SWISSPACER

# Living Comfort

## How comfort and hygiene criteria can be met for windows in different climates

A study of the Passivhaus Institut (PHI)
On behalf of SWISSPACER, Kreuzlingen, Switzerland

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# 1 Introduction

Everyone wants to have a cosy, comfortable home. What could be nicer than to be at home surrounded by your family on cold, grey days with a cup of hot tea or a glass of red wine?
Comfort has a lot to do with warmth. And to have a warm home, it has to be heated. But in times of climate change, doesn't that give rise to a bad conscience?
It doesn't have to, because a building envelope of high thermal quality makes it possible to decouple cosy warmth from high levels of energy consumption. What's more, high-quality windows and glazing units are fundamental to achieving the desired thermal comfort. With good components, factors such as condensation and mould on the edge of the glass are also a thing of the past. And, by the way, high energy savings or even a net energy gain through the window can also be achieved.
But what exactly is thermal comfort? And how can it be achieved? Condensate and mould on the edge of the glass – how are they produced and what can be done to avoid them?
This study answers these questions.

## 1.1 Thermal Comfort

We perceive a room as being thermally comfortable when it has a certain operational temperature ($\theta_{op}$), which is composed of the average temperature value of the air and the surrounding surfaces. Moreover, drafts and large temperature differences between individual surfaces ($\theta_{si}$) and the operational indoor temperature are perceived as disruptive. In the case of an old window, for example, the indoor surface is relatively cold in winter. The body loses a lot of warmth to this cold surface, which is perceived as uncomfortable. The air in front of this cold surface also cools, its density increases and it sinks. This produces cold air circulations that cause disruptive drafts. If the temperature difference between these colder surfaces and the operational indoor temperature is less than 4.2 Kelvin [1], these disruptive effects no longer occur.
Accordingly, the comfort requirement is: $\theta_{si} \geq \theta_{op} - 4.2\ K$

Location-related statements on the thermal comfort can be made on this basis. Moreover, the relevant minimum outside temperature ($\theta_a$) is determined on the basis of the coldest daily average of a reference year at this location. This relevant minimum outside temperature and the maximum temperature difference can be used to calculate the heat transmission coefficient U, below which thermal comfort is guaranteed:

$$U \leq \frac{4{,}2}{R_{si} \cdot (\theta_{op} - \theta_a)}$$

Here, $R_{si}$ is the inner heat transfer resistance at 0.13 m²K/W.

If the operational indoor temperature is taken to be 22 °C and the outside temperature -16 °C, this gives a U-value of 0.85 W/(m²K). This value is known as the Passivhaus comfort criterion for the cool-temperate climate. This U-value also applies to the installed window. If the non-installed window is considered on its own, the limit valve in the cool-temperate climate is 0.80 W/(m²K) in order to ensure a buffer for the built-in thermal bridges. If it is not possible to reach this value, a heat source should be placed under the window to stop the disruptive sinking of cold air and radiant heat extraction and to achieve the desired level of comfort.

[1] See, for example, Pfluger, R., Schnieders J., Kaufmann B, Feist, W.: **HIWIN – Highly insulating window systems: Examination and optimisation in the installed condition.** Darmstadt, 2003. Download at www.passiv.de. Similar recommendations in ISO 7730, Comfort Class A.

As the comfort formula shows, the maximum U-value of the component depends on the outside temperature and thus on the local climate.

Table 1 lists the design temperatures for the different climates and the associated U-values. The figure “Maximum U-values in Europe” represents the comfort requirement for the heat transmission coefficient in graphic form. The map shows the highest requirements in northern and north-eastern Europe. This region is the coldest and the heating season the longest. In extreme cases, it never gets properly light in these regions in the depths of winter, so there is no solar gain at this time. At these latitudes, it also makes sense to install smaller windows for economic reasons. The same applies, if for exactly the opposite reason, in the Mediterranean region. The U-values can remain high here, but the solar gain is so high that overheating easily occurs. This can be avoided by shading, solar control glass or reducing the size of the windows. Simplification is achieved by glazing units that have a much lower U-value than is required by the comfort criterion. In the British Isles, the influence of the Gulf Stream is evident in the high U-values. The climate here is mild, the requirements remain low. The higher the elevation of a location, the lower the temperature, which increases the glazing requirements. This can be seen on the map, for example, in the Alpine region.

Table 1: Design and requirements values for hygiene and comfort in the various climates. © Passivhaus Institut

| | Kennwert / Klima | Arktisch | Kalt | Kühl-gemäßigt | Warm-Gemäßigt | Warm |
|---|---|---|---|---|---|---|
| Behaglichkeit | Auslegungstemperatur [°C] | -50 | -28 | -16 | -9 | -4 |
| | Behaglichkeits-U-Wert [W/(m²K)] | 0,45 | 0,65 | 0,85 | 1,05 | 1,25 |
| | … für Fenster ohne Einbauwärmebrücken [W/(m²K)] | 0,40 | 0,60 | 0,80 | 1,00 | 1,20 |
| Hygiene | Auslegungstemperatur [°C] | -34 | -16 | -5 | 3 | 10 |
| | Relative Raumluftfeuchte [%] | 40% | 45% | 50% | 55% | 70% |
| | Temperaturfaktor $\mathbf{f}_{Rsi=0,25\ m^2K/W}$ [-] | 0,8 | 0,75 | 0,7 | 0,65 | 0,55 |

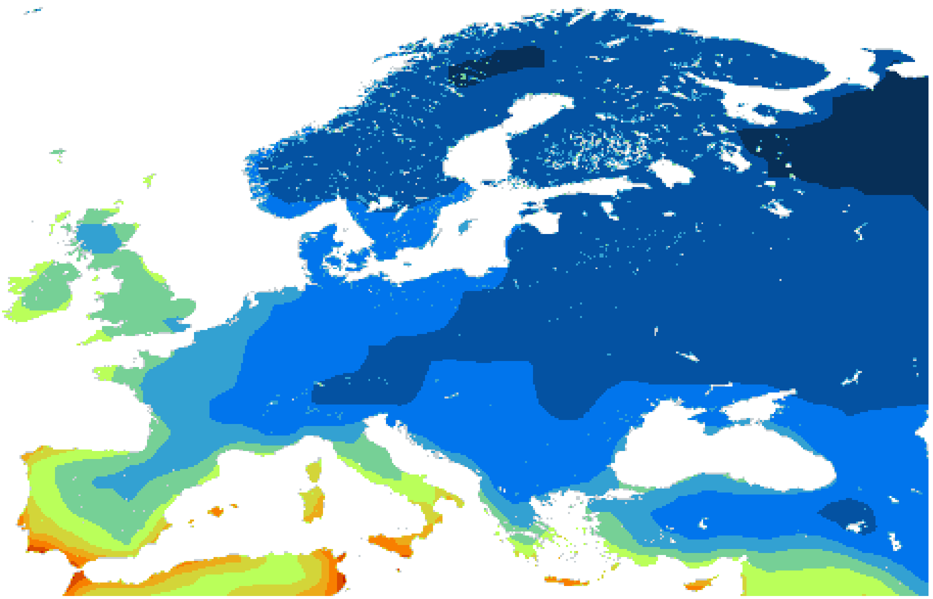


Figure 1 1: Maximum U-values in Europe for achieving the comfort criterion. © Passivhaus Institut

## 1.2 Hygiene

Everyone knows this situation: After taking a shower, condensation forms around the edge of the glass in the windows. It appears there first because this is generally the coldest place in the room. This often leads to the formation of mould, which spreads quickly here because of the high levels of moisture – and can lead to health problems. In combination with the condensation, this can also cause structural damage, which can lead to a marked shortening of service life, especially for wooden windows. One remedy, apart from a correctly set ventilation system, is to increase the temperature around the edge of the glass. As already mentioned, this is dependent on the selected spacer and on the thickness of the glazing unit and how the panes are installed in the window. The best outcome is always offered by the combination of high-quality thermal spacer bar, triple glazing with the widest possible gap between the panes, and a well-insulated window frame.

The temperature factor $f_{Rsi}$ = 0.25 m²K/W has established itself as an indicator for the hygienic conditions on the edge of the glass. If this value is at least 0.7 in a cool-temperate climate, it can be assumed that no mould will grow at normal levels of indoor humidity.
This criterion is derived from DIN 4108-3. This assumes an outside air temperature of -5 °C, an inside air temperature of 20 °C and an inside relative humidity of 50%. Under these conditions, the dew point is 9.3 °C. As the temperature increases, air is able to hold an increasing amount of water vapour. A relative humidity of 50% at 20 °C means that the humidity storage capacity of air is 50% full at this temperature. If the temperature falls, the storage capacity reduces, the degree of filling increases and along with it the relative humidity. At a certain level of moisture, a humidity of 100% is reached, meaning that the humidity storage capacity of air is full. This point is called the dew point and in our example is 9.3 °C. As the temperature falls further, the storage capacity becomes smaller; metaphorically speaking, it overflows. Condensation precipitates and becomes evident in the

form of condensate, e.g. on the cold window pane or even around the edge of the glass.

Like the dew point, a mould point can also be defined. And not as 100% relative humidity at the cold point, but at 80% relative humidity. Because when the humidity exceeds 80% for a extended period of time, the growth conditions for relevant types of mould are in place. This condition (at 20 °C indoor air temperature and 50% relative indoor humidity) occurs from a surface temperature of 12.6 °C.
The above-mentioned temperature factor can be calculated with these general conditions:

$$f_{Rsi=0,25m^2K/W} = \frac{\theta_{si} - \theta_a}{\theta_i - \theta_a} = \frac{12{,}6°C - -5°C}{20°C - -5°C} = 0{,}7$$

Other climates with different humidities and outside temperatures give rise to other temperature factors, which must not be undershot in order to avoid mould. The temperature factors and general conditions are shown in Table 1.

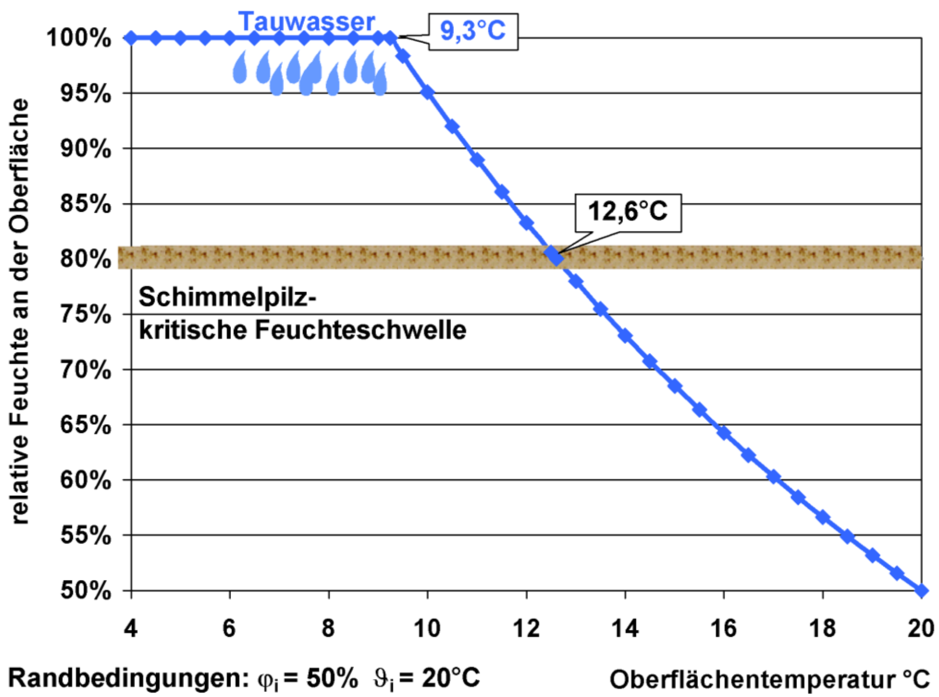



Figure 1 2: Surface temperature and associated relative humidity on the surface at an indoor temperature of 20 °C and a relative humidity of 50%. Condensation is produced below 9.3 °C, mould below 12.6 °C. © Passivhaus Institut

## 2 Windows – Touchstone for comfort and hygiene

Windows are special components in every building. They enable contact with the outside world. Windows differ from other components in that they don’t just lose energy. They are also capable of gaining energy. Ideally more than they lose. This is when the window becomes a heater.

Windows play a special role in comfort as they are generally the weakest elements of the entire building in thermal terms.  They primarily determine whether the building can achieve the desired thermal comfort. The prerequisite is always to see the window in conjunction with the building’s location. A window may offer perfect comfort in the warm

Mediterranean climate, but be far from adequate in the cold north.
The glazing has the biggest impact on the window's U-value because it accounts for the biggest proportion of the window by area. In warm climates, double glazing is sufficient. But in warm-temperate areas, triple glazing is recommended. In cool-temperate and cold regions, triple glazing is a necessity. In Arctic (polar) climates, quadruple glazing must be used.
The window frame also plays a role. While uninsulated window frames will suffice for warm and warm-temperate climates, insulation is recommended in the window frame for the cool-temperate climate and a necessity for colder climates.

With regard to hygiene, the window – or, more precisely, the point where the window frame meets the glass – is also a weak point. The lowest temperature in the entire building can generally be found at the edge of the glass. It's so cold that mould and condensation can form here. The so-called edge seal plays a decisive role here. An important element of the edge seal is the spacer bar, which maintains the distance between the individual panes of glass and prevents the gas in the gap between them from escaping.
If an aluminium spacer bar is used here, as is unfortunately all too often the case, hygiene problems are preprogrammed into the window. Aluminium may be affordable and easy to work with. But its thermal conductivity of 160 W/(mK) is very high. A large heat bridge forms, which on the one hand cause high levels of energy loss and thus fuels climate change. On the other, this heat bridge also leads to low surface temperatures, which are the cause of mould and condensation.
Using a spacer bar made from stainless steel instead of aluminium significantly lowers heat losses and the temperature around the edge of the glass rises, as stainless steel has only about one tenth the thermal conductivity of aluminium. The slightly higher material costs can generally be offset by the lower energy losses.

Generally speaking, the best choice is to use a highly efficient plastic spacer bar, such as the Swisspacer Ultimate. It has a body made from fibre-reinforced plastic for stability and a plastic film steamed with metal to prevent the filling gas escaping from the gap between the panes. The thermal conductivity of the fibre-reinforced plastic is about one four hundredth the thermal conductivity of aluminium. It is easy to understand how both the heat loss and the lower temperatures can be significantly alleviated with this material.

There follows a presentation of various plastic windows with spacer bars made from aluminium, stainless steel and plastic respectively, and a discussion of their suitability with regard to comfort and hygiene in different climates. The dimensions of the windows were selected at 1.2 m in width and 2.5 m in height.

## 2.1 Aluplast Ideal 4000: Plastic window frame with double thermal insulation glazing

The Ideal 4000 is a 5-chamber profile with a depth of 70 mm, which is above all suitable for accepting double glazing, which has been estimated here to have a glass U-value of $U_g$ = 1.12 W/(m²K). In general, plastic windows need reinforcement to deliver the necessary stability. The Ideal 4000 is reinforced with steel. As steel has a high thermal conductivity, the reinforcement has a negative impact on the thermal quality of the frame, which is represented by the heat transmission coefficient $U_f$ [W/(m²K)]. With the selected double glazing, $U_f$ is 1.50 W/(m²K). This is a relatively high, i.e. thermally unfavourable value.

Figure 1 3: Aluplast Ideal 4000. © Aluplast

The glass edge Ψ-values are 0.072 W/(mK) with the aluminium spacer bar, 0.050 W/(mK) with the stainless steel spacer bar and 0.033 W/(mK) with the Swisspacer Ultimate. The reduction in thermal bridge losses due to the better spacer bar is clear.

The temperature factors and window U-values can be found in the following table.

This table also clearly shows: The window with U-values of between 1.32 and 1.42 W/(m²K) does not fulfil the comfort criterion of any climate. Still: The hygiene criterion for the warm climate is achieved with the stainless steel spacer bar and the Swisspacer Ultimate.

The current Energy-Saving Regulation EnEV 2014/16 prescribes certain thermal qualities when replacing components. For windows in normally heated residential buildings, a heat transmission coefficient of the windows is specified as $U_W$ = max. 1.3 W/(m²K). Rounded to the nearest decimal place, this value is achieved only by the window with the Swisspacer Ultimate. From this, it follows: The double glazed Ideal 4000 with aluminium or stainless steel spacer bar may not be used for refurbishment purposes in Germany for legal reasons.

Summary: With the glass-frame combination selected here, comfort and hygiene requirements cannot be met under any of the selected general conditions.

The use of double glazing in a warm climate can be a good idea. But in this case a better frame should be selected.

It must additionally be noted that there are plenty of climates with requirements below those of the climate selected here In these cases, the selected glass-frame combination fulfils the requirements.

Table 2: Characteristic values of the Aluplast Ideal 4000 with different spacer bars and suitability for the different climates.

| | **Abstand-halter** | **Aluplast Ideal 4000** | **Klima** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Arktisch | Kalt | Kühl-gemäßigt | Warm-Gemäßigt | Warm |
| Behaglichkeit **$U_W$** [W/(m²K)] | Aluminium | 1,42 | | | | | |
| | Edelstahl | 1,37 | | | | | |
| | Swisspacer Ultimate | 1,32 | | | | | |
| Hygiene **$f_{Rsi=0,25\ m^2K/W}$** [-] | Aluminium | 0,48 | | | | | |
| | Edelstahl | 0,56 | | | | | ✓ |
| | Swisspacer Ultimate | 0,62 | | | | | ✓ |

## 2.2 Aluplast Ideal 8000: Plastic window frame with triple thermal insulation glazing

The Ideal 8000 has a depth of 85 mm, 6 chambers and 3 sealing levels, and is thermally much better. It was considered here with triple glazing, $U_g$ = 0.72 W/(m²K). Each of the two gaps between the panes is 12 mm wide, filled with argon and does not achieve the thermal optimum of 18 mm gaps. This is a regrettably common practice, although the additional costs of large gaps are low and most window frames are able to hold sealed units with gaps between the panes of at least 14 mm. The heat transmission coefficient of the frame is also influenced by the thickness of the pane. With the selected glazing, $U_f$ is determined to be 1.11 W/(m²K). The Ideal 8000 is also reinforced with steel.

Figure 1 4: Aluplast Ideal 8000. © Aluplast

The glass edge Ψ-values are 0.075 W/(mK) with the aluminium spacer bar, 0.050 W/(mK) with the stainless steel spacer bar and 0.031 W/(mK) with the Swisspacer Ultimate. The reduction in thermal bridge losses due to the better spacer bar is clear.

The temperature factors and window U-values can be found in the following table.

This table also clearly shows: The window with U-values of between 0.92 and 1.03 W/(m²K) fulfils the comfort criteria of the warm-temperate climate with all spacer bars and those of the warm climate with the stainless steel spacer bar and the Swisspacer Ultimate. The hygiene criterion of the warm climate is also met by all variants. However, those of the warm-temperate climate are met only with the Swisspacer Ultimate.

Summary: With the selected glass-frame combination, the window is suitable for the warm climate with all spacer bars, and also for the warm-temperate climate with the Swisspacer Ultimate.

Table 3: Characteristic values of the Aluplast Ideal 8000 with different spacer bars and suitability for the different climates.

| | **Abstand-halter** | **Aluplast Ideal 8000** | **Klima** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Arktisch | Kalt | Kühl-gemäßigt | Warm-Gemäßigt | Warm |
| Behaglichkeit **$U_W$** [W/(m²K)] | Aluminium | 1,03 | | | | | ✓ |
| | Edelstahl | 0,97 | | | | ✓ | ✓ |
| | Swisspacer Ultimate | 0,92 | | | | ✓ | ✓ |
| Hygiene **$f_{Rsi=0,25\ m^2K/W}$** [-] | Aluminium | 0,56 | | | | | ✓ |
| | Edelstahl | 0,64 | | | | | ✓ |
| | Swisspacer Ultimate | 0,70 | | | | ✓ | ✓ |

## 2.3 Aluplast Energeto 8000: Insulated Passivhaus plastic window frame with triple thermal insulation glazing

The Energeto 8000 is the premium product from the house of Aluplast. In the variant investigated with frame insulation, the Energeto 8000 | Passiv, it achieves contemporary standards of thermal insulation and is certified as a window system for the cool-temperate climate by the Passivhaus Institut. The special feature of this window: It is strengthened not with steel but with fibre-reinforced plastic bars. In combination with the insulation, frame -U-values of 0.83 W/(m²K) are achieved.

Figure 1 5: Aluplast Energeto 8000 | Passive. © Aluplast

The window was considered here with triple glazing, $U_g$ = 0.50 W/(m²K). Both gaps between the panes are 18 mm thick, filled with argon, and represent the optimum in thermal protection currently attainable with triple glazing.

The glass edge Ψ-values are 0.096 W/(mK) with the aluminium spacer bar, 0.052 W/(mK) with the stainless steel spacer bar and 0.026 W/(mK) with the Swisspacer Ultimate. The reduction in thermal bridge losses due to the better spacer bar is clear.

The temperature factors and window U-values can be found in the following table.

This table also clearly shows: The window with U-values of between 0.67 and 0.84 W/(m²K) fulfils the comfort criteria of the warm-temperate climate with all spacer bars and those of the cool-temperate climate with the stainless steel spacer bar and with the Swisspacer Ultimate. The hygiene criterion for the warm-temperate and cool-temperate climates is achieved with the stainless steel spacer bar and with the Swisspacer Ultimate.

Summary: With the selected glass-frame combination, the window is suitable for the warm climate with all spacer bars, and with the stainless steel spacer bar and with the Swisspacer Ultimate for the warm-temperate climate. Suitability for the cool-temperate climate is given with the stainless steel spacer bar and with the Swisspacer Ultimate.

Whether the heat insulated – and thus more expensive – window frame is also economically meaningful in a warm climate must be clarified on a case-by-case basis.

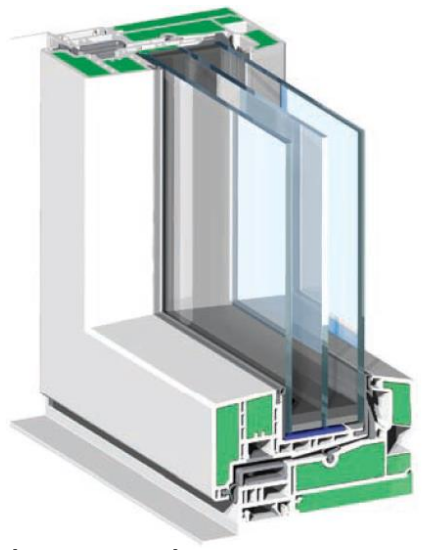
Table 4: Characteristic values of the Aluplast Energeto 8000 | Passiv with different spacer bars and suitability for the different climates.

| | **Abstand-halter** | **Alupl. Energeto 8000 \| P.** | **Klima** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Arktisch | Kalt | Kühl-gemäßigt | Warm-Gemäßigt | Warm |
| Behaglichkeit $U_W$ [W/(m²K)] | Aluminium | 0,84 | | | | ✓ | ✓ |
| | Edelstahl | 0,73 | | | ✓ | ✓ | ✓ |
| | Swisspacer Ultimate | 0,67 | | | ✓ | ✓ | ✓ |
| Hygiene $f_{Rsi=0,25\ m^2K/W}$ [-] | Aluminium | 0,58 | | | | | ✓ |
| | Edelstahl | 0,70 | | | ✓ | ✓ | ✓ |
| | Swisspacer Ultimate | 0,74 | | | ✓ | ✓ | ✓ |

## 2.1 Hilzinger VADB 550+: Insulated plastic window frame with triple thermal insulation glazing

The Hilzinger VADB 550+ is a development from the house of Over. In thermal terms, it is the best plastic window to have ever been honoured as a Certified Passivhaus component. Unfortunately, production ceased a number of years ago.

With its deep, insulated frame with a $U_f$-value of only 0.62 W/(m²K) and the deep glazing inset, the window achieves outstanding thermal protection. The visible frame width of 100 mm or 75 mm is also very low. This enables a higher proportion of glass. This is useful, as the glass has lower U-values than the frame and also enables solar gain. Here, too, the glass described above with a $U_g$-value of 0.50 W/(m²K) is used.



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Aluplast

The glass edge Ψ-values are 0.063 W/(mK) with the aluminium spacer bar, 0.038 W/(mK) with the stainless steel spacer bar and 0.022 W/(mK) with the Swisspacer Ultimate. These low values can be traced to the deep glass inset. The reduction in thermal bridge losses due to the better spacer bar is particularly clear here.

The temperature factors and window U-values can be found in the following table.

This table also clearly shows: The window with U-values of between 0.58 and 0.69 W/(m²K) fulfils the comfort criteria down to the cool-temperate climate with all spacer bars and additionally those of the cold climate with the Swisspacer Ultimate. The hygiene criterion for the warm-temperate and cool-temperate climates is not achieved with the aluminium spacer bar. With the Swisspacer Ultimate, there is no mould in a cold climate either.

Summary: With the selected glass-frame combination, the window is suitable for the warm climate with all spacer bars, and with the stainless steel spacer bar and with the Swisspacer Ultimate for the warm-temperate and the cool-temperate climates. Suitability for the cold climate is given solely with the Swisspacer Ultimate.

Whether the heat insulated – and thus more expensive – window frame is also economically meaningful in a warm climate must be clarified on a case-by-case basis.

Table 5: Characteristic values of the VADB 550+ with different spacer bars and suitability for the different climates.

| | **Abstand-halter** | **Hilzinger VADB 550+** | **Klima** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Arktisch | Kalt | Kühl-gemäßigt | Warm-Gemäßigt | Warm |
| Behaglichkeit $U_W$ [W/(m²K)] | Aluminium | 0,69 | | | ✓ | ✓ | ✓ |
| | Edelstahl | 0,62 | | | ✓ | ✓ | ✓ |
| | Swisspacer Ultimate | 0,58 | | ✓ | ✓ | ✓ | ✓ |
| Hygiene $f_{Rsi=0,25\ m^2K/W}$ [-] | Aluminium | 0,64 | | | | | ✓ |
| | Edelstahl | 0,72 | | | ✓ | ✓ | ✓ |
| | Swisspacer Ultimate | 0,77 | | ✓ | ✓ | ✓ | ✓ |

## 2.2 VADB 550pro: Insulated plastic window frame with quadruple thermal insulation glazing

The VADB 550pro, which is considered here as a kind of thermal best practice solution, is a modification of the Hilzinger 550+ calculated for this study. Unlike the original, the frame profile has a visible width of just 75 mm at the bottom. This further increases the proportion of glass. The frame insulation consists of Resol foam with a thermal conductivity of 0.22 W/(mK). This reduces the frame U-value to 0.57 W/(m²K).

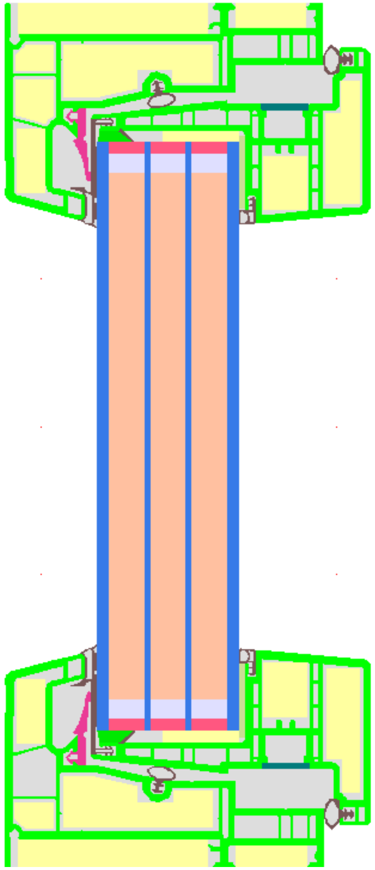

Figure 1 7: VADB 550pro
© Passivhaus Institut

Krypton-filled, quadruple glazing with a 12 mm gap between the panes is used. The $U_g$-value is 0.30 W/(m²K) and thus corresponds to the thermal optimum possible today.

Unlike in the previously discussed windows, a secondary seal made from a special silicone of the company Dow was used around the edge of the glass. This has a thermal conductivity of 0.19 W/(mK) instead of the previously used polysulphide with 0.40 W/(mK). Particularly in the case of the Swisspacer Ultimate, this measure has a positive impact on the temperatures at the glass edge and the glass edge Ψ-values. These are 0.063 W/(mK) with the aluminium spacer bar, 0.037 W/(mK) with the stainless steel spacer bar and 0.018 W/(mK) with the Swisspacer Ultimate. The reduction in thermal bridge losses due to the better spacer bar is even more significant here than before.

The temperature factors and window U-values can be found in the following table.

This table also clearly shows: The window with U-values of between 0.40 and 0.52 W/(m²K) fulfils the comfort criteria down to the cold climate with all spacer bars and additionally that of the Arctic climate with the Swisspacer Ultimate. The hygiene criterion for the cool-temperate and cold climates is not achieved with the aluminium spacer bar. With the Swisspacer Ultimate, there is no mould in an Arctic climate either.

Summary: With the selected glass-frame combination, the window is suitable for the warm and warm-temperate climates with all spacer bars, and with the stainless steel spacer bar and with the Swisspacer Ultimate for the cool-temperate and cold climates as well. Suitability for the Arctic climate is given solely with the Swisspacer Ultimate.

Whether the heat insulated – and thus more expensive – window frame is also economically meaningful in a warm climate and warm-temperate climate must be clarified on a case-by-case basis.

Table 6: Characteristic values of the VADB 550pro with different spacer bars and suitability for the different climates.

| | **Abstand-halter** | **Hilzinger VADB 550pro** | **Klima** | | | | |
|---|---|---|---|---|---|---|---|
| | | | Arktisch | Kalt | Kühl-gemäßigt | Warm-Gemäßigt | Warm |
| Behaglichkeit **$U_W$** [W/(m²K)] | Aluminium | 0,52 | | ✓ | ✓ | ✓ | ✓ |
| | Edelstahl | 0,45 | | ✓ | ✓ | ✓ | ✓ |
| | Swisspacer Ultimate | 0,40 | ✓ | ✓ | ✓ | ✓ | ✓ |
| Hygiene $f_{Rsi=0,25\ m^2K/W}$ [-] | Aluminium | 0,66 | | | | ✓ | ✓ |
| | Edelstahl | 0,75 | | ✓ | ✓ | ✓ | ✓ |
| | Swisspacer Ultimate | 0,82 | ✓ | ✓ | ✓ | ✓ | ✓ |

# 3 Summary

Table 7: Presentation of the suitability of all investigated window spacer bar variants for the discussed general conditions regarding comfort and hygiene.

| **Fenster** | **Aluplast Ideal 4000** | | | **Aluplast Ideal 8000** | | | **Alupl. Energeto 8000 \| P.** | | | **Hilzinger VADB 550+** | | | **Hilzinger VADB 550pro** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spacer | Alumi-nium | Edel-stahl | Swsp. Ultimate | Alumi-nium | Edel-stahl | Swsp. Ultimate | Alumi-nium | Edel-stahl | Swsp. Ultimate | Alumi-nium | Edel-stahl | Swsp. Ultimate | Alumi-nium | Edel-stahl | Swsp. Ultimate |
| Warm | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Warm-Gemäßigt | | | | | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| Kühl-gemäßigt | | | | | | | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ |
| Kalt | | | | | | | | | | | | ✓ | | ✓ | ✓ |
| Arktisch | | | | | | | | | | | | | | | ✓ |

Table 7 summarises the results of the study. The first noticeable result: No single variant of the investigated double glazed Aluplast Ideal 4000 is suitable for one of the climates investigated here with regard to the combined hygiene-comfort requirement. This result is not synonymous with an in principle exclusion of double glazing for warm climates. A deeper glass inset, the use of other secondary seals or other measures can deliver the decisive improvement for meeting the requirement. Naturally, the range of warm-temperate regions also has climates in which the presented combinations are non-critical.

However, triple glazing should be used as a rule in the warm-temperate climate and colder. Here, the requirements, can already be met with the uninsulated window frame Ideal 8000. However, the prerequisite for this is the use of a highly energy-efficient plastic spacer bar such as the Swisspacer Ultimate.

If the thermally insulated frame Energeto 8000 | Passiv is used, the comfort and hygiene criteria can be achieved both for the warm-temperate and for the cool-temperate climate with the stainless steel spacer bar and the Swisspacer Ultimate.

The same is true of the VAB 550+, where the Swisspacer Ultimate enables suitability for the cold climate.

The requirements of the Arctic climate can also be met with only this spacer bar in the best practice solution investigated for this study, the improved VADB 550+.

Summary: The choice of spacer bar has a decisive impact on the thermal quality of the window and thus on comfort and hygiene. Moreover, highly energy-efficient spacer bars made from plastic make it possible to meet the requirement with tried and tested means and low cost for the window maker.

In this way, everyone wins. The occupier of the building, who profits from greater comfort and mould-free glass edges, the window maker, who can simply improve his products and thus also increase the satisfaction of his customers. And the climate, which is relieved by the high levels of energy saved thanks to lower $CO_2$ emissions.