Criteria and Algorithms for Certified Passive House Components: Transparent Building Components

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Contents

Note: Certificates are currently only being issued for ‘arctic’, ‘cold’, ‘cool, temperate’, ‘warm, temperate’ and ‘warm’ climate zones.
The criteria for climate zones ‘warm, temperate’ and ‘warm’ as well as the category ‘Window System’ are provisional and therefore subject of specific changes.

1 Preface

Passive House buildings provide optimal thermal comfort with minimum energy costs, and they lie within the economically profitable range with reference to their life-cycle costs. In order to achieve this level of comfort and the low life-cycle costs, the thermal quality of the components used in Passive Houses must meet stringent requirements. These requirements are directly derived from Passive House criteria for hygiene and comfort as well as from feasibility studies. The Passive House Institute has established component certification in order to define quality standards, facilitate the availability of highly efficient products and promote their expansion, and to provide planners and building owners with reliable characteristic values for input into energy balancing tools. The present document contains the criteria and algorithms for the calculation and certification of transparent building components.

2 Certification criteria

2.1 Verifying Passive House suitability, certificate

Passive House suitability is verified using the U-value of the installed/uninstalled components and the temperature factor at the glazing edge as the coldest point of the component.
The thermal transmittance coefficients (U-values) and the thermal bridge loss coefficients (ψ-values) are determined based on DIN EN ISO 10077, EN 673 and DIN EN 12631. The U-values and the respective ψ-values of the defined frame cross-sections must be verified. Passive House suitability should be determined for the specified dimensions of the products to be certified. The installation ψ-value must be calculated for the specified details, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. Verification of the hygiene criterion is provided using 2-dimensional heat flow calculations of the standard cross-sections. The most unfavourable temperature factor shall be applicable.
In addition, efficiency classes shall be stated for informative purposes, see Section 2.2. Class phC must be achieved at least.

The certificate consists of the actual certificate with the product data, representation of a frame cross-section, and the efficiency class as well as verification of certifiability. Characteristic values, illustrations and drawings of the frames and the installation situations are shown in the data sheets belonging to the certificate.
Table 1 contains the requirements that need to be met for the various climate zones. The corresponding dimensions can be found in Table 3.

Table 1: Adequate certification criteria and U-values of the reference glazing

Climate zone	Hygiene criterion $f_{Rsi=0.25\ m^2K/W} \geq$	Orientation	Component U-value [W/(m²K)]	U-value installed [W/(m²K)]	Reference glazing[1] [W/(m²K)]
1 Arctic	0.80	**Vertical**	**0.40**	**0.45**	**0.35**
		Inclined (45°)	0.50	0.50	Actual U-value[2]
		Horizontal	0.60	0.60	
2 Cold	0.75	**Vertical**	**0.60**	**0.65**	**0.52**
		Inclined (45°)	0.70	0.70	Actual U-value
		Horizontal	0.80	0.80	
3 Cool-temperate	0.70	**Vertical**	**0.80**	**0.85**	**0.70**
		Inclined (45°)	1.00	1.00	Actual U-value
		Horizontal	1.10	1.10	
4 Warm-temperate	0.65	**Vertical**	**1.00**	**1.05**	**0.90**
		Inclined (45°)	1.10	1.10	Actual U-value
		Horizontal	1.20	1.20	
5 Warm	0.55	**Vertical**	**1.20**	**1.25**	**1.10**
		Inclined (45°)	1.30	1.30	Actual U-value
		Horizontal	1.40	1.40	
6 Hot	none	**Vertical**	**1.20**	**1.25**	**1.10**
		Inclined (45°)	1.30	1.30	Actual U-value
		Horizontal	1.40	1.40	
7 Very hot	none	**Vertical**	**1.00**	**1.05**	**0.90**
		Inclined (45°)	1.10	1.10	Actual U-value
		Horizontal	1.20	1.20	

2.2 Passive House efficiency classes

Depending on the heat losses through the opaque part, windows are also allocated to efficiency classes which are based on Ψ_{opaque}[3]. The frame U-values, frame widths, the glass edge Ψ-values and the glass edge lengths are included in these heat losses (see Table 2). The average values of the respective characteristic values are used. In the case of curtain wall façades and inclined glazing, the heat losses through the glass carriers (χ_{GT}) are included in the calculation of the losses similarly to Ψ_g. The same applies for heat losses due to screws.

Table 2: Passive House efficiency classes for transparent building components

Ψ_{opaque}		Passive House efficiency class	Description	
≤ 0.065 W/(mK)		phA+	Very advanced component	$\Psi_{opak} = \Psi_g + \frac{U_f \cdot A_f}{l_g}$
≤ 0.110 W/(mK)		phA	Advanced component	
≤ 0.155 W/(mK)		phB	Basic component	
≤ 0.200 W/(mK)		phC	Certifiable component	

[1] The U-values mentioned here are used as a reference value within the framework of certification in order to allow comparison of the quality of the window frames within a climatic category. The actually installed glazing may be different. Excellent quality low-e quadruple glazing or multiple vacuum glazing is recommended in the arctic climate zone, while low-e quadruple glazing or excellent quality low-e triple glazing, possibly with hard coating on the outside, is recommended for cold climate zones. Low-e triple glazing is suitable for the cool-temperate climate zone, and triple glazing or excellent quality double glazing with hard coating on the outside is suitable for the warm-temperate climate. Low-e double glazing, possibly with a solar protection coating is recommended for warm climates. Double glazing should be used in hot climates, and solar control triple-glazing should be used in very hot climates, with both having a high degree of selectivity.

[2] With reference inclination, the actual U-values should be determined in accordance with DIN EN 673 or alternatively ISO 15099.

[3] As information on possible solar gains are not available, U_w is not sufficient to describe the effect the window has for the building. That is why PHI is using Ψ_{opaque} which is a value for the heat losses via the opaque window elements. The solar irradiation does not form a part of this equation. By defining all frame losses, a general result can be obtained for the possible gains and thus for the window's energy balance. The smaller Ψ_{opaque} the better the window's energy balance.

2.3 Certification categories

Table 3: Certification categories: Definitions and specifications

<table>
<tr><th>Category</th><th>External frame dimensions (w * h) [m]</th><th>U and Ψ values included in the calculation</th><th>Informative U and Ψ-values</th><th>Installation situations[4]</th><th>Additional specifications:</th></tr>
<tr><td>Window frame (vertical)[5]</td><td rowspan="2">1.23 * 1.48</td><td rowspan="2">Bottom, sides/top</td><td>Face plate/ mullion</td><td rowspan="5">Any 3 of the following:
EIFS (obligatory), concrete formwork block, lightweight timber wall, double layer masonry wall, curtain wall façade.
For sliding doors: any 1 of the mentioned
For a window system: connections with shading.</td><td></td></tr>
<tr><td>Fixed glazing (vertical)[6]</td><td>Mullion</td><td></td></tr>
<tr><td>Window system (vertical)[7]</td><td>1.23*1.48

in addition:
2.46 * 1.48[8]</td><td>Bottom, sides/top for casement and fixed glazing as well as mullions</td><td>barrier-free threshold, at the sides with door handle fittings, mullion Fix-Fix, mullion casement-casement, face plate, transom, transom Fix-Fix [9]</td><td>Verification of CE labelling (or equivalent) testing of airtightness, protection against driving rain, suitability for use.</td></tr>
<tr><td>Sliding door (sl) (vertical)[10]</td><td>External frame dimensions 2.4 * 2.5</td><td>All relevant values</td><td>/</td><td>Testing of airtightness</td></tr>
<tr><td>Curtain wall façade (cw) (vertical)[11]</td><td rowspan="2">Unit size 1.20 * 2.50, see Fehler! Verweisquelle konnte nicht gefunden werden.</td><td rowspan="2">Mullions, transoms</td><td rowspan="2">Transom with opening casement below</td><td></td></tr>
<tr><td>Inclined curtain wall façade (cwi) (45°)[12, 13]</td><td rowspan="2">Lightweight roof structure</td><td></td></tr>
<tr><td>Roof windows (rw) (45°)[14]</td><td>1.14 * 1.40</td><td rowspan="2">All relevant values</td><td rowspan="2">Lateral connection between two windows</td><td></td></tr>
<tr><td>Skylights, domelights (sk) (horizontal)[15, 16]</td><td>1.50 * 1.50</td><td>Flat roof of reinforced concrete</td><td></td></tr>
</table>

[4] Installation situations are specified by the PHI, deviation from specifications is possible if required, and other installation situations can be calculated. The U-value of the walls/roofs may not exceed the maximum value permissible in the criteria for opaque building components.
[5] Building components in a vertical façade that are openable
[6] Building components in a vertical façade which cannot be opened and which are not curtain wall façades
[7] Combined window frames and fixed glazing
[8] Fixed glazing and casements in equal proportion, linked to a mullion
[9] The thermal standard of the cross-sections stated for information purposes must correspond with those of the regulative cross-sections, f_{Rsi} must be complied with for all cross-sections.
[10] Fully glazed elements in a vertical façade which consist of a horizontal sliding section and a fixed glazing section
[11] Transparent building components with fixed glazing areas next to each other, the glass panes of which are pressed onto the supporting construction by means of fasteners and supported vertically by means of glass carriers and installed in a vertical façade
[12] So far it has not been adequately investigated whether the comfort requirement for $V_{Luft} \leq 0.1$ m/s is met by this criterion. This therefore refers only to comfort with reference to radiation temperature asymmetry.
[13] Verification is for a module installed below and to the left in a Passive House suitable exterior wall
[14] Openable building component in a roof construction
[15] Openable and non-openable transparent building component with a single or multiple-curved transparent proportion in a roof construction
[16] The criterion U_g must be verified for the actual geometry. The criteria U_{sk} and $U_{sk,installed}$ must be verified for glazing that projects horizontally.

2.4 *Assignment of the climate zones (regions with similar requirements)*

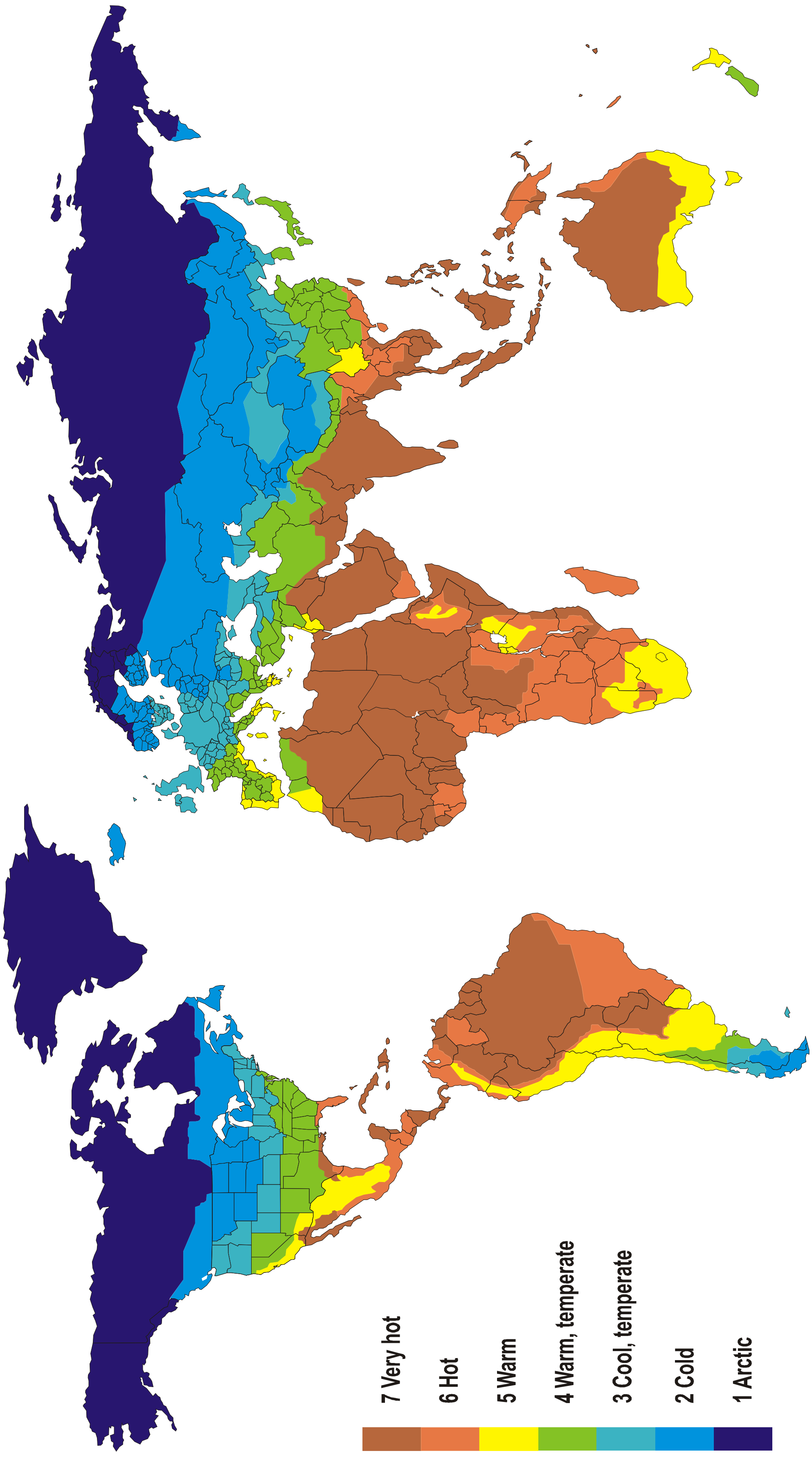


Fig. 1: Assignment of regions with identical requirements

3 Functional requirements, boundary conditions, calculation

3.1 Functional requirement for the hygiene criterion

Passive House requirement: maximum water activity (interior building components): **$a_w \leq 0.80$**

This requirement restricts the minimum temperature at the window surface for health reasons. Mould growth may occur if water activity exceeds 0.80. Such conditions should therefore be consistently avoided. For boundary conditions, see 3.4. Water activity is the relative humidity either in a material's pores or directly on its surface.

The $f_{Rsi=0.25}$ temperature factors given in **Fehler! Verweisquelle konnte nicht gefunden werden.** result as acceptable certification criteria for different climates.

This f_{Rsi} is the temperature factor at the coldest point of the window frame. Criteria for other climate zones are currently being determined.

3.2 Functional requirement for comfort criteria

Passive House requirement: Minimum temperature of volume enclosing surfaces: **$|\theta_{si}-\theta_{op}| \leq 4.2K$**

This temperature difference requirement limits the minimum average temperature of a window for reasons of comfort. In contrast with the average operative indoor temperature, the minimum surface temperature may deviate by a maximum of 4.2K. A greater difference may lead to unpleasant cold air descent and perceptible radiant heat deprivation. The operative temperature (θ_{op}) is the average temperature of the surfaces enclosing a room's volume and the temperature of the air. It is also known as the perceived temperature and is assumed to be 22°C in the formula below.

The maximum thermal transmittance coefficients (U-values) of installed certified transparent Passive House building components under heating dominated situations can be calculated from this temperature difference criterion using the formula below:

$$U_{transparent,installed} \leq \frac{4{,}2K}{(-0{,}03 \cdot \cos\beta + 0{,}13)\ \ m^2K/W \cdot (\theta_{op}K - \theta_a K)}$$

Due to the additional heat losses from the installation-based thermal bridge, the requirement is increased by 0.05 W/(m²K) for the uninstalled component and by 0.10 W/(m²K) for the glazing.

The U-values given in Table 1 result as acceptable certification criteria for different climates.

Economic feasibility studies have shown that in warmer, heating-dominated climates, heat transfer coefficients better than those required by the comfort criterion alone are needed to reach an economic optimum. In these climates, heat transfer coefficients based on the economic optimum are required for certification. The same applies for cooling-dominated climates.

Passive House requirement: limiting the risk of draughts: **$v_{Air} \leq$ 0.1 m/s**

The air velocity in the living area must be less than 0.1m/s. This requirement restricts the air permeability of a building component as well as cold air descent. For vertical surfaces, adherence to the temperature difference requirement means compliance with the draught requirement. This has not been examined conclusively for inclined surfaces.

3.3 Temperatures and heat transfer resistances for heat flow simulations

Table 1: Temperatures and heat transfer resistances for heat flow simulations

Climate	**Heat transfer resistance R_S [m²K/W]**			**Temperature [°C]**
	Upward, 0° ... 60°	Horizontal, 60° ... 120°	Downward, 0° ... 60°	
Inside (EN 6946)	0.10	0.13	0.17	20
Inside - sloped glazing	$R_{Si} = -0.03 \cdot \cos\beta + 0.13$ (β = angle of inclination to horizontal)			
Increased on inside (at glass edge area)	0.20			
Inside for determination of f_{Rsi}	0.25			
Outside (EN 6946)	0.04			0
Outside (ventilated)	0.13			
Outside (against ground)	0.00			5

3.4 Calculation of f_{Rsi}

Calculation of the temperature factor at the glass edge f_{Rsi}: $f_{Rsi} = \dfrac{\theta_{si} - \theta_a}{\theta_i - \theta_a}$

with θ_{si}: minimum interior surface temperature as per multi-dimensional heat flow calculation [°C]

θ_a: outside temperature as per multi-dimensional heat flow calculation [°C]

θ_i: Inside temperature as per multi-dimensional heat flow calculation [°C]

3.5 Calculation of U-values of transparent building components

In order to obtain directly comparable thermal parameters, the same glazing U-values are used for individual components in different regions, see **Fehler! Verweisquelle konnte nicht gefunden werden.**. This applies for vertical components. For horizontal and inclined components, the actual U-value of the glazing is used.

U-value of an uninstalled transparent building component

See DIN EN ISO 10077-1:2009 Section 5.1: $U_t = \dfrac{U_g \cdot A_g + U_f \cdot A_f + \Psi_g \cdot l_g}{A_g + A_f}$

U_t: U-value of the uninstalled transparent building component [W/(m²K)]

U-value of an installed transparent building component

$$U_{t,installed} = \frac{U_t \cdot A_t + \sum l_e \cdot \psi_e}{A_t}$$

$U_{t,installed}$: Heat transfer coefficient of an installed transparent building component [W/(m²K)]

A_t: Area of the window ($A_g + \sum A_f$) [m²]

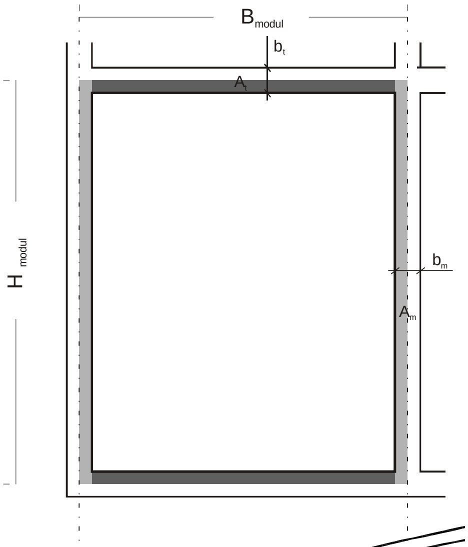
$\sum l_e \cdot \psi_e$: Sum of all installed lengths [m] multiplied by the respective installed Ψ-value [W/(mK)]. See Section **Fehler! Verweisquelle konnte nicht gefunden werden.** for determination of the geometric characteristic values; see Section **Fehler! Verweisquelle konnte nicht gefunden werden.** for determination of installation-based thermal bridges.

3.6 *Geometric characteristic values*

Façade and roof windows

See DIN EN ISO 10077-1 Section 4

In addition: profiles, for example for connecting window sills, are considered part of the frame.

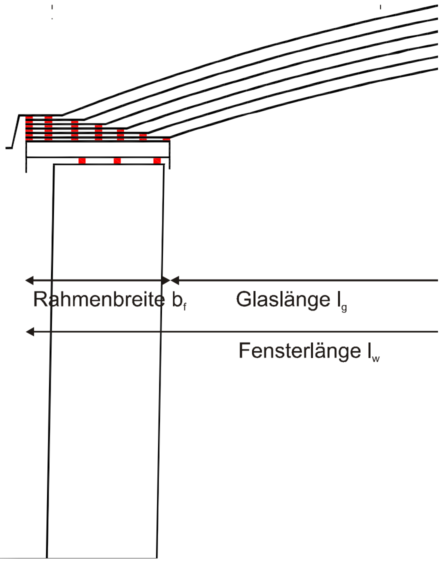


Curtain-wall façades and inclined glazing

See DIN EN 12631. Variance: the unit size is the testing size (B_{unit} * H_{unit} = 1.2 m * 2.5 m). The left and bottom sides are installed.

Skylights and domelights

See DIN EN ISO 10077-1 Section 4. Addition or variance: l_g is the clearance size between the frames; b_f is the horizontally projecting frame width. Fixing attachments etc. are not considered part of the frame width. Skylight frames and crowns are included in the installation-based thermal bridge. They are not considered part of the frame. 0.30 W/(m²K) is specified as the maximum U-value for skylight frames/ crowns. This value should be ascertained in accordance with DIN EN ISO 6946.



With curved domelights, the actual length of the glass or its area differs from the horizontally projecting glass area to be entered in the PHPP. In the certificate and the data sheet, the projected area is given with a correspondingly increased U-value adjusted for the reduced area. These values can be taken directly for the PHPP.

3.7 *Thermal characteristic values*

Frame U-value and glass edge Ψ-value

Ascertained by means of a two-dimensional heat flow simulation; see DIN EN ISO 10077-2 Appendix C. Deviation: profiles, for example for connecting window sills, belong to the frame. The actual glass insertion depth should be used.

Installation Ψ-value

Ascertained by means of a two-dimensional heat flow simulation; the model for determining Ψ-values at the glass edge is dependent upon the exact details of the connection situation. Attention should be paid that the model is sufficiently large. As a rule, point attachments of the frame are not included.

$\Psi_{installed}$ is determined as follows: $$\Psi_{Install} = \frac{Q_{Install} - Q_g - U_{wall} \cdot l_{wall} \cdot \Delta\theta}{\Delta\theta}$$

Since the exterior frame dimensions are used in the energy balance (PHPP), the same reference dimensions are used here. Accordingly, the installation gap is included in the installation-based thermal bridge.

For curtain-wall façades, the unit size is used in the energy balance (PHPP), therefore the installation gap and half of the mullion/transom width is taken into account in the installation-based thermal bridge.

Determining the influence of screws in curtain-wall façades

The influence of screws is represented by ΔU and can be determined with the following procedure:

1. Measurement in accordance with EN 1241-2
2. Calculation using 3D heat flow software
3. Application of general overall values for screws with a distance between 0.2 and 0.3 m: screws made of steel: ΔU = 0.300 W/(m²K)

ΔU, due to the influence of screws, is calculated as follows: $\Delta U = \frac{(Q_S - Q_0)}{l \cdot \Delta\theta \cdot b_t}$

Q_S:	Heat flow with screws (determined numerically or by measurement) [W]
Q_0:	Heat flow without screws (determined numerically or by measurement) [W]
l:	Lengths of the calculation model [m]
Δθ:	Temperature difference between the inside and outside (numerical boundary conditions or those of the measurement) [K]

If the transoms and mullions have different widths, the smaller width should be used for calculation.

Determining the influence of glass carriers in curtain-wall façades

The influence of glass carriers is represented by the point thermal bridge coefficient of the glass carrier χ_{GT} and can be determined with the following procedure:

1. Measurement in accordance with EN 1241-2
2. Calculation using 3D heat flow software
3. Application of the following overall values: glass carrier made of metal: χ_{GT} = 0.040 W/K, non-metallic glass carrier with screws: χ_{GT} = 0.004 W/K, non-metallic glass carrier: χ_{GT} = 0.003 W/K

χ_{GT} multiplied by the number of glass carriers present in the unit is included in the U-value calculation of the façade. If the glass carriers are screwed on or fixed on bolts, then these screws or bolts should be included in the calculation.

Glass carriers able to support triple glazing corresponding with the unit size should be used. The Passive House Institute does not test the structural stability of the glass carrier.

χ_{GT} [W/(mK)] is calculated as follows: $\chi_{GT} = \frac{Q_{GT} - Q_0}{\Delta T} \cdot l$

Q_{GT}:	Heat flow with glass carrier (determined numerically or by measurement) [W]
Q_0:	Heat flow without glass carrier (determined numerically or by measurement) [W]
ΔT:	Temperature difference between the inside and the outside (numerical boundary conditions or those of the measurement) [K]

3.8 Special regulations

Compound and box windows

- Glazing U-value U_g to be used is the actual glazing U-value of the combined insulated glass unit, the intermediate space and the glazing in front. In the case of triple glazing of the insulated glass unit, U_g =0.70 W/(m²K) is set at best, and 1.10 W/(m²K) is set for double glazing.
- Thermal conductivity of the air space from the R-value in accordance with the table in DIN EN ISO 10077-2 Appendix C. The R-value for 50 mm given in the table can be used for air spaces larger than 50 mm. Alternatively, DIN EN ISO 673 can be used for calculation.
- Basic approach for the calibration plate in box windows: geometry of glass panes as calibration plate, air space as before. For compound windows: as stated in DIN EN ISO 10077-2.

Basic approach for thermal conductivities

- Basically, only the rated value of the conductivity is taken into account.
- If no rated value is available, the procedure in DIN EN ISO 10077-2:2012 Section 5.1 is to be followed.

Spacers

- Warm edge spacers can be chosen freely by the certificate holder. The 2-Box models of the “Warm Edge Working Group” should be referred to for calculation.
- The secondary seal (Box 1) is also freely selectable provided that it has been approved for the chosen spacer. In deviation from DIN EN ISO 10077-2:2012, the thermal conductivity of polyurethane sealing compound is set as 0.25 W/(mK) in accordance with DIN EN ISO 10077-2:2008.
- Beyond this, there is the possibility of certification with a spacer category corresponding with the criteria for "Spacers in low-e glazing" of the Passive House Institute. Reference spacer are created for this

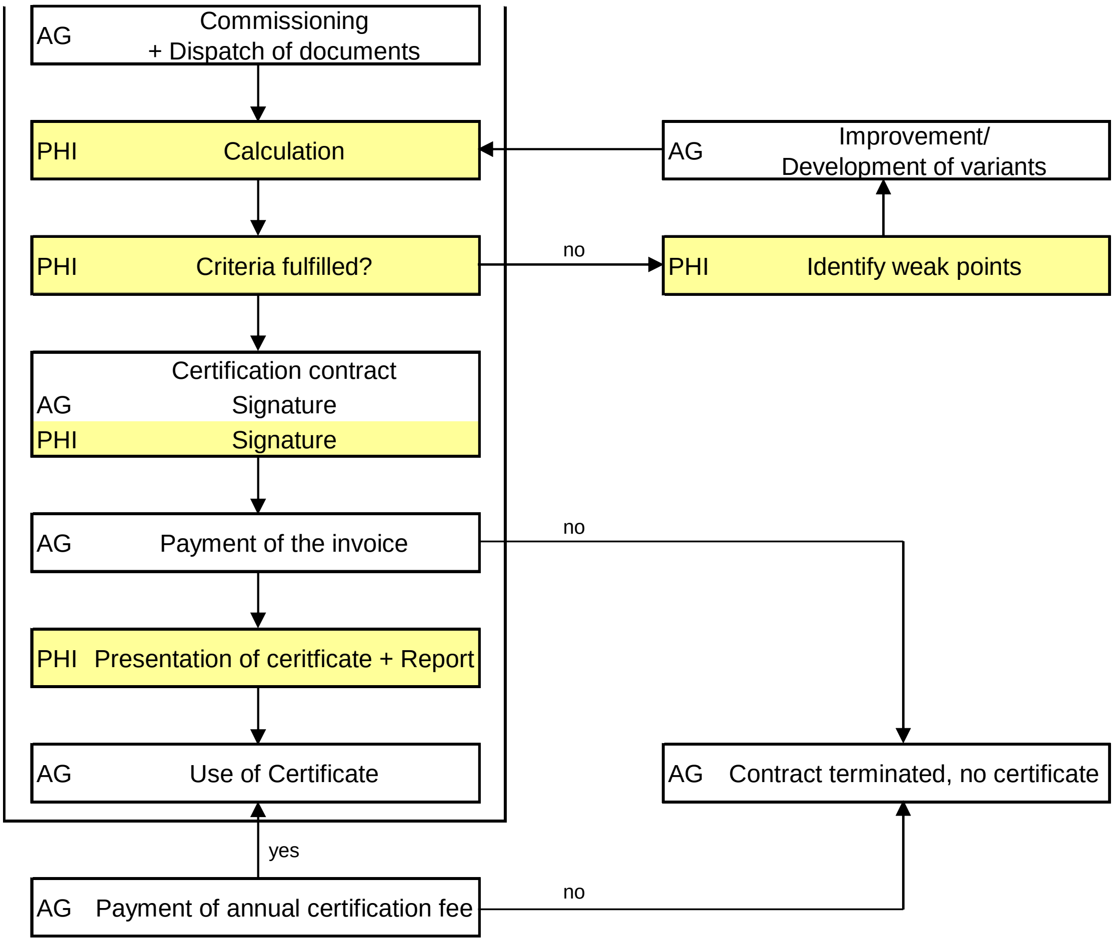
purpose: Height box 2: 7 mm, thermal conductivity of box 2: [W/(mK)]: phA: 0,2, phB: 0,4, phC: 1,0.

Other stipulations

- The connection at the top of masonry walls with a compound insulation system is calculated without the concrete lintel for windows and fixed glazing.
- A possibility for drainage must be provided, specifically for the lower frame section. This drainage is part of the window frame and is not part of the installation situation.

4 General information, services provided by the Passive House Institute

4.1 Certification procedure



4.2 Documents required

The following documents should be provided by the manufacturer to the PHI for the calculation.

1. **Sectional drawings** (for all different sections) of the window frames or mullion/transoms, including installed low-e triple glazing, as DXF or DWG files.

2. Information about the **materials and rated values of the conductivities** used (and the density, if necessary). It must be possible to assign the materials clearly on the basis of the drawings (legend; hachure). The rated values of the thermal conductivities of the materials used should be given in accordance with DIN V 4108-4, DIN EN ISO 10077-2 or DIN EN ISO 10456. If the thermal conductivity of a material is not listed in any of these standards, it can be substantiated on the basis of general building approval permits or by a general

building approval examination. If a rated value for the thermal conductivity cannot be given, the PHI reserves the right to apply a security surcharge of 25%.

3. Exact **product information about the spacer**. If necessary, exact information about the geometry and materials, if the spacer is as yet not known to the PHI.

4. **Drawings of installation variants** for installation in three Passive House suitable exterior walls with U_{wall} < 0.15 W/(m²K). Sectional drawings (for all different sections) as DXF or DWG files.

4.3 Services provided by the Passive House Institute

Frame sections:

1. Processing of the CAD drawings of the window frames or mullion and transoms for further calculation in accordance with the documents available. All sections (top, bottom, sides and face plate/mullion/opening casement) are necessary for certification if they differ from each other.
2. Calculation of the temperature factor and calculation of the window U-values and Ψ-values required for certification, in compliance with DIN EN 10077.
3. Calculation of variants for the thermal optimisation of the frame in consultation with the client.

After prior consultation, the costs incurred for the calculation of variants will be invoiced to the client. If the window frame has different cross sections (bottom, sides, top), then these will be treated as variants.

Installation situations:

It is recommended that calculation of the installation situations is only carried out if the frame meets the certified Passive House component criteria.

4. Processing of the CAD drawings of the window installation for further calculation in accordance with the documents available. All sections (top, bottom, sides) are necessary for certification if they differ from each other.
5. Calculation of the Ψ-values required for certification, in compliance with DIN EN 10077.
6. Documentation with isothermal images, results sheets and final report.

Certification:

7. Inclusion of the certification and presentation of the certified product on the Passive House Institute website and in the continually updated "List of Certified Components".

4.4 Legal validity, temporary provisions, further development

The certification requirements and calculation regulations for certified Passive House transparent building components shall become fully effective with the publication of this document. All previously published criteria shall cease to apply with the coming into force of these provisions. The Passive House Institute retains the right to make future changes.

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