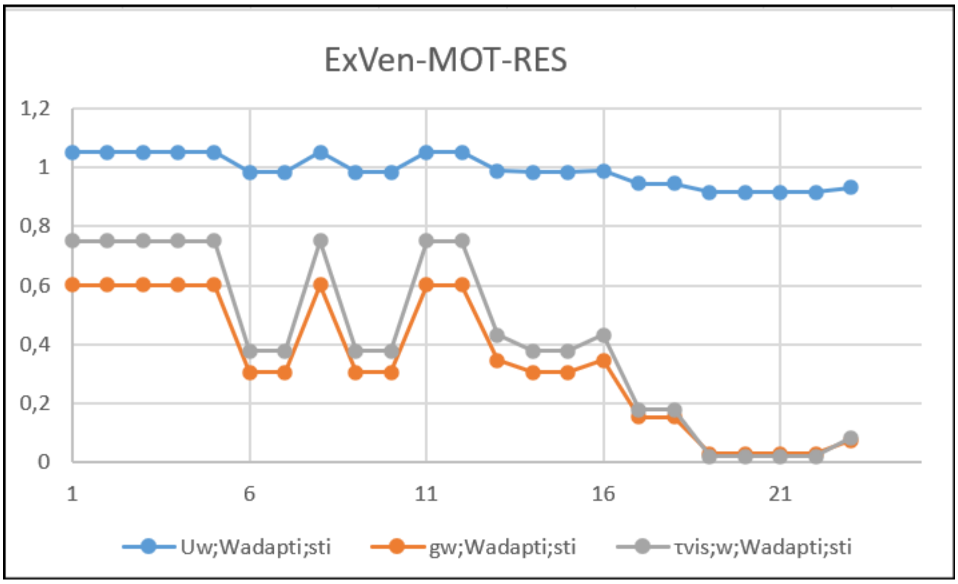
- for states 1 -5, 8, 11, 12, 13, 16 and 19-23: 10% extended;
- for states 6, 7, 9, 10, 14 and 15 (high operative temperature, high irradiance): 60% extended;
- states 17 and 18 (cooling mode, very high operative temperature, high irradiance): 80% extended.

So for the roller blinds case during heating season and during night time there are no changes at all.

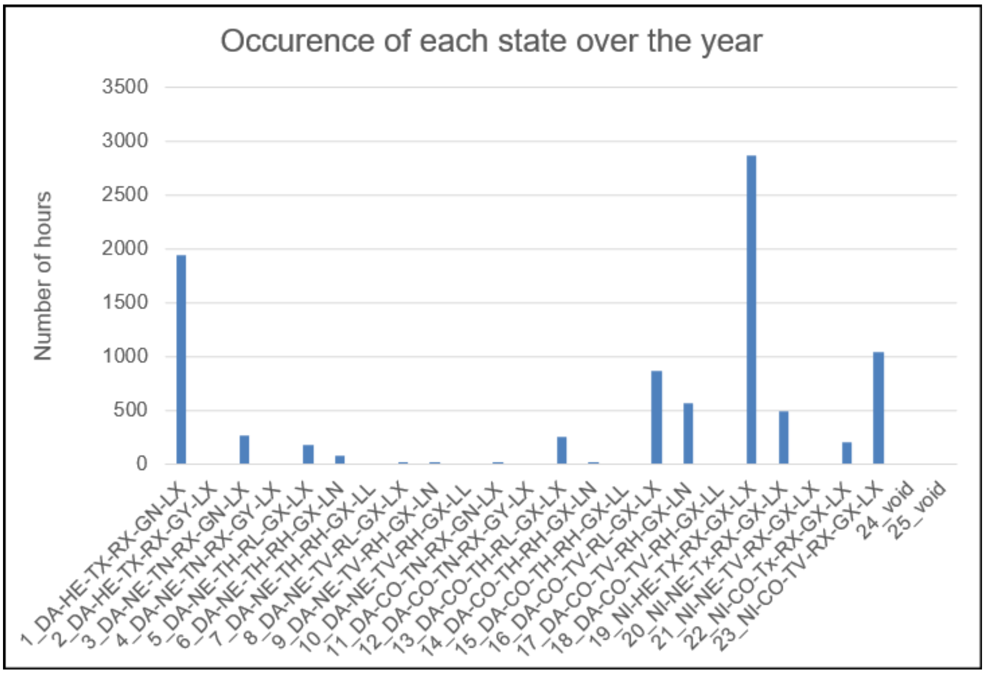
For the venetian blinds during the heating season there is a difference between day- and night-time and also during the other seasons there is more differentiation.

Note again that in residential buildings it is assumed that there is no glare disturbance, so for office spaces the patterns of state variations will be different.

However, the possible states for various conditions does not mean that they really occur, in a given climate, orientation and pattern of use. However, as shown in **Figures 20 and 21** both for the venetian blinds as for the roller blinds different states do occur during the year.

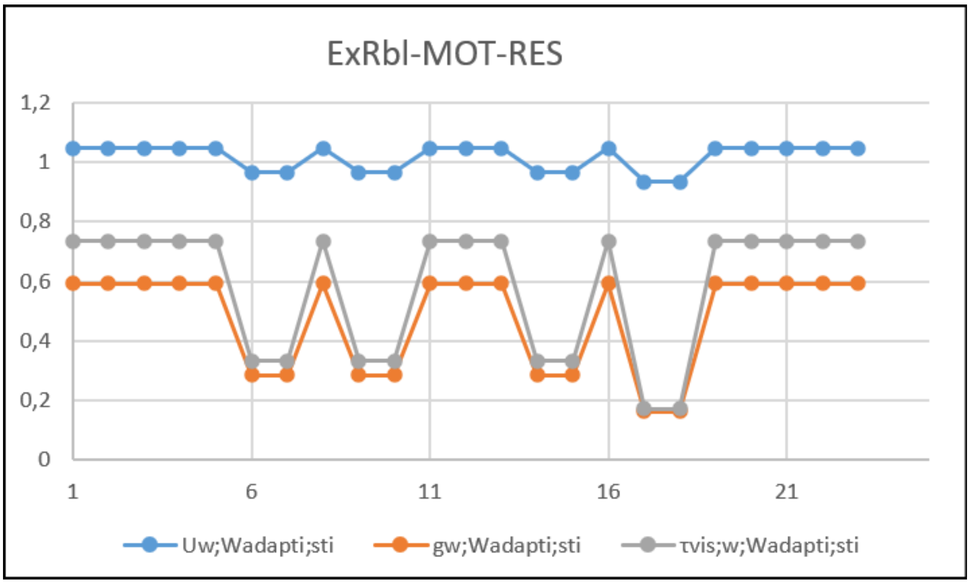


a) Properties

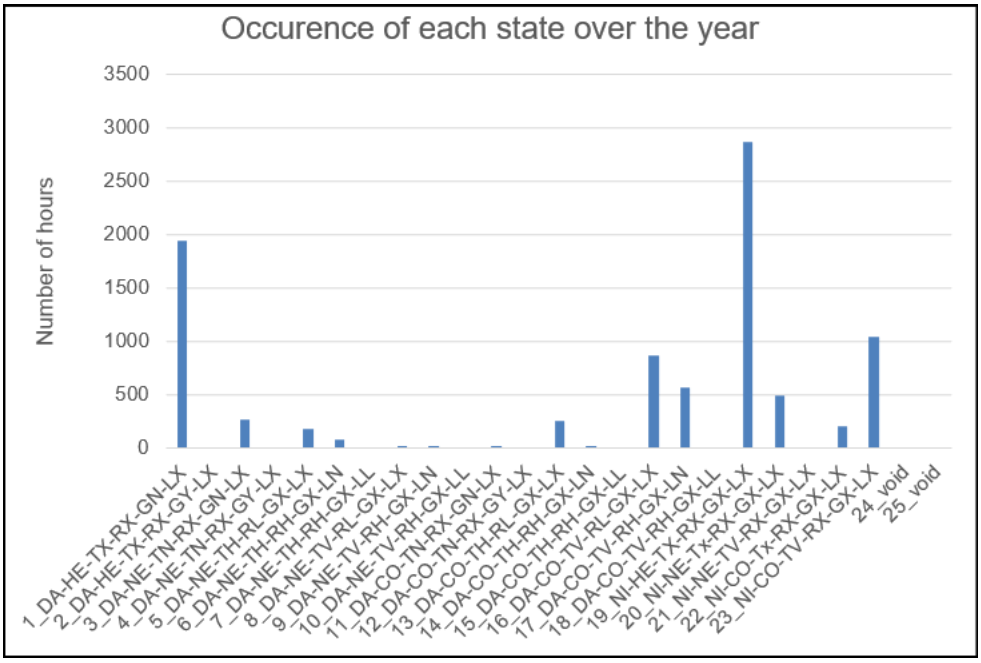


b) Occurrence

Figure 20 – Properties (a) and occurrence (b) for each state over the year, example case with external venetian blinds; motorized; residential space



a) Properties



b) Occurrence

Figure 21 – Properties (a) and occurrence (b) for each state over the year, example case with external roller blinds; motorized; residential space

Going back to **Table 8**: The differences in heating energy and summer thermal comfort between external venetian blinds and external roller blinds in this example are small. The external venetian blinds performing slightly better on both fronts (see **Figure 20.a** versus **Figure 21.a**):

- on heating energy because the *U*-value at night (state 19-23) is lower at night and the same during daytime;
- on thermal comfort because the *g*-values for states during cooling mode is also lower (and the same during heating mode).

6.2.2.1.5 External venetian blinds heating and cooling versus heating only

See **Table 12:**

Table 12 - Main results external venetian blinds heating and cooling versus heating only

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
SFHn_Sbg_ExVen_AUT_HE	7872	0	7872	1,6	1,9	6,8
SFHn_Sbg_ExVen_AUT_HECO	7871	445	8316	1,6	1,4	6,5

For this single family house the cooling needs are small. This explains why only with absence of blinds the summer thermal comfort score is "bad" and with internal blinds "insufficient".

The thermal comfort score further improves with the use of mechanical cooling, but it was already good, thanks to the external blinds. The frequency of changes of the properties remain almost the same.

6.2.2.2 Single office space

6.2.2.2.1 External venetian blinds versus no solar shading; heating only

See **Table 13:**

Table 13 - Main results external venetian blinds versus no solar shading; heating only

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
Soff_Sbg_UnProt_FIX_HE	2127	0	2127	2,2	4,8	n.a.
Soff_Sbg_UnProt_FIX_FF	0	0	0	4,3	4,8	n.a.
Soff_Sbg_ExVen_MOT_HE	2741	0	2741	1,9	4,4	4,2

In case of free floating conditions (no heating or cooling system), the thermal comfort score in winter and summer is very bad.

With heating and no solar shading provision, the summer comfort score remains, obviously, the same. With heating and motorized external venetian blinds the heating need are significantly higher, due to the blinds that are partly extended with sometimes closed slats due to occupants behaviour that deviates from the ideal; see **Table 16** in 6.2.2.2.3.

As expected, the average frequency of change in properties for external venetian blinds is higher (1/4,2 hour) than in case of the residential space (1/5,9 hour), but still reasonable.

6.2.2.2.2 External venetian blinds automated versus motorized; heating only

See **Table 14:**

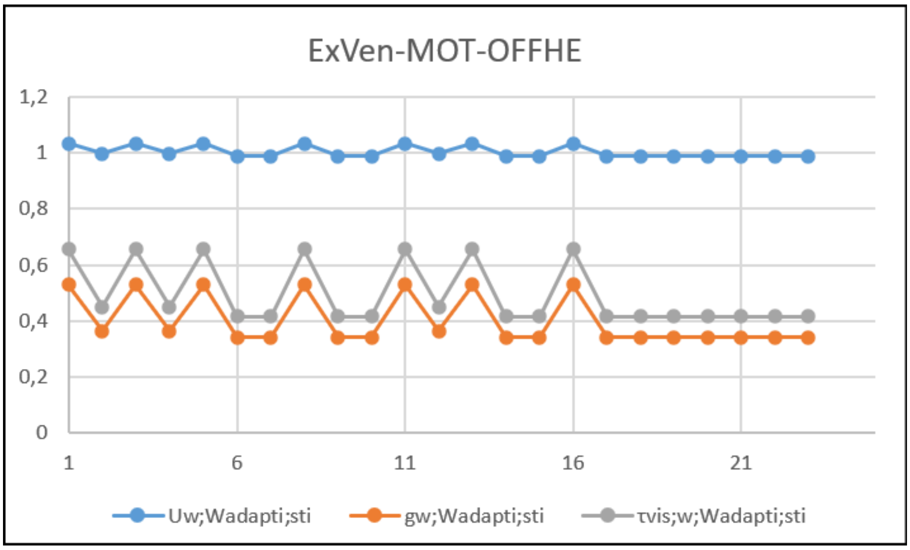
Table 14 - Main results external venetian blinds automated versus motorized; heating only

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
Soff_Sbg_ExVen_MOT_HE	2741	0	2741	1,9	4,4	4,2
Soff_Sbg_ExVen_AUT_HE	3923	0	3923	2,0	2,8	4,0

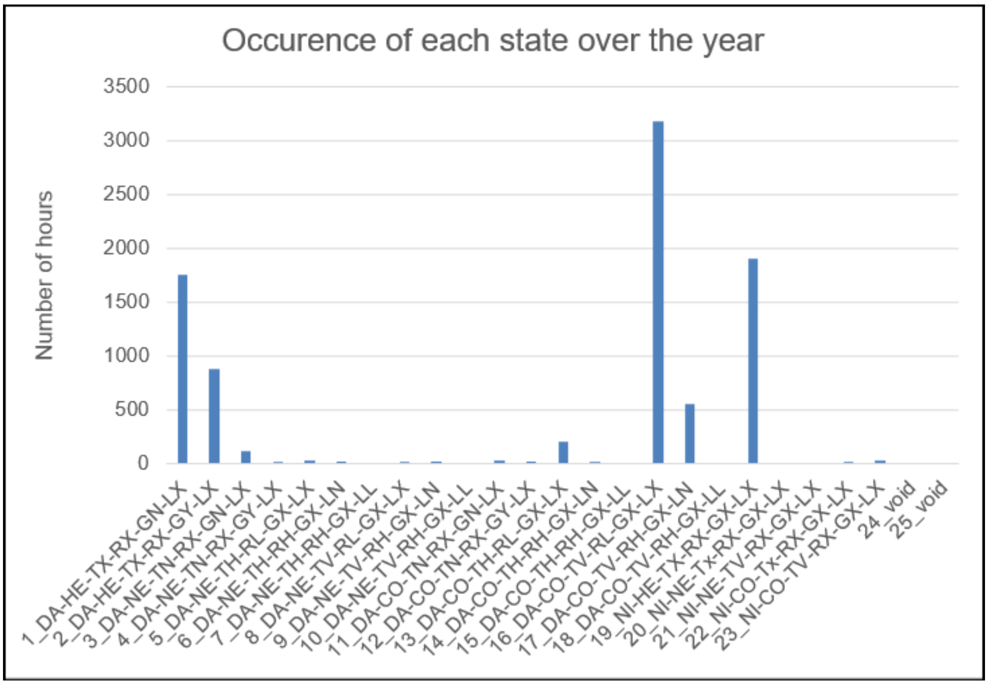
The summer thermal comfort is bad in case of motorized external blinds. It is less bad in case of automated external blinds.

The much higher heating need in case of automated control is striking. This is due to the assumption that during the heating season the automated venetian blinds are always down; only the slat position is changed; while in case of manual control with motorized operation it is assumed that under favourable conditions for solar gain the venetian blinds are at least partly retracted.

Figure 22 and **Figure 23** show that the full extension of the blinds, even with open slats, dramatically decreases the solar (and visual) transmittance, and hence increases the heating needs: much less solar heat is gained with the blinds permanent extended (AUT).

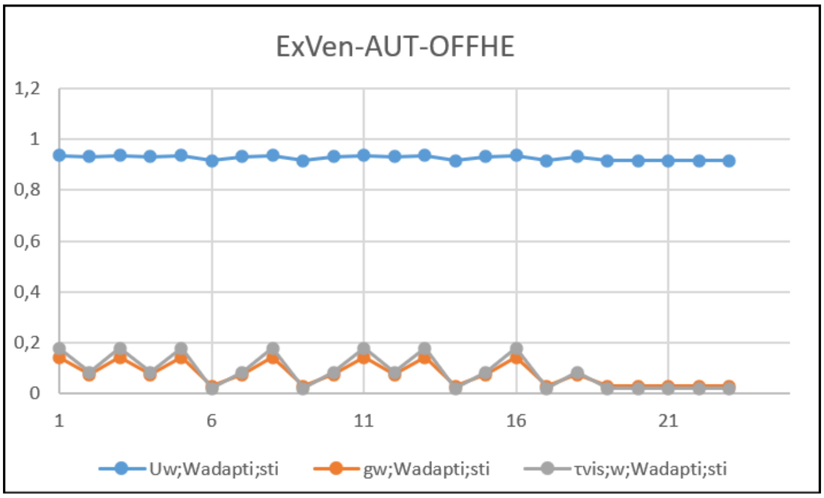


a) Properties for each state

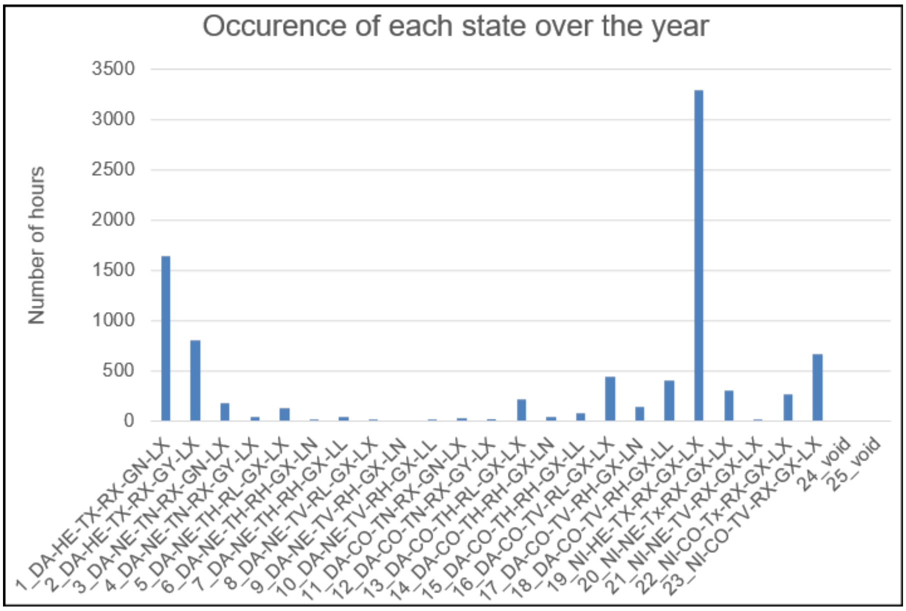


b) Occurrence of each state

Figure 22 – Properties (a) and occurrence (b) for each state over the year, example case with external venetian blinds motorized, office; heated only (Soff_Sbg_ExVen_MOT_HE)



a) Properties for each state



b) Occurrence of each state

Figure 23 – Properties (a) and occurrence (b) for each state over the year, example case with external venetian blinds, automated, office; heated only (Soff_Sbg_ExVen_AUT_HE)

6.2.2.2.3 External venetian blinds heating and cooling versus heating only

See **Table 15:**

Table 15 - Main results external venetian blinds heating and cooling versus heating only

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
Soff_Sbg_ExVen_MOT_HE	2741	0	2741	1,9	4,4	4,2
Soff_Sbg_ExVen_AUT_HE	3923	0	3923	2,0	2,8	4,0
Soff_Sbg_ExVen_MOT_HECO	2748	1054	3802	1,9	1,8	3,8
Soff_Sbg_ExVen_AUT_HECO	3927	220	4147	2,0	2,2	4,0

This Table shows, for both motorized and automated control, the difference between only heating and heating plus cooling.

The difference between motorized and automated with respect to the heating mode has been discussed in 6.2.2.2.2.

In case of manual control with motorized operation, the mechanical cooling need is significantly higher than in case of automated control. This is because part of the occupants don't operate the blinds as they should for optimized solar control: also during cooling the blinds are partly (as an average) kept retracted, see **Table 16**:

Table 16 – External venetian blinds, office space, retracted or extended (0->1) with correction for deviating occupants (more extended [+x] or less extended [-x]), resulting in the corrected fraction extended (Soff_ ExVen_MOT)

State number	Fraction extended, by rule	Correction for deviating occupants	=> Corrected fraction extended	Slat position *(for the extended part)*
1	0	0,2	0,2	80°
2	1	-0,5	0,5	45°
3	0	0,2	0,2	80°
4	1	-0,5	0,5	45°
5	0	0,2	0,2	80°
6	1	-0,5	0,5	80°
7	1	-0,5	0,5	80°
8	0	0,2	0,2	80°
9	1	-0,5	0,5	80°
10	1	-0,5	0,5	80°
11	0	0,2	0,2	80°

12	1	-0,5	0,5	45°
13	0	0,2	0,2	80°
14	1	-0,5	0,5	80°
15	1	-0,5	0,5	80°
16	0	0,2	0,2	80°
17	1	-0,5	0,5	80°
18	1	-0,5	0,5	80°
19	1	-0,5	0,5	80°
20	1	-0,5	0,5	80°
21	1	-0,5	0,5	80°
22	1	-0,5	0,5	80°
23	1	-0,5	0,5	80°

Note in this respect that **one of the key simplifications in the control scenarios in EN 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 CEN ISO/TR 52016-4, 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.

In case of automated control and mechanical cooling the summer thermal comfort score is reasonable, but less good than in case of motorized control. However, this is **not** due to **too high** operative temperature, but due to operative temperatures that are sometimes (e.g. in the morning) **below** the lower limit for IEQ categories I, II and sometimes 'even' III. See "OUT" in **Figure 24.**

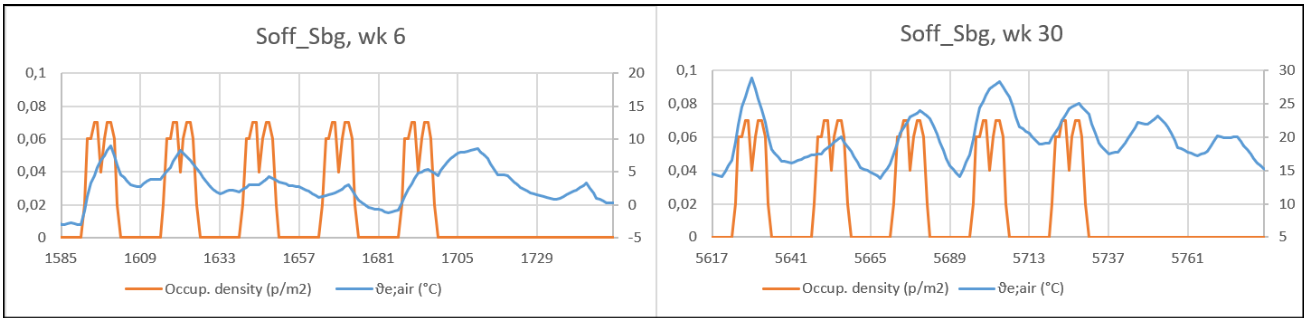
Note that for these example calculations the fixed heating and cooling setpoints from EN 16798-1 have been chosen, and not the adaptive comfort criteria (see introduction of the thermal comfort score in 5.1.3), which are -by the way- also not intended for fully airconditioned spaces.

	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	B
1					Thermal comfort score acc. ALDREN (See sheet Explan.)				Added for RES_: T setb corr.:			4	EN 16798-1, Table B.5, for RES_. Cat I, II, III, I			
2					(**Step 1:** get ext. and int.temp.)			I	II	III	IV	Win, low	21,0	20,0	18,0	17
3	Input_t)						OFF_single	21,0	20,0	19,0	17,0	Win, high	25,0	25,0	25,0	25
4	If occupied	If occupied	20	26	0,8	<= coeff. A T setb.corr. applies?=>	0	23,0	24,0	25,0	25,0	Sum, Low	23,5	23,0	22,0	21
5	For lower limit: $\vartheta_{int;op}$ for comfort level >=	For upper limit: $\vartheta_{int;op}$ for comfort level >=	Temp.cumul. time below base temp.1, per month	Temp.cumul. time above base temp.2, per month	**Step 2:** ϑ_{rm_3days} (after init.1 wk)	-> Clothing season	**Step 3:** IEQ categ.	23,5	23,0	22,0	21,0	Sum, high	25,5	26,0	27,0	28
6	2	1	K.h	K.h	C		Temp.setb.?	25,5	26,0	27,0	28,0	Count comf.	Count comf.hrs			
5291	-	-	0,0	0,0	19,1	Sum	0	-	-	-	-	55	55			
5292	-	-	0,0	0,0	19,1	Sum	0	-	-	-	-	55	55			
5293	-	-	0,0	0,0	19,1	Sum	0	-	-	-	-	55	55			
5294	21,46	21,46	0,0	0,0	19,1	Sum	0	OUT	OUT	OUT	IN	56	56			
5295	21,85	21,85	0,0	0,0	19,1	Sum	0	OUT	OUT	OUT	IN	57	57			
5296	22,04	22,04	0,0	0,0	19,1	Sum	0	OUT	OUT	IN	IN	58	58			
5297	22,30	22,30	0,0	0,0	19,1	Sum	0	OUT	OUT	IN	IN	59	59			

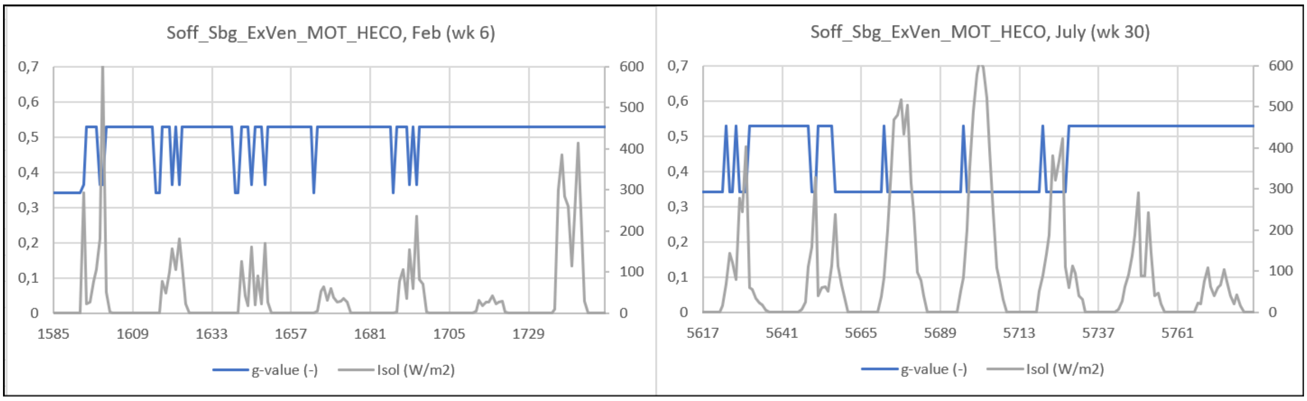
Figure 24 – Screenshot of sheet Output_t: during some hours in summer the *lower* limit for thermal comfort is exceeded for IEQ Categories I, II and III (Soff_Sbg_ExVen_AUT_HECO)

Finally, **Figure 25** shows, as an example, the time sequence for an arbitrarily selected week in winter and in summer. First, **Figure 25-a)** shows the assumed occupancy density (according to EN 16798-1) and the external air temperature.

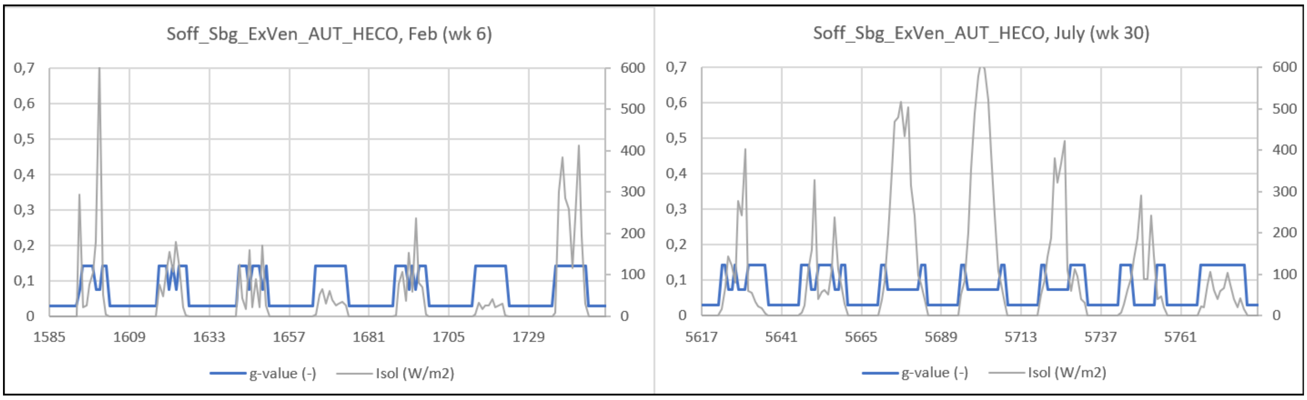
Figure 25-b) shows the *g*-value of the adaptive element, together with the solar irradiance on this South vertical window, for manual control with motorized operation. **Figure 25-c)** shows the same for automated control.



a) Assumed occupancy density and the external air temperature



b) The solar irradiance and the *g*-value of the adaptive element, motorized



c) The solar irradiance and the *g*-value of the adaptive element, automated

Figure 25 – Illustration of the hourly time sequence (Soff_Sbg_ExVen_MOT/AUT_HECO)

6.2.2.2.4 Different climates

See **Table 17:**

Table 17 - Main results external venetian blinds different climates

Identifier	Heating need $Q_{H;nd}$	Cooling need $Q_{C;nd}$	Heating and cooling need $Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
Soff_Osl_ExVen_AUT_HE	7177	0	7177	2,0	2,6	4,4
Soff_Osl_ExVen_AUT_HECO	7179	81	7260	2,0	2,1	4,5
Soff_Sbg_ExVen_AUT_HE	3923	0	3923	2,0	2,8	4,0
Soff_Sbg_ExVen_AUT_HECO	3927	220	4147	2,0	2,2	4,0
Soff_Ath_ExVen_AUT_CO	0	1339	1339	5,0	2,2	4,5
Soff_Ath_ExVen_AUT_HECO	920	1339	2259	2,0	2,2	4,5

The Oslo climate is colder than Strasbourg. So, as could be expected, the summer comfort score is better and the cooling need is lower.

The winter thermal comfort score without heating in Athens is very bad, despite the warmer climate. The case with a heating system shows that the heating need in Athens is not negligible compared to the cooling need.

Note that the summer solar heat loads through the South window in Athens are not high compared to e.g. Strasbourg, because of the relatively high solar altitude; see **Figure 26**.

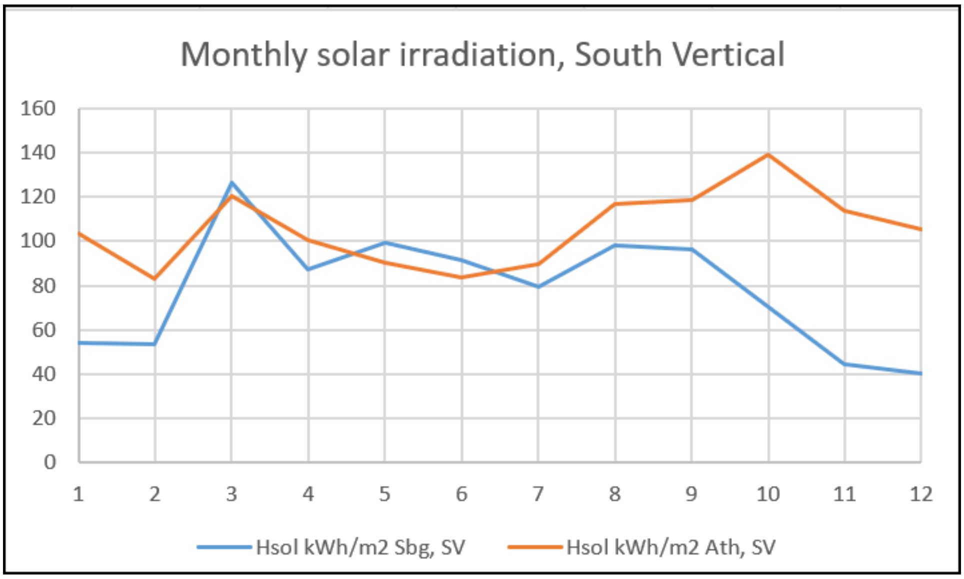


Figure 26 – Monthly solar irradiation of Athens compared to Strasbourg

So it could be that the internal heat sources are dominating the summer heat load. In that case the impact of the solar control provisions would be limited. Therefore, an extra calculation case has been added: no solar shading provisions. See **Table 18.**

Table 18 - Main results external venetian blinds versus no solar shading provisions, Athens

Identifier	$Q_{H;nd}$	$Q_{C;nd}$	$Q_{HC;nd}$	Thermal comfort score		Avg number of hours without properties change
	kWh/an	kWh/an	kWh/an	Winter	Summer	
Soff_Ath_UnProt_FIX_HECO	52	6431	6483	3,0	2,0	n.a.
Soff_Ath_ExVen_AUT_HECO	920	1339	2259	2,0	2,2	4,5

Apparently, the cooling need is still drastically reduced by the application of the external venetian blinds. Compared to Strasbourg the cooling need is much higher despite the similar amount of solar load (see also **Figure 27**). This is due to the much smaller cooling capacity by transmission and ventilation heat transfer, given the higher outdoor temperatures in Athens.

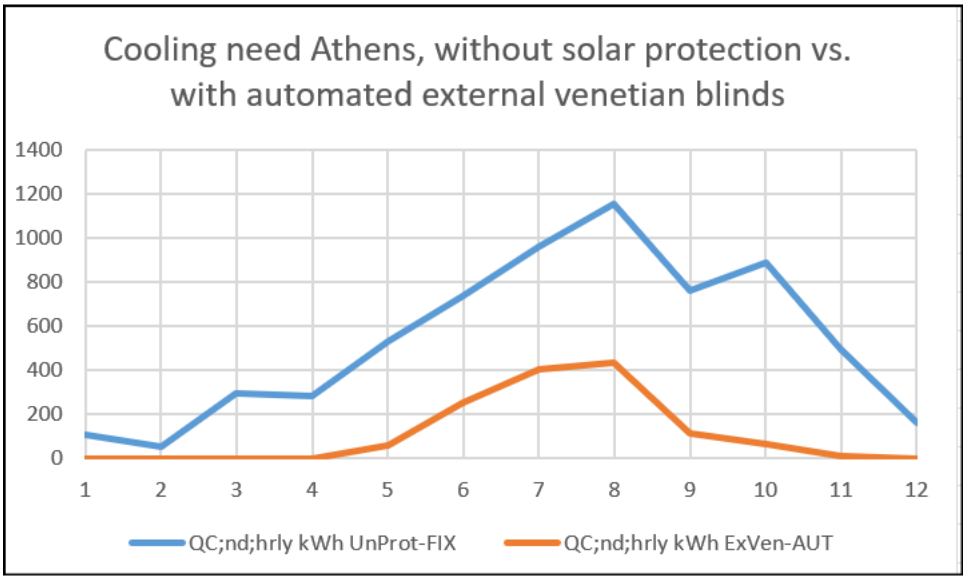


Figure 27 – Monthly cooling need, Athens, with and without external venetian blinds

As for the other examples, again, a warning is needed that these results cannot be extrapolated to other situations. That is the key reason for applying the holistic approach: the results depend on the combination of several factors. For instance, if this office space would have been a detached building, a high solar heat load on the roof could be dominating the cooling need, in which case the relative impact of the window shading provisions could be smaller; and vice versa.

7 Analysis

7.1 Functionality

The updated spreadsheet on EN ISO 52016-1 with the added sheet for (optional) application of EN ISO 52016-3 enabled to check and demonstrate the functionalities of EN ISO 52016-3 and the interaction with the calculation procedures of EN ISO 52016-1.

This case study demonstrates that the standard EN ISO 52016-3 provides the necessary information for EN ISO 52016-1, on the basis of available input data.

7.2 Completeness

This case study demonstrates that the hourly calculation procedures in EN ISO 52016-3 provide the data that are needed to enable calculation according to EN ISO 52016-1 with adaptive building envelope elements; both in terms of energy needs and thermal comfort.

7.3 Sensitivity

The hourly calculation procedures in the standard and spreadsheet can handle a wide variety of situations (types of adaptive elements, control types, space types) and take into account dynamic (hourly) interactions that are important for the control and to bring down the energy needs for heating and cooling while safeguarding or improving thermal comfort.

7.4 Usability

This case study has shown that EN ISO 52016-3 is usable in practice: the input data are conventional and the output is easily understandable.

Each specific reference control scenario (Tables C.2 to C,8 of the standard, distinguishing the type of adaptive element, control and space) is based on a generic reference control scenario with 23 states (Figure 2 of the standard). Each of these specific scenarios ignores several of these choices. Consequently, the specification of these control scenarios in the Tables of Annex C is (much) more complex than needed in practice. However, as stated in CEN ISO/TR 52016-4 [2], adhering to this generic control scenario as the basis for each specific scenario has the tremendous advantage that the 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.

And to accommodate the human user in this respect, flow diagrams are available in CEN ISO/TR 52016-4 [2]. for each of the specific reference scenarios, with the choices deleted that are not applicable for that combination.

8 Conclusions and recommendations

The updated spreadsheet on EN ISO 52016-1 [3] with the added sheet for (optional) application of EN ISO 52016-3 [1] enabled to check and demonstrate the functionalities of EN ISO 52016-3 and the interaction with the calculation procedures of EN ISO 52016-1.

This case study demonstrates that the standard EN ISO 52016-3 provides the necessary information for EN ISO 52016-1.

The standard covers adequately the scope: on the basis of available input data and choices with respect to adaptive building envelope elements and the type of control, it produces results that can be integrated in the calculation according to EN ISO 52016-1, for different categories of spaces, with or without heating or cooling systems.

The spreadsheet works well to demonstrate, validate and illustrate the calculation procedure of EN ISO 52016-3. In particular because each step of the calculation is visible and can be tracked and traced, as has been demonstrated with the example cases.

It is essential to assess the **thermal comfort**, at the same level as the energy performance, to avoid that, e.g. in case of undersized or absent heating or cooling system, the energy performance is rated as very good, at the cost of the thermal comfort. A recently internationally developed (overall and seasonal) thermal comfort score (ALDREN, [16]) has been built in in the spreadsheet and proved it's usability for this case study.

All data and the updated **spreadsheet tool** will be made **publicly available** at the EPB Center website for additional exercises.

Link: https://epb.center/support/documents/demo-en-iso-52016-1/

Limitations of this case study

- As the spreadsheet tools on other EPB standards, this **spreadsheet tool is not suited for application in daily practice**. It has not been developed for that purpose. For daily use in practice, software tools can be used that have a user-friendly interface and that make the connections to other parts of the overall EPB calculation.
- **Conclusions on** the difference between **the example cases shall not be extrapolated** to other cases, because there is a multitude of combined effects (climate, orientation, window size, space type, insulation level, building mass, …) that lead to the final result, in terms of energy and comfort. That is why the set of EPB standards adopted the holistic approach: the performance of a component or product can only be properly appreciated in the full and dynamic context of the specific building.
- One of the objectives of adaptive building envelope elements is to optimize **lighting and visual comfort** conditions, including the positive influence of natural lighting. Consequently, this is an intrinsic element in the control scenarios. However, in the spreadsheet, the visual aspects have been treated in a simplified way. A more detailed way to assess the lighting quality requires more detailed information on the room's geometry and properties, occupants position and luminance distribution of the sky. for testing and demonstrating EN ISO 52016-3 through the spreadsheet tool a simplification is acceptable. This also goes for the evaluation of the calculation results in terms of performance indicators for the lighting quality.
- **Chromogenic glazings** are not explicitly covered in this case study. Actively operated chromogenic glazing follows the same reference control scenarios as roller blinds, so the roller blind variants are also applicable for active chromogenic glazings. The thermal, solar and visual properties for each state can be specified as input data. So, it is easy to run additional, tailored, example cases with specific chromogenic glazing products.
- **Environmentally controlled (passive) adaptive building elements** are disregarded in this case study (and in the spreadsheet), because they are much more straightforward and quite trivial to calculate.
- Building envelope element with an **actively ventilated cavity** have not been included in this case study, because it would have added many additional choices and variations. Plus, for a proper assessment it requires a dynamic coupling of the calculations according to EN ISO 52016-1 with the EPB standard on the natural ventilation air flow calculations (EN 16798-7). Such a dynamic (hourly) coupling has been demonstrated in an earlier case study [14]. Such coupling, however, is more the task of a software tool that covers and connects the major EPB standards.

Annex A

Overview of identifiers and examples of flow diagrams

A.1 General

This annex provides an overview of all identifiers used in this document and examples of flow diagrams on the reference control scenarios.

A.2 Overview of all identifiers

Table A.1 provides an overview of the identifiers from ISO 52016-3 that are used in this report.

Table A.1 - Overview of identifiers used in the diagrams; conditions or events

Description	Identifier	Values	Explanation
General		**X**	Placeholder for any option EXAMPLE RX
		x	Placeholder for any but one option EXAMPLE Tx
Day or night	**DAY-MODE**	**DA**	Daytime (after sunrise)
		NI	Night time (after sunset)
Heating or cooling mode of the thermal zone	**HC-MODE**	**HE**	Heating mode
		NE	Neutral mode
		CO	Cooling mode
Operating temperature	**TINT-MODE**	**TN**	Normal operating temperature level of the thermal zone
		TH	High operating temperature level of the thermal zone
		TV	Very high operating temperature level of the thermal zone
Level of solar irradiance or illuminance	**RAD-MODE**	**RL**	Low solar irradiance or illuminance
		RH	High solar irradiance or illuminance
Occupancy	**OCC-MODE**	**OCC-AW**	Space is occupied, occupants are awake
		OCC-SLP	Space is occupied, occupants are sleeping
		UNOCC	Space is unoccupied
Glare occurrence	**GLARE-MODE**	**GN**	Protection against glare not needed
		GY	Protection against glare needed
Daylight level	**DAYL-MODE**	**LN**	Daylight level is fine
		LL	Daylight level is low
Adaptive element, position of adaptive component		**Ex**	External or integrated
		In	Internal
Adaptive element, type of adaptive component		**UnProt**	None
		RoChr	Roller blinds or chromogenic glazing
		Shu	Shutters
		Ven	Venetian blinds
Control type	**CONTRL**	**FIX**	Fixed properties (no control)
		MAN	Manual control, manual operation
		MOT	Manual control, motorized operation

		MM	Manual control, manual or motorized operation
		AUT	Automated control
Space type		**RES**	Residential
		OFF	Office
		OFF-HE	Office, heated only
		OFF-HECO	Office, heated and cooled

To facilitate reading, **Table A.2** provides a summary of all identifiers used in the example cases.

Table A.2 - Summary of identifiers used in the example cases

Description	**Identifier**	**Explanation**
Space	**SFHn**	Single family house with night time temperature setback for heating
	Soff	Single office room
Climate	**Sbg**	Strasbourg
	Osl	Oslo
	Ath	Athens
Heating and/or cooling	**HE**	With heating system
	CO	With cooling system
	HECO	With heating and cooling system
	FF	Free floating conditions: no heating or cooling system
Glazing type	**SG**	Single glazing
	DG	Double glazing
	SCG	Solar control glazing
	TG	Triple glazing

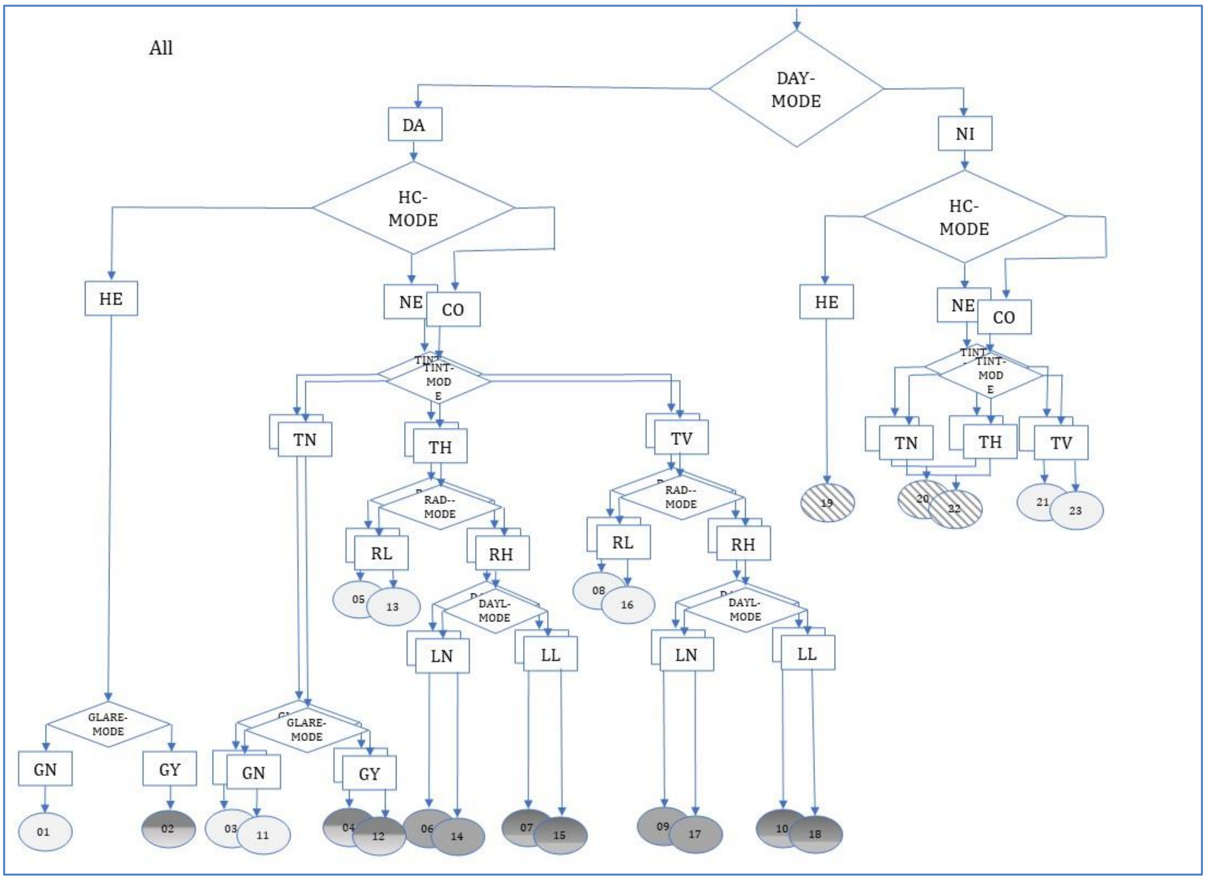
A.3 Examples of flow diagrams on the reference control scenarios

As stated in CEN ISO/TR 52016-4:

The generic control scenario, illustrated with the flow chart in EN ISO 52016-3, 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 CEN ISO/TR 52016-4 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.

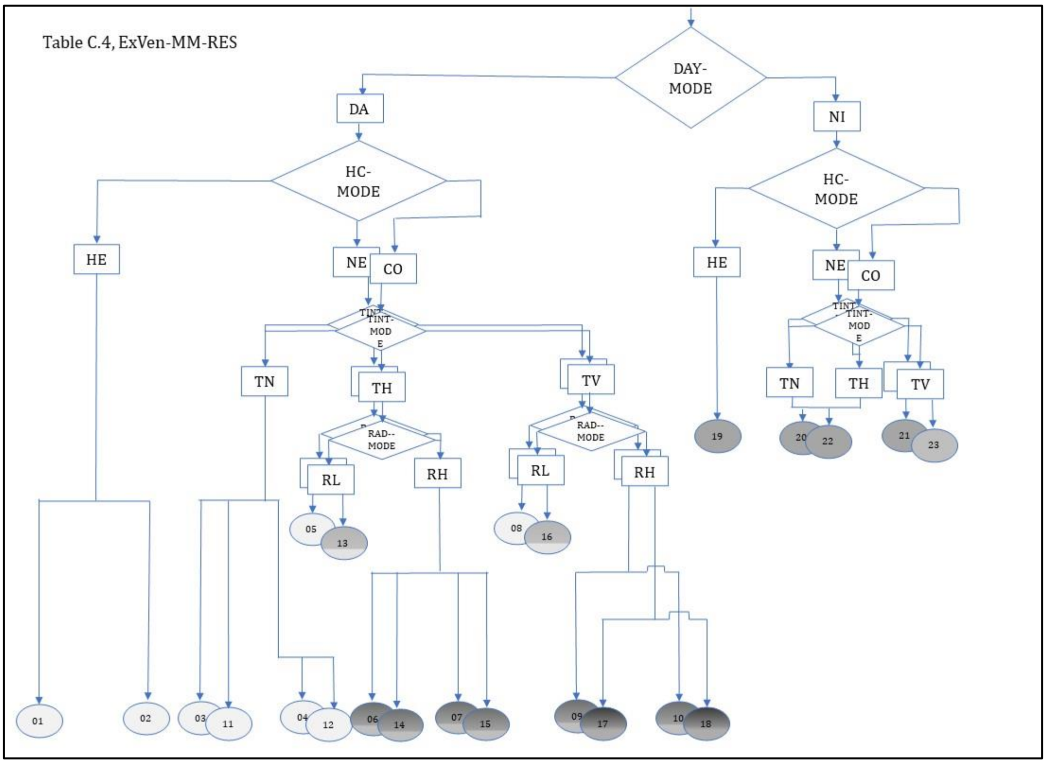
As also stated in CEN ISO/TR 52016-4, the obvious question is then: why use this generic scenario instead of directly introducing the specific scenarios for each combination? The answer is that using the generic scenario as starting point, the specific scenarios can be modified and expanded to other combinations by just changing the input data: the thermal, solar and visual transmittance of the adaptive element for each of the 23 states, as shown in 5.2.1.2 (input of thermal, solar and visual properties of an adaptive building envelope element). There is no need for any re-programming of software or spreadsheet and consequently no risk of introducing programming errors, ambiguities or conflicts.

As illustration, a few of the flow diagrams from CEN ISO/TR 52016-4, Annex C are shown in **Figure A.1 – Figure A.3.**

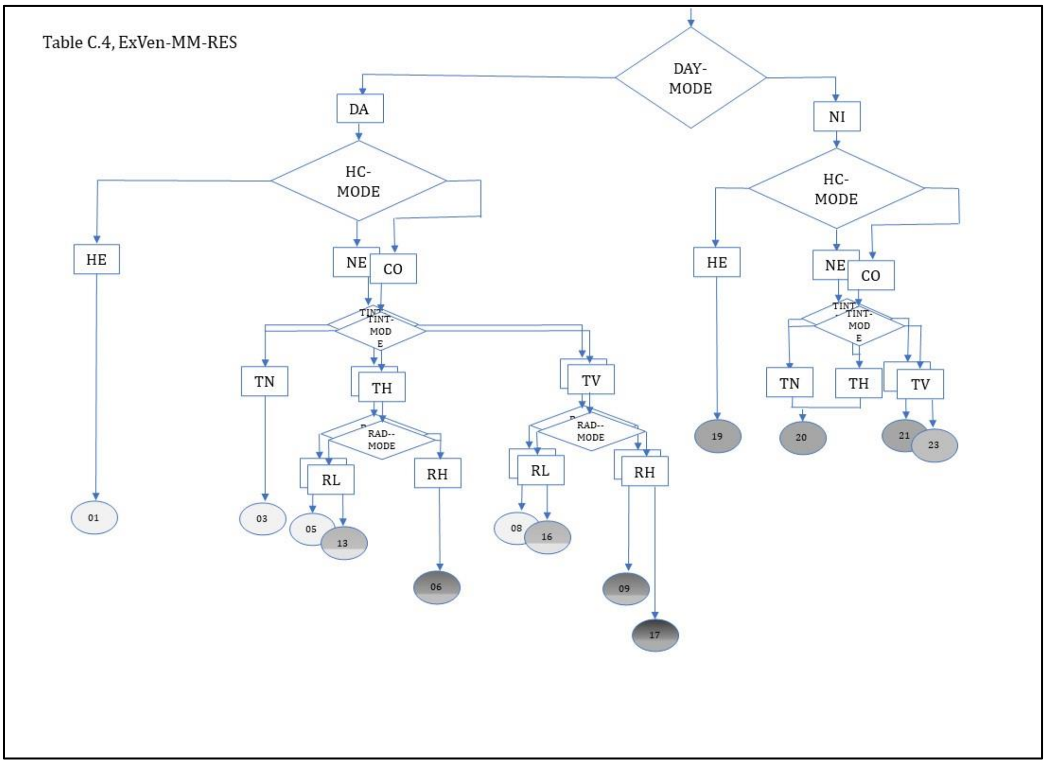


Key: see **Table A.1**

Figure A.1 — The main elements of the reference control scenarios (the generic reference scenario; from EN ISO 52016-3)

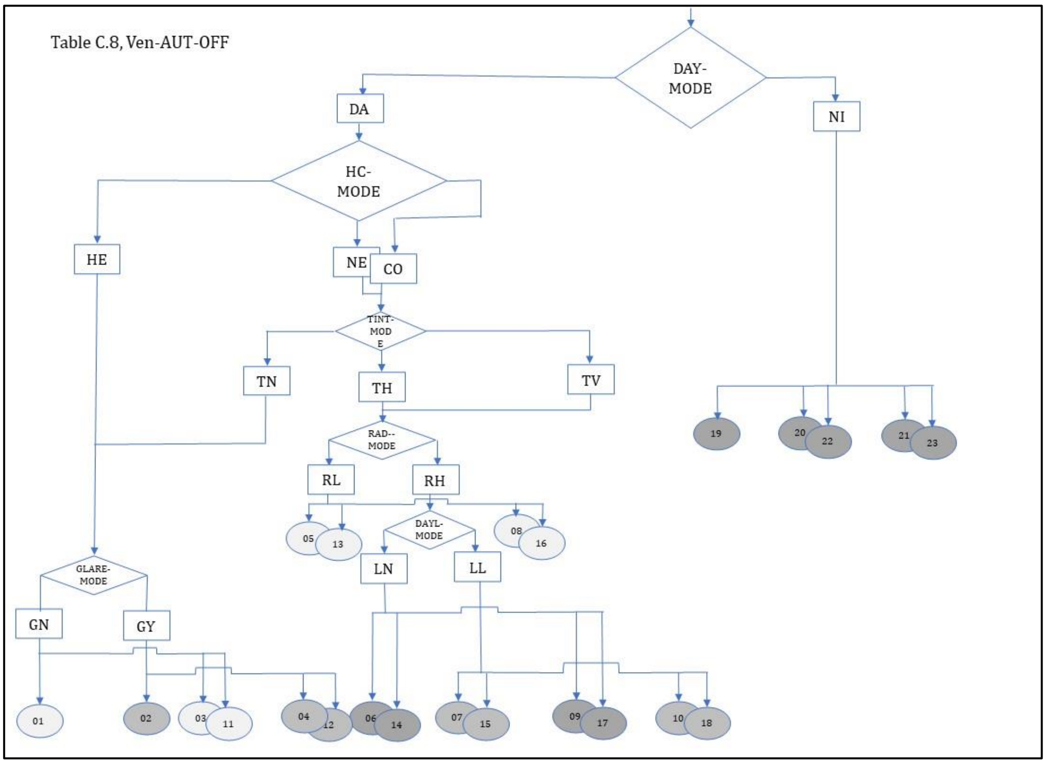


a) Reference control scenario, keeping the numbered states from the generic scheme

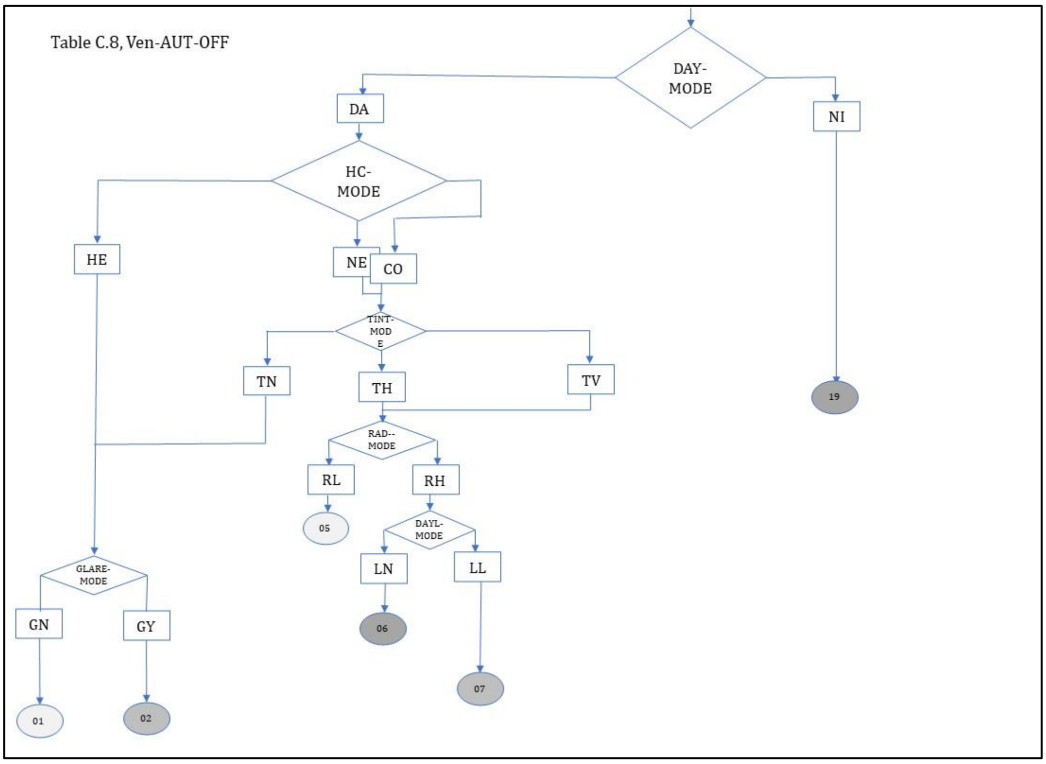


b) Same, with the identical states aggregated at the end of each path

Figure A.2 — External venetian blinds, manual control, residential spaces (EN ISO 52016-3, Table C.4 - MM)



a) Reference control scenario, keeping the numbered states from the generic scheme



b) Same, with the identical states aggregated at the end of each path

Figure A.3 Venetian blinds, automated control, office spaces (EN ISO 52016-3, Table C.8 - AUT)

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[1] (EN) 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*
Including proposed amendment 2023 regarding Annex C
https://epb.center/support/documents/iso-52016-3/

[2] (CEN) ISO/TR 52016-4:2023, *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* (under preparation)

[3] (EN) 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*
https://epb.center/support/documents/iso-52016-1/

[4] (CEN) ISO/TR 52016-2:2017, *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*

[5] (EN) ISO 52010-1:2017, *Energy performance of buildings — External climatic conditions — Part 1: Conversion of climatic data for energy calculations*
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[6] (CEN) ISO/TR 52010-2:2017, *Energy performance of buildings — External climatic conditions — Part 2: Explanation and justification of ISO 52010-1*

[7] EN 16798-1:2019, *Energy performance of buildings — Ventilation of buildings — Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (Module M1–6)*
Similar ISO version: ISO 17772-1
https://epb.center/support/documents/en-16798-1/

[8] EPB Center webinars, in particular webinars 4, 5, 7, 8, 9, 10,
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[11] ENERC32017-437-SI2-785.185, *Case study on EN ISO 52016-1 – Heating and cooling needs and internal temperatures*
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[12] ENERC32017-437-SI2-785.185, *Case study on EN ISO 52016-1, Annex F, Solar shading reduction factors*
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[13] ENERC32017-437-SI2-785.185, *Case study on EN 16798-1, Conditions of use*
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[14] ENERC32017-437-SI2-785.185, *Case study on EN 16798-7, Natural ventilation*
October 31, 2021

[15] ENERC32017-437-SI2-785.185, *Case study on EN 15316-4-2, Heat pumps* October 31, 2021

[16] Bendzalova, Jana, Simon Ligier, Johann Zirngibl and Daniela Muskatova, *D2.2 - ALDREN Methodology- note on energy rating procedure*, Sept. 2020 (update: Nov. 2021). https://aldren.eu/wp-content/uploads/2021/11/D2_2.pdf

You are invited to check the EPB Center website for the overview and most recent list and versions of all case study reports.

Link: EPB Center support documents

NOTE 1 Information on each EPB standard, including links to spreadsheet tools, suggested improvements, etc. can also be found at EPB Center support documents

NOTE 2 References to the applied tools and supporting data are provided in the relevant paragraphs of this document.

Acknowledgements

The author likes to thank the EPB Center experts and ISO TC 163/SC 2/WG 15 experts who provided valuable input and critical comments.