COMPONENT AWARD 2014

Full Documentation

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1 Motivation

Passive Houses are comfortable and highly energy-efficient; they can be supplied with energy affordably in a sustainable way, and if the investment costs and energy costs over the life-cycle are taken into consideration, they are within the economic optimum[1]. Thus Passive Houses have already been proven to be a functioning option for solving the energy-related problems in the building sector. In this regard, they anticipate the energy revolution, as well as the EU Buildings Directive, which will come into effect from 2019/2020[2].

Even so, the economic efficiency of Passive Houses is often called into question. It is a fact that the economic efficiency of these buildings depends crucially on the availability of components which are necessary in Passive Houses[3] - in addition to the competence of the planning team and the provision of energy in an unsubsidised market.

For this reason, the Passive House Institute announced the COMPONENT AWARD for the first time at the 18th International Passive House Conference.

With reference to costs and thermal quality, a lot of progress has been achieved in recent years in the case of windows in particular[4]. In addition, a large selection of these components are available on the European market, particularly in German-speaking countries. That is why the COMPONENT AWARD 2014 was devoted to Passive House window components. Other components will follow in the coming years.

2 Methods

Based on the retail price, an economic assessment of certified Passive House windows was carried out taking into account the investment and energy costs throughout the life-cycle compared with a “standard” window corresponding with the specifications for reference buildings in the (German) energy saving regulations for 2014.

For this purpose, all Passive House Institute certificate holders of window frames or window connection details were invited to offer their certified products for an example building at retail prices, with installation inclusive. A fictional distance of 50 km was given as the distance from the delivery works to the construction site. Costs and thermal characteristic values were to be entered by the manufacturer (or by the PHI if required) into a Passive House Planning Package calculation (based on the PHPP 8.4) prepared specially for this purpose. The savings compared with the standard windows were calculated by the PHPP. The costs for the standard window were based on the price standard in Germany. The quotations were calibrated to the standard for Germany using the Consumer-Price-Index[5]. The offer with the highest savings won in each category. While frames and spacers had to comply with the information stated in

[1] See: Feist, Wolfgang (publisher.): Research Group for Cost-effective Passive Houses Protocol Volume No. 42 – Economic evaluation of energy efficiency measures, Passive House Institute Darmstadt, 2013

[2] See Krick, Benjamin: Nearly Zero Energy Building? The Passive House provides an answer. In: Conference Proceedings of the 17th International Passive House Conference 2013 in Frankfurt/Main. Passive House Institute, Darmstadt 2014

[3] See Feist, Wolfgang: The Passive House is more In: Conference Proceedings of the 18th Intl. Passive House Conference 2014 in Aachen, Passive House Institute, Darmstadt 2014

[4] See Krick, Benjamin: PHI Window certification: Previous success and venturing into new climate zones. In: Conference Proceedings of the 18th Intl. Passive House Conference 2014 in Aachen. PHI, Darmstadt 2014

[5] Source http://epp.eurostat.ec.europa.eu

the certification, participants were free to choose the type of glazing. The values for installation in a wall with a compound insulation system were consistently used as the installation thermal bridge loss coefficients. Evaluation took place in the categories Timber, Timber- Aluminium, Aluminium and PVC.

3 Reference *building*

The reference building was an actual single-family house belonging to the architects' firm passivhaus-eco, with a living area of 155 m². The building can be found in the Passive House Database (www.passvihausprojekte.de) under the ID number 1200. The building successfully took part in the Passive House Award competition in 2010[6]. In an internal selection procedure, it was chosen by a jury consisting of Professor Feist (University of Innsbruck), DI architect Harald Konrad Malzer (PHI Innsbruck), Professor Helmut Krappmeier (Energy Institute of Vorarlberg) and Dr. Ing. Benjamin Krick (PHI Darmstadt), see Figure 1.
The building has a window area of 42.8 m², of which 1.9 m² face north, 9.1 m² face east, 22 m² face south and 9.9 m² face west, see Figure 2 and Table 1.

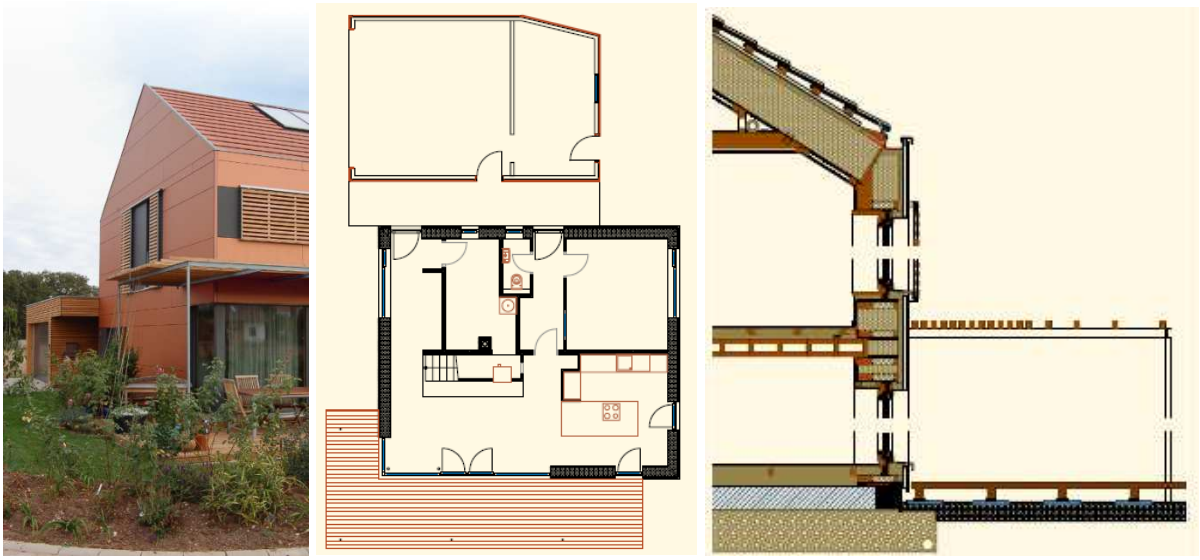


Figure 1: Example building: Elevation, floor plan of ground floor, cross section

[6] See documentation of the Passive House Architecture Award, which can be obtained from the Passive House Institute (www.passiv.de) for an overall postage fee: 1st Passive House Architecture Award – The Finalists, Passive House Institute, Darmstadt, 2010

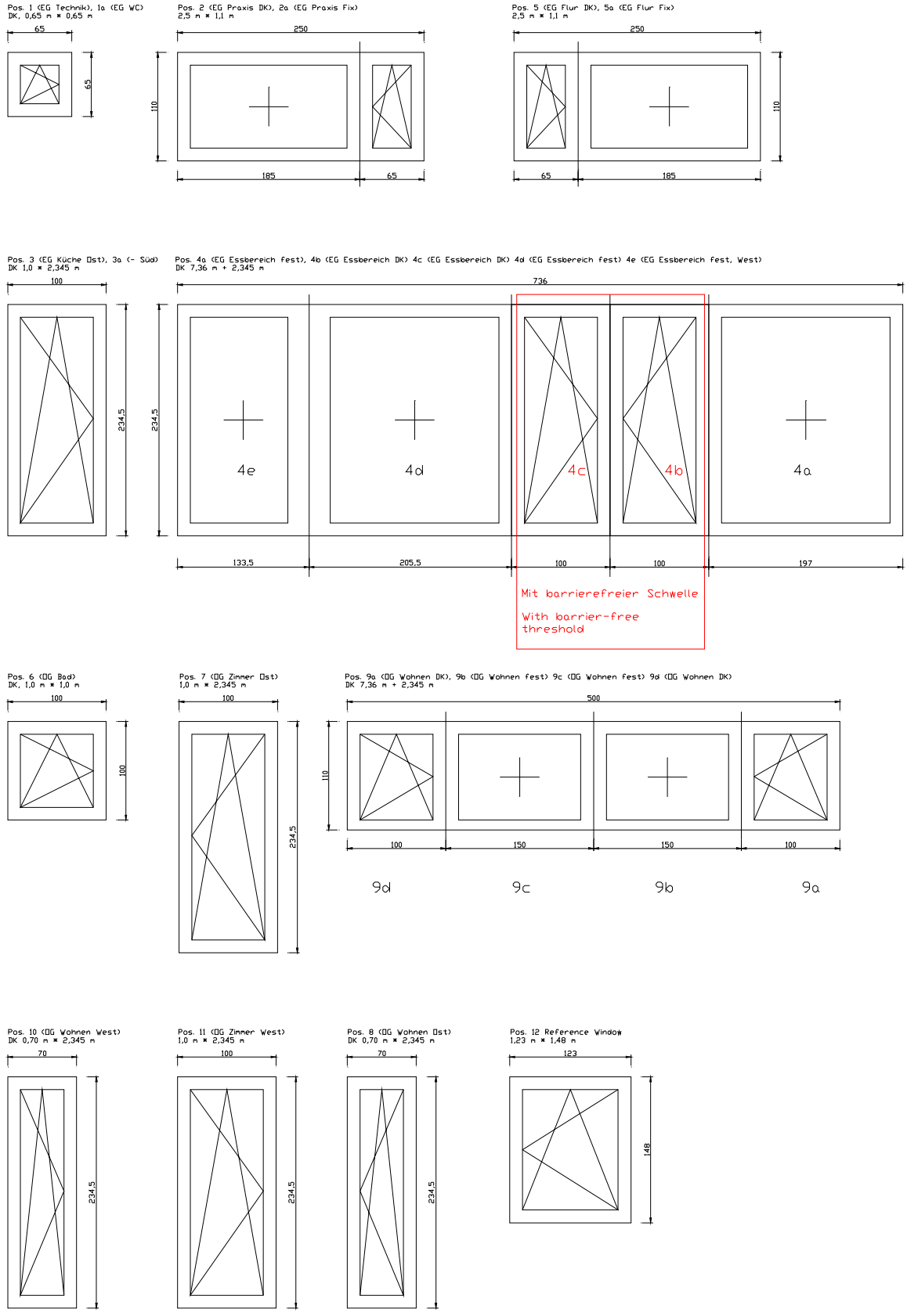


Figure 2: Windows of the reference building

Table 1: Description, orientation and size of the windows offered in the COMPONENT AWARD 2014

Quantity/ Anzahl	Description / Bezeichnung	Deviation from north / Abweichung zur Nordrichtung	Angle of inclination from the horizontal / Neigung gegen die Horizontale	Orientation/ Orientierung	Width / Breite	Hight / Höhe
		Grad	Grad		m	m
2	1, 1a EG-WC,HA	0	90	Nord	0,650	0,650
1	6 OG-Bad	0	90	Nord	1,000	1,000
1	2 EG-P	90	90	Ost	0,650	1,100
1	2a EG-P,fix	90	90	Ost	1,850	1,100
1	3 EG-Kü	90	90	Ost	1,000	2,345
1	7 OG-Sch	90	90	Ost	1,000	2,345
1	8 OG-Wo	90	90	Ost	0,700	2,345
1	3a EG-Kü	180	90	Süd	1,000	2,345
1	4a EG-Ess,fix	180	90	Süd	1,970	2,345
1	4b EG-Ess	180	90	Süd	1,000	2,345
1	4c EG-Ess	180	90	Süd	1,000	2,345
1	4d EG-Ess,fix	180	90	Süd	2,055	2,345
1	9a OG-Wo	180	90	Süd	1,000	1,100
1	9b OG-Wo,fix	180	90	Süd	1,500	1,100
1	9c OG-Wo,fix	180	90	Süd	1,500	1,100
1	9d OG-Wo	180	90	Süd	1,000	1,100
1	4e EG-Ess,fix	270	90	West	1,335	2,345
1	5 EG-Flur,fix	270	90	West	1,850	1,100
1	5a EG-Flur	270	90	West	0,650	1,100
1	10 OG-Wo	270	90	West	0,700	2,345
1	11 OG-Zi	270	90	West	1,000	2,345
0	12 reference window	270	90	West	1,230	1,480

1.1 Reference windows

2.2.1 Thermal and geometric characteristic values

The reference windows in the categories Timber, Timber- Aluminium, Aluminium and PVC correspond with those for the reference building in the (German) energy saving regulations (EnEV) of 2014, Appendix 1, Table 1. This stipulates a window U-value (not installed) of 1.3 W/(m²K) based on the reference window size of 1.23 m * 1.48 m. A g-value of 60 % is defined in the table, which was assumed for the glazing used here. A glazing U-value of 1.2 W/(m²K) was adopted uniformly for all categories. The heat transfer coefficient and facing widths of the frames, as well as the thermal bridge loss coefficients of the glass edge vary according to the category and profile, see Table 2 toTable 5. The U-values for the installed and uninstalled windows can be taken from Table 6.

The installation thermal bridge loss coefficient conforms with installation in the masonry level of a wall with a compound insulation system.

Table 2: Thermal and geometric characteristic values for a reference window in the category Timber. The descriptions correspond with those in Figure 2

Section/ Schnitt	**U_f** [W/(m²K)]	**b_f** [mm]	**Ψ_g** [W/(mK)]	**$\Psi_{install}$** [W/(mK)]
Bottom/ Unten	**1.30**	**0.13**	**0.035**	**0.060**
Side, top/ Seitlich, oben	**1.20**	**0.10**	**0.035**	**0.060**
Bottom, terrace door/ Unten, Terrassentür	**1.50**	**0.15**	**0.045**	**0.070**
Side, top/ Seitlich, oben	**1.30**	**0.13**	**0.035**	**0.040**
Side, top/ Seitlich, oben	**1.20**	**0.10**	**0.045**	**0.040**
Section/ Schnitt **2-2a**	**1.30**	**0.15**	**0.035**	
Section/ Schnitt **4a-4b**	**1.30**	**0.23**	**0.045**	
Section/ Schnitt **4b-4c**	**1.30**	**0.18**	**0.035**	
Section/ Schnitt **4c-4d**	**1.30**	**0.23**	**0.045**	
Section/ Schnitt **4d-4e**	**1.00**	**0.35**	**0.035**	
Section/ Schnitt **5-5a**	**1.30**	**0.15**	**0.035**	
Section/ Schnitt **4a-4b**	**1.30**	**0.15**	**0.035**	
Section/ Schnitt **4b-4c**	**1.30**	**0.20**	**0.035**	
Section/ Schnitt **4c-4d**	**1.30**	**0.15**	**0.035**	

Table 3: Thermal and geometric characteristic values for a reference window in the category Timber/Aluminium. The descriptions correspond with those in Figure 2

Section/ Schnitt	**U_f** [W/(m²K)]	**b_f** [m]	**Ψ_g** [W/(mK)]	**$\Psi_{install}$** [W/(mK)]
Bottom/ Unten	**1.30**	**0.130**	**0.040**	**0.080**
Side, top/ Seitlich, oben	**1.20**	**0.100**	**0.040**	**0.080**
Bottom, terrace door/ Unten, Terrassentür	**1.50**	**0.150**	**0.050**	**0.090**
Side, top/ Seitlich, oben	**1.30**	**0.130**	**0.040**	**0.050**
Side, top/ Seitlich, oben	**1.20**	**0.100**	**0.050**	**0.050**
Section/ Schnitt**2-2a**	**1.30**	**0.150**	**0.040**	
Section/ Schnitt**4a-4b**	**1.30**	**0.230**	**0.050**	
Section/ Schnitt**4b-4c**	**1.30**	**0.180**	**0.040**	
Section/ Schnitt**4c-4d**	**1.30**	**0.230**	**0.050**	
Section/ Schnitt**4d-4e**	**1.00**	**0.350**	**0.040**	
Section/ Schnitt**5-5a**	1.30	0.150	0.040	
Section/ Schnitt**4a-4b**	**1.30**	**0.150**	**0.040**	
Section/ Schnitt**4b-4c**	**1.30**	**0.200**	**0.040**	
Section/ Schnitt**4c-4d**	**1.30**	**0.150**	**0.040**	

Table 4: Thermal and geometric characteristic values for a reference window in the category PVC. The descriptions correspond with those in Figure 2

Section/ Schnitt	**U_f** [W/(m²K)]	**b_f** [m]	**Ψ_g** [W/(mK)]	**$\Psi_{install}$** [W/(mK)]
Bottom/ Unten	**1.30**	**0.140**	**0.035**	**0.060**
Side, top/ Seitlich, oben	**1.20**	**0.100**	**0.035**	**0.060**
Bottom, terrace door/ Unten, Terrassentür	**1.50**	**0.160**	**0.040**	**0.070**
Side, top/ Seitlich, oben	**1.30**	**0.140**	**0.035**	**0.040**
Side, top/ Seitlich, oben	**1.20**	**0.110**	**0.040**	**0.040**
Section/ Schnitt **2-2a**	**1.30**	**0.170**	**0.035**	
Section/ Schnitt **4a-4b**	**1.30**	**0.250**	**0.040**	
Section/ Schnitt **4b-4c**	**1.30**	**0.200**	**0.035**	
Section/ Schnitt **4c-4d**	**1.30**	**0.270**	**0.040**	
Section/ Schnitt **4d-4e**	**1.00**	**0.370**	**0.035**	
Section/ Schnitt **5-5a**	1.30	0.170	0.035	
Section/ Schnitt **4a-4b**	**1.30**	**0.170**	**0.035**	
Section/ Schnitt **4b-4c**	**1.30**	**0.220**	**0.035**	
Section/ Schnitt **4c-4d**	**1.30**	**0.170**	**0.035**	

Table 5: Thermal and geometric characteristic values for a reference window in the category Aluminium. The descriptions correspond with those in Figure 2

Section/ Schnitt	**U_f** [W/(m²K)]	**b_f** [m]	**Ψ_g** [W/(mK)]	**$\Psi_{install}$** [W/(mK)]
Bottom/ Unten	**1.30**	**0.140**	**0.045**	**0.090**
Side, top/ Seitlich, oben	**1.20**	**0.100**	**0.045**	**0.090**
Bottom, terrace door/ Unten, Terrassentür	**1.50**	**0.160**	**0.055**	**0.100**
Side, top/ Seitlich, oben	**1.30**	**0.140**	**0.045**	**0.060**
Side, top/ Seitlich, oben	**1.20**	**0.110**	**0.055**	**0.060**
Section/ Schnitt **2-2a**	**1.30**	**0.170**	**0.045**	
Section/ Schnitt **4a-4b**	**1.30**	**0.250**	**0.055**	
Section/ Schnitt **4b-4c**	**1.30**	**0.200**	**0.045**	
Section/ Schnitt **4c-4d**	**1.30**	**0.270**	**0.055**	
Section/ Schnitt **4d-4e**	**1.00**	**0.370**	**0.045**	
Section/ Schnitt **5-5a**	1.30	0.170	0.045	
Section/ Schnitt **4a-4b**	**1.30**	**0.170**	**0.045**	
Section/ Schnitt **4b-4c**	**1.30**	**0.220**	**0.045**	
Section/ Schnitt **4c-4d**	**1.30**	**0.170**	**0.045**	

2.2.2 Costs for the reference window

First of all, an effort was made to determine the prices for the reference window based on the construction costs index which states the price per square metre for an installed window. Prices were researched for the category “single family house without basement” in the construction costs index of 2006 to 2013 for the Simple, Average and High standards (data is available from 2008 onwards for the High standard). Analysis of the data showed a significant increase in the price between 2006 and 2013 in all categories, therefore prices were interpolated to the year 2014 by forward projection of the price increases. The category PVC was allocated to the “Simple” standard, the category Timber was allocated to the “Average” standard and the categories for Timber/Aluminium and Aluminium were allocated to the “High” standard. The following costs resulted from this: Timber: € 505/m², Timber/Aluminium and Aluminium: € 532/m², PVC: € 403/m². All previously mentioned costs and those mentioned further on are retail prices including VAT.

In the course of the Award, it became clear that thus the ascertained prices were significantly high, therefore the costs for the reference windows were determined again through research on the Internet. fensterversand.de was selected from several online shops that supplied windows, because this offered particularly low prices as well as the possibility of online offers and supplied timber, timber/aluminium and PVC windows. The prices of timber/aluminium windows were assumed for aluminium windows. Calculation of the costs took place on 23.03.2014. The shop states prices for an uninstalled window. The average installation costs of Award participants plus standard deviation were used as installation costs. This is justified since liability of the window manufacturer is extended considerably by the installation. A detailed list of the costs for the reference window is given in Table 6.

2.3 Calibration of quotations to the German standard

The price level of windows varies regionally as well as nationally. In order to allow comparison of quotations from different countries, all quotations were calibrated to the German standard. An index of 100 corresponds with the average price in Europe; a higher index means above-average costs, while a lower index indicates below-average costs. The indices of the relevant countries are as follows: Germany: 103, Austria: 107, Slovenia: 84, Italy: 103, France: 111, United Kingdom: 102, Poland: 60, Russia: 71. It must be noted that this approach with calibration using the general price index may lead to errors; however, there is no other approach available. In particular, simple conversion of monetary parities would not be appropriate.

Table 6: Characteristic values of the reference windows. The descriptions correspond with those in Figure 2.

	Ref. Timber / Holz			Ref. Timber-Alu / Holz-Alu			Ref. PVC			Ref. Aluminium		
Pos.	$U_{W,\ installed}$	Price window/ Preis Fenster		$U_{W,\ installed}$	Price window/ Preis Fenster		$U_{W,\ installed}$	Price window/ Preis Fenster		$U_{W,\ installed}$	Price window/ Preis Fenster	
		uninstalled/ nicht installiert	installed/ installiert		un-installed/ nicht installiert	installed/ installiert		un-installed/ nicht installiert	installed/ installiert		un-installed/ nicht installiert	installed/ installiert
	[W/(m²K)]	[€]	[€]	[W/(m²K)]	[€]	[€]	[W/(m²K)]	[€]	[€]	[W/(m²K)]	[€]	[€]
1	**1,67**	**253**		1,77	**323**		1,67	**143**		1,84	**323**	
1a	**1,67**	**253**		1,77	**323**		1,67	**143**		1,84	**323**	
2	**1,53**			1,60			1,53			1,65		
2a	**1,42**			1,46			1,41			1,50		
2 total		**558**			**711**			**308**			**711**	
3	**1,45**	**589**		1,49	**755**		1,45	**497**		1,54	**755**	
3a	**1,45**	**589**		1,49	**755**		1,45	**497**		1,54	**755**	
4a	**1,34**			1,37			1,33			1,39		
4b	**1,39**			1,41			1,38			1,43		
4c	**1,39**			1,41			1,38			1,43		
4d	**1,30**			1,32			1,29			1,33		
4e	**1,33**			1,36			1,32			1,39		
4 total		**3380**			**4251**			**1780**			**4251**	
5	**1,43**			1,48			1,43			1,52		
5a	**1,51**			1,57			1,50			1,62		
5 total		**558**			**711**			**308**			**711**	
6	**1,53**	**310**		1,59	**396**		1,53	**173**		1,65	**396**	
7	**1,45**	**589**		1,49	**755**		1,45	**497**		1,54	**755**	
8	**1,52**	**544**		1,58	**696**		1,52	**311**		1,63	**696**	
9a	**1,47**			1,53			1,47			1,57		
9b	**1,40**			1,44			1,40			1,47		
9c	**1,40**			1,44			1,40			1,47		
9d	**1,43**			1,48			1,43			1,51		
9 total		**1116**			**1392**			**616**			**1392**	
10	**1,52**	**544**		1,58	**696**		1,52	**311**		1,63	**696**	
11	**1,45**	**589**		1,49	**755**		1,45	**497**		1,54	**755**	
12	**1,32**	**392**		1,33	**501**		1,32	**220**		1,34	**501**	
Total investment		9873	**16544**		12519	**19190**		6079	**12751**		12519	**19190**
	UW,i,av	**€/m²**	**€/m²**	UW,i,av	**€/m²**	**€/m²**	UW,i,av	**€/m²**	**€/m²**	UW,i,av	**€/m²**	**€/m²**
	1,41	231	**387**	1,45	293	**449**	1,41	142	**298**	1,49	293	**449**

2.4 Determination of life cycle costs and present value savings

The life-cycle costs consist of the invested costs for insulation (roof, walls, floor), windows, possibly a heat distribution system, and the energy costs for the building over the observation period (50 years). The life duration of the insulation (cellulose in lightweight timber walls) and the heat distribution system is the same as the observation period (50 years). The service life of windows is 40 years. The investment costs for windows are therefore usually multiplied by an investment factor in order to adjust the life duration to the observation period.

Since the reference building is designed as a Passive House, a ventilation system is a must. Heat distribution takes place via this ventilation system as long as the heating load does not exceed 10 W/m². If it exceeds 10 W/m², heat can no longer be transported via the supply air; an additional heat distribution system will then be necessary. The costs for this are included in the investment costs, so this will result in a cost minus for the heat distribution system.

First, the energy demand and the present value of the described components of the reference building with the chosen windows are determined. The insulation thickness of the walls is 284 mm, that of the roof is 286 mm and for the floor it is 180 mm. As the next step, the insulation thicknesses are varied millimetre by millimetre. The minimal life-cycle costs are thus determined for the given windows and investment costs, taking into account the cost minus for the additional heat distribution system. Thus a change in the thermal characteristic values or the costs for the window will require a different ratio of investment and energy costs. The building characteristics in the economic optimum will therefore change, resulting in a change in the insulation thicknesses and possibly the heating system. Table 7 shows the relevant input parameters for optimisation. The results for the reference windows are listed in Table 8.

Table 7: Relevant parameters for calculating the present value

Observation period	50 years		Energy price	0,092 €/kWh
Service life	40 years		Price insulation roof, wall	60 €/m³
Real interest	2 %		Price insulation floor	50 €/m³

Table 8: Results of optimisation for the reference building with reference windows

Reference	Anual heating demand/ Jahresheiz-wärme-bedarf [kWh/(m²a)]	Trans-mission losses/ Trans-missions-verluste [kWh/a]	Solar gains/ Solare Gewinne [kWh/a]	Calibrated investment total [€]	Present value/ Barwert [€]
Timber/ Holz	28,2	4757	2918	16544	42638
Timber-Aluminium/ Holz-Aluminium	29,0	4894	2918	19190	46147
PVC	28.6	4747	2824	15952	39360
Aluminum/ Aluminium	30.1	5007	2824	21683	45857

4 Results

3.1 Overview

Altogether, 42 of the submitted components met the participation requirements. These included a box window and a coupled window which were not comparable with the reference window in terms of price. One participant had to be disqualified later because of untenable information regarding prices. Six of the windows were quadruple glazing variants. Figure 3 shows the savings based on the life-cycle costs for all components without the quadruple-glazing variants, the box-style window and the double window. It is apparent that considerable cost savings are achievable with most of these components. On average, over the usage period these savings are 12 % or approximately € 5400. This proves that despite the higher initial investment, Passive House windows are generally profitable for building owners. Nevertheless, there are considerable differences in performance and prices even with Passive House windows. These differences can be ascertained easily using the new variants function of the PHPP Version 9 or higher[7]. The average investment costs of all submitted components installed (windows) were around € 511 per m².

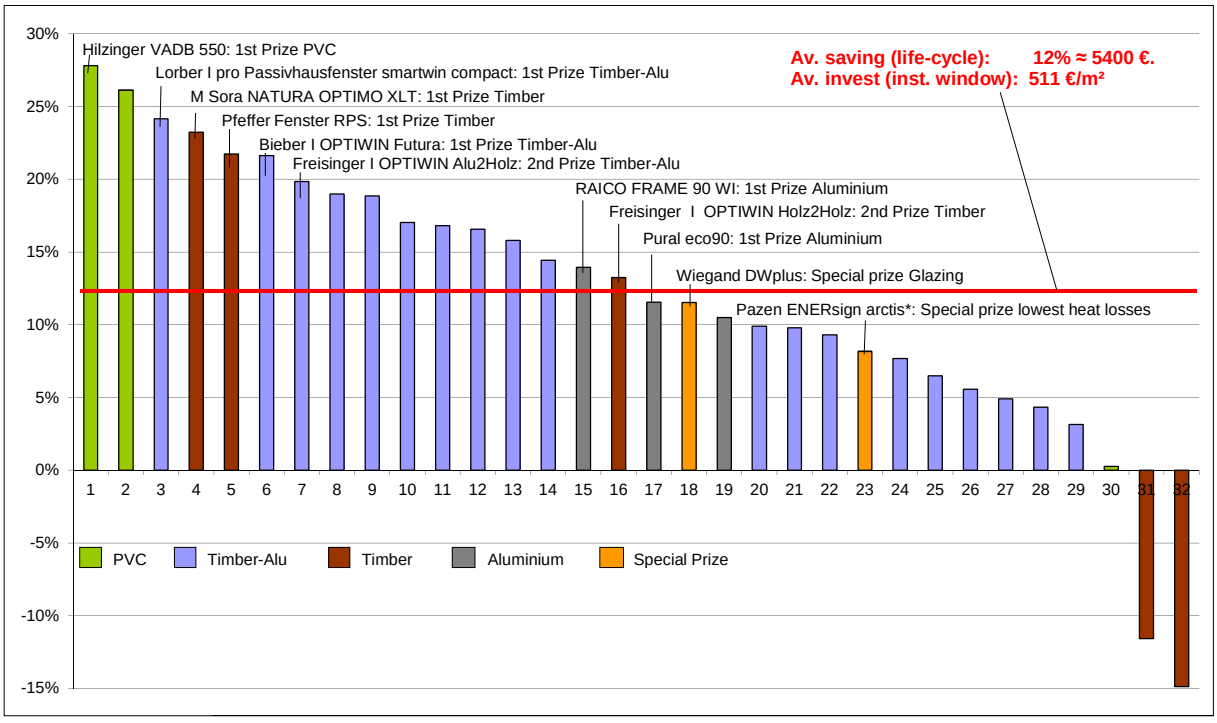
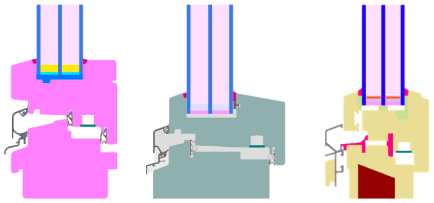


Figure 3: Savings (life-cycle costs) achieved with the submitted components, without the quadruple-glazing variant, the box-style window and the double window.

[7] See Passive House Institute (publisher): Usual Handbook for the PHPP 9 (2014), Passive House Institute, Darmstadt 2014.

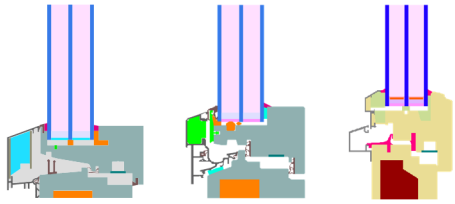
3.2 Categories

5 participants were evaluated in the category **Timber**. The windows Natura Optimo XLT by M Sora and RPS by Pfeffer Fenster won the first position, while the Holz2Holz by Freisinger of the OPTIWIN Group came second, see Figure 4. The average investment costs for this category are € 525/m², and average savings over the life-cycle are 6%.



1 M SORA	1 Pfeffer Fenster	2 Freisinger I OPTIWIN	Price, Company
NATURA OPTIMO XLT	RPS	Holz2Holz	Product name
384	396	452	Price [€/m²inst.w]
23%	22%	13%	LCC savings [%]
228	222	201	Oil savings [l/m²]

Figure 4: Winner in the category Timber

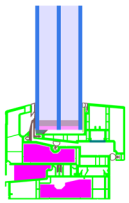


1 Lorber I pro PHf.	1 Bieber I OPTIWIN	2 Freisinger I OPTIWIN	Price, Company
smartwin compact	FUTURA	Alu2Holz	Product name
451	450	452	Price [€/m²inst.w]
24%	22%	20%	LCC savings [%]
288	246	214	Oil savings [l/m²]

Figure 5: Winner in the category Timber/Aluminium

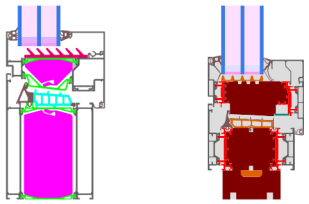
The largest number of components were submitted in the category **Timber/Aluminium**, with a total of 18. The first prize was jointly awarded to two windows: the smartwin compact by the Lorber proPassivhausfenster cooperative and the Futura by the OPTIWIN partner Bieber. The second position was achieved by the window Alu2Holz by the OPTIWIN partner Freisinger. The average investment costs in this category are € 528/m², and the average savings over the life-cycle are 13%.

There were only 3 components submitted in the category for **PVC** windows. The first position was achieved by the window VADB plus 550 by Hilzinger. No other prize was awarded in this category. The second position was achieved by the window VADB plus 550+ by Hilzinger, which is more expensive, although it has better thermal characteristics. In this case the higher investment costs could not be compensated by the lower energy demand. The average investment costs in this category are € 356/m², with average savings of 19% over the life-cycle.



1 Hilzinger	Price, Company
VADB 550	Product name
296	Price [€/m²inst.w]
28%	LCC savings [%]
257	Oil savings [l/m²]

Figure 6: Winner in the category PVC



1 RAICO	1 PURAL	Price, Company
FRAME 90 WI	eco90	Product name
492	540	Price [€/m²inst.w]
14%	12%	LCC savings [%]
185	230	Oil savings [l/m²]

Figure 7: Winner in the category Aluminium

Three aluminium windows were submitted. The joint first position went to the System FRAME 90 WI by Raico and the eco90 by Pural. The average investment costs in this category are € 526/m², while the average cost saving is 12 % over the life-cycle.

2 special prizes were awarded in addition, one to the company Wiegand for its use of innovative triple-glazing with 3 mm panes of non-tightened white glass, with a coated centre pane. This resulted in a g-value of 66% with U_g = 0.62 W/(m²K). The other special prize was

awarded to the company Pazen Fenster und Technik for their window ENERsign arctis* for the best U-value of all submitted components. This window (1.23 x 1.48 m) achieved a U-value of 0.46 W/(m²K) in the installed state due to its quadruple-glazing with U_g = 0.34 W/(m²K), a frame U-value of 0.61 W/(m²K) with a facing frame width of 94 mm, and a glass edge thermal bridge loss coefficient of 0.020 W/(mK).

3.3 Quadruple glazing

As mentioned above, some windows with quadruple glazing were also submitted. All quadruple-glazed windows were submitted in the category Timber-Aluminum. These were invariably glass panes filled with krypton gas and three coatings. Currently, this kind of glazing is still considerably more expensive than triple-glazing. Although economies of scale can be expected in the future as in the case of triple-glazing, availability of krypton is limited. The price will rise due to increased use of the gas in glazing. Krypton-filled quadruple-glazing should therefore be reserved for special situations and extremely cold climates. Argon-filled quadruple-glazing may be an option if the issue of the so-called pumping effect can be solved[8].

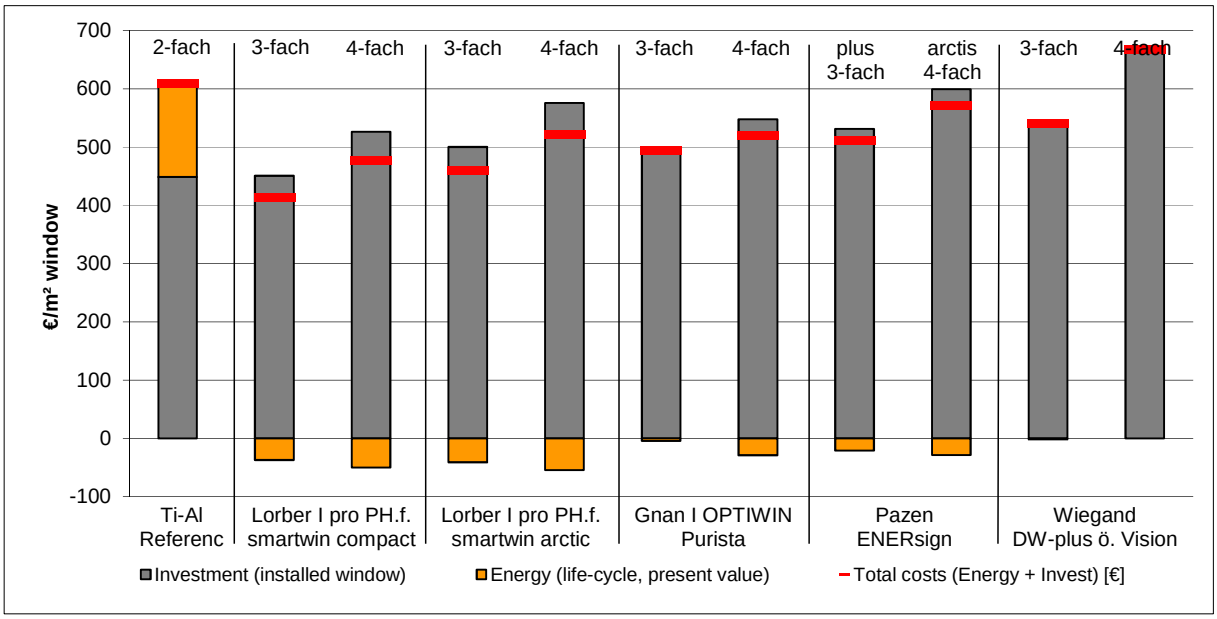


Figure 8: Costs for investment and energy and total costs (red bar: investment + energy costs) for the quadruple-glazed window in comparison with the triple-glazed variants and the reference window.

Figure 8 depicts the costs for investment and energy and the total costs for the quadruple-glazed variant in a comparison with the triple-glazed windows and the timber/aluminium reference window. It is apparent that with the exception of the window Wiegand DW-plus Öko Vision, the variants with quadruple glazing achieve the highest net energy gains (orange bar) (or the highest negative costs for energy); the quadruple-glazing is thus the best variant with

[8] See for example Benjamin Krick: PHI Window certification: Previous success and venturing into new climate zones, in: Conference Proceedings of the 18th International Passive House Conference 2014 in Aachen. PHI, Darmstadt 2014

reference to the energy-relevant quality[9]. However, the investment costs of the quadruple-glazed variants are considerably higher than those for the triple-glazed variants (grey bar). For this reason, the triple-glazing with the lowest total costs (red bar) is the most profitable solution for building owners in all cases. Nonetheless, it is noteworthy that in the majority of cases, as well as on average, the quadruple glazing scores better than the reference window. To conclude: triple-glazing is the best choice in the selected climate (Frankfurt am Main, Germany). The fact that the quadruple-glazed variant is superior to the reference window highlights once again the absurdity of using double glazing in cool, temperate climates[10].

3.4 Winners

3.4.1 Overview

Figure 9 shows the investment and energy costs of the winning products (without the special prizes) compared with each other and with the respective reference windows. In the case of timber/aluminium windows, it is striking that the investment costs for all winning windows and the reference window are approximately the same. The energy costs, which are in the negative range in the case of the windows smartwin compact and FUTURA, are a decisive factor for the total costs and thus for winning the Award. The same is true for the PVC window VADBplus 550 by Hilzinger, which has the lowest investment costs as well as the highest savings compared with the reference windows.

The costs of the timber windows are obviously lower than those of the timber/aluminium windows. The reference windows and the first prize winners are also in the same range here. The windows holz2holz and alu2holz by the company Freisinger are an exception as they are identical in construction except for a covering shell which may either be of timber or aluminium, and are marketed at the same investment cost. The investment costs of the winning windows in the aluminium category are not much higher than those of the reference windows either. Achieving the stringent certification criteria of the Passive House Institute is an exceptional accomplishment on account of the high thermal conductivity of aluminium. In the beginning these criteria could only be achieved with the help of a frame with a relatively high facing frame width. This is reflected in the energy balance of the windows. The proportion of glass, and accordingly the solar gains, are reduced due to the wider frame. The energy costs were significantly higher in relation to the winners in other categories.

One of the greatest challenges of our times is climate change, which is directly linked with the anthropogenically induced emission of greenhouse gases, the most important of which is carbon dioxide. The emission of this greenhouse gas can be reduced effectively by using Passive House technologies in general and Passive House windows in particular. For example, a window chosen from the winning components will relieve the atmosphere by 700

[9] The same results were obtained by Benjamin Krick, even when embodied energy is taken into account: Optimum glazing in the regions of Europe considering the embodied energy. Passive House Institute Darmstadt, July 2014

[10] A similar conclusion was reached in the studies by Benjamin Krick and Günter Pazen: Passive House windows are cost-effective! In: Conference Proceedings of the 18th International Passive House Conference 2014 in Aachen. PHI, Darmstadt 2014, and in Benjamin Krick: smartwin compact: Economic optimum in the regions of Europe.

kg CO_{2eq} per square metre of window area throughout its life-cycle, see Figure 10.
In order to better represent this for laypersons, energy savings are often shown as litres of heating oil saved. This is visualised in Figure 11. Here the example window provides a saving of 288 litres per m² of window area over its life-cycle (40 years), equating to about 308 litres per year for all windows of the house. An economical car (consumption 6 litres per 100 km) can travel about 5130 km with this amount of heating oil that is saved annually.

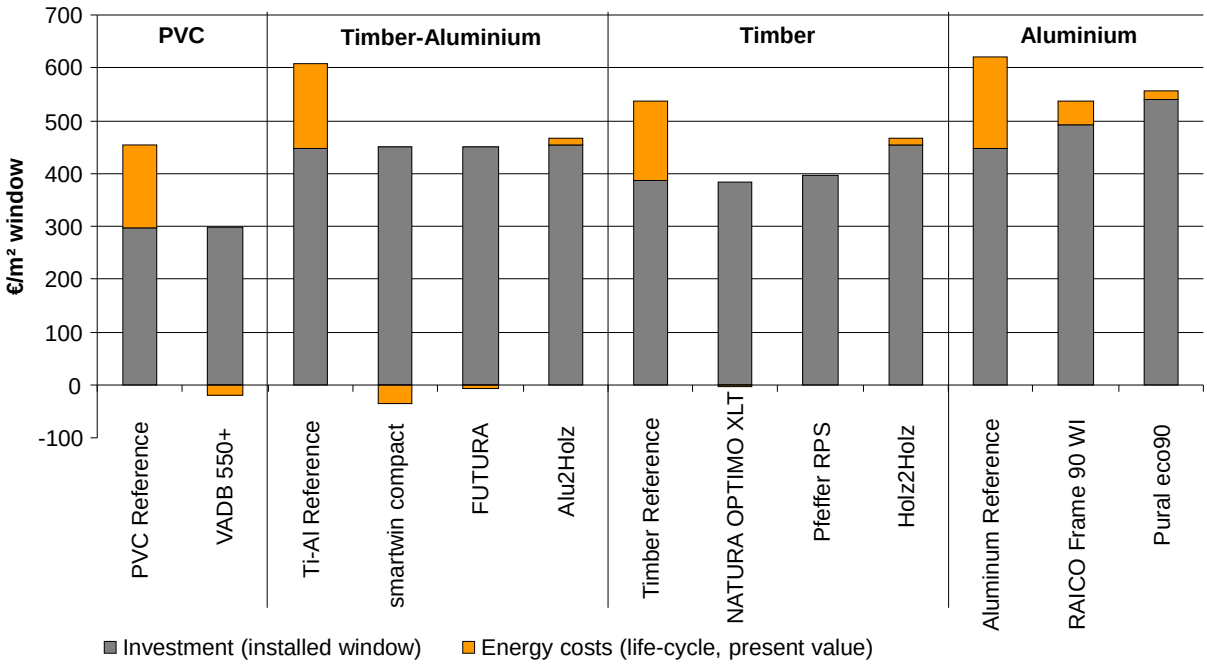


Figure 9: Investment and energy costs of the winning windows compared with each other and with the reference windows

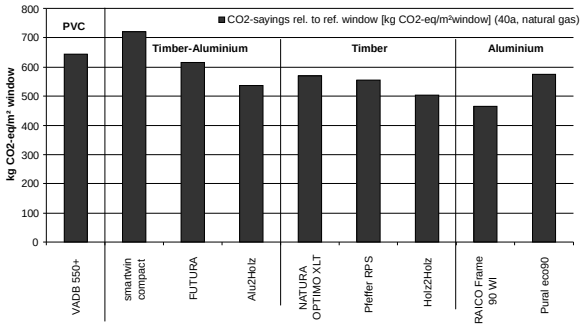


Figure 10: CO_2 saved (energy carrier natural gas) compared with the respective reference window throughout the life-cycle per m² of window.

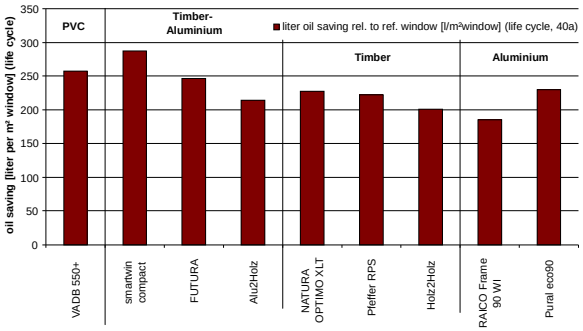


Figure 11: Heating oil saved compared with the respective reference window throughout the life-cycle per m² of window.

3.4.3 Example calculation

The following example serves to illustrate how profitable this is for building owners; see also Figure 12. Let us compare the costs for a standard window (here: the average of all categories) and a Passive House window (here: the average of all winning windows, without the special prizes). The investment for the standard windows is ca. € 16 920, for the Passive House windows this is significantly higher with € 18 600. A loan with a real interest rate of 2 % is taken out for financing this investment (the real interest rate is the difference between the nominal interest rate and the rate of inflation). The loan period is 20 years. This results in an annual rate of € 1035 for the standard windows and € 1137 for the Passive House windows. However, the resulting extra costs of € 102 per year for the Passive House window are offset by the energy savings to the amount of € 247/a (€ 0.10 per kWh are assumed as the energy price). This results in a cost advantage of ca. € 145/a over the loan period (20 years), equating to a profit of 11%. The loan is paid off after 20 years; the service life of the windows is predicted as 40 years. In the following 20 years, the building owner will profit from the lower energy costs as a result of the Passive House windows. Here, energy costs of € 250/a for the standard windows stand against energy costs of €3 for the Passive House windows, which is a saving of 99%. The low energy costs for the Passive House windows indicate an almost equalised energy balance: solar gains in the heating period correspond approximately with the transmission heat losses.

It should be noted that the cost savings presented here are additionally accompanied by a significant increase in living comfort. In this regard too, it can be concluded that the use of Passive House windows is recommended without reservation!

	Standard window* *Standardfenster*	Passive House Window** *Passivhausfenster*
Investment *Investition*	~ 16.920 €	~ 18.600 €
Credit *Kredit*	2% real interest, 20 years I 2% Realzins, 20 Jahre	
Annual rate *Jährliche Rate*	~ 1.035 €/a	~ 1.137 €/a
Energy costs *Energiekosten*	~ 250 €/a	~ 3 €/a
Sum *Summe*	~ 1.285 €/a	~ 1.140 €/a

Savings I *Einsparung*: ~ 145 €/a (11%)

After 20 years I *Nach 20 Jahren*: 250 € - 3 € = 247 € (99%)

* Average over the standard windows of all categories.
** Average over all winners excepted special prices.

Figure 12: Example calculation

3.4.4 Category Timber 1st Prize: M SORA, SLOVENIA: NATURA OPTIMO XLT

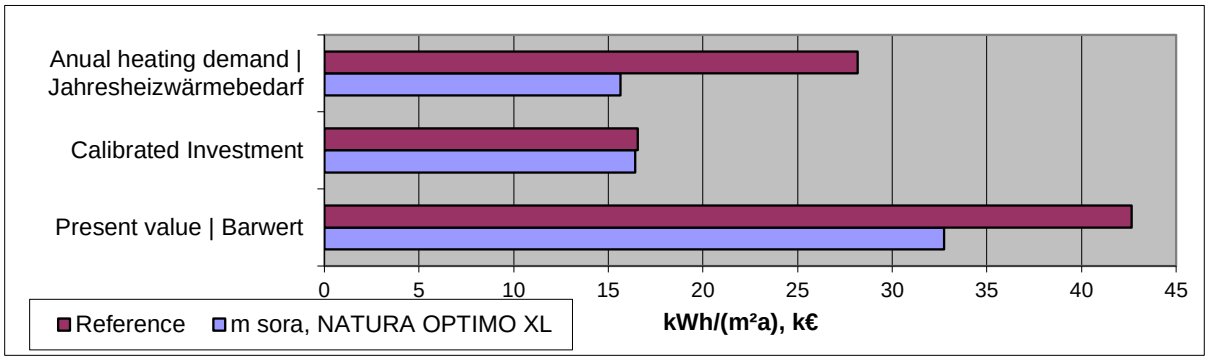
M SORA is one of leading Slovenian producers of timber and timber/aluminium windows as well as panoramic walls. The company's history dates back to 1948. A long history, a lot of experience and systematically planned development activities in past years helped the company towards stability and continual growth. Nowadays M SORA is well known for its flexibility and "custom made" windows. M SORA also invests a lot of effort in research and development of new products, while active participation in national and international calls is also a strong part of research and development activities of M SORA.
Natura Optimo XLT is one of the outcomes of M SORAs research and development activities. It is a simple but innovative solution made of thermally modified spruce timber, which has an almost 20% lower conductivity than ordinary spruce. In addition, the thermally modified timber has a better durability, dimensional stability and an exotic appearance.

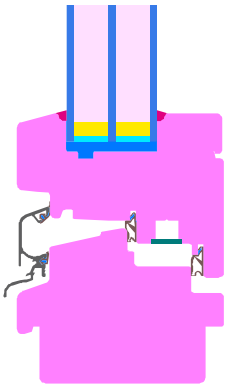
Product description | Produktbeschreibung
Frame from thermally modified spruce (0.09 W/(mK)) | Rahmen aus thermisch modifiziertem Holz (0,09 W/(mK)).

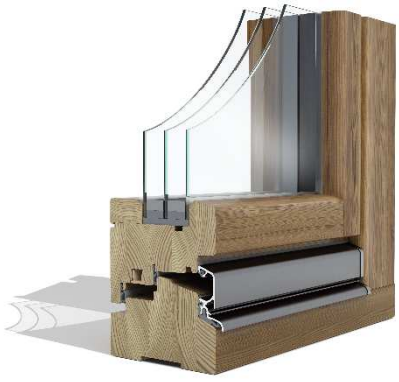
Spacer | Abstandhalter: SuperSp. Tri-Seal, PU secondary seal

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,63	0,61	0,74	-1,7	15,6	316	384	23

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes
** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude







3.4.5 Timber Category 1st Prize: Pfeffer Fenster, GERMANY: Pfeffer RPS

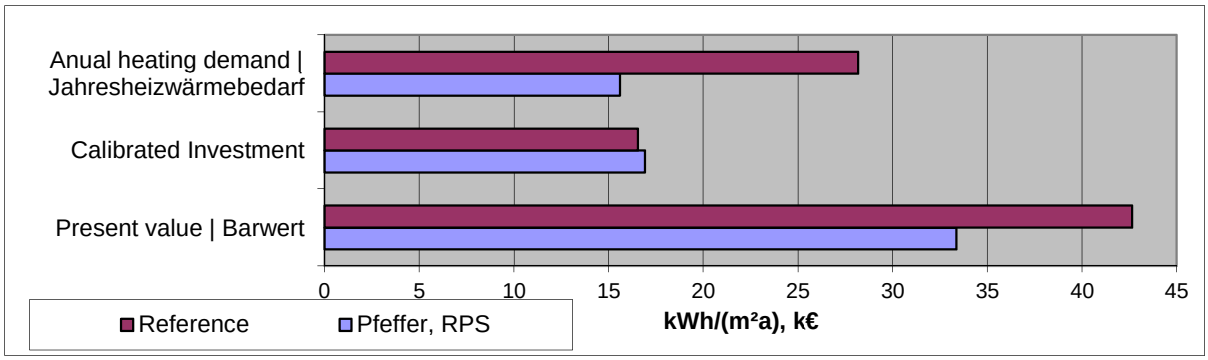
The company Pfeffer is a medium size enterprise specialising in the construction of windows, facades and doors.
The window Pfeffer RPS dispenses with extra insulation in the frame by its use of lightweight pine or fir timber, a good quality spacer and optimised frame geometry, while still achieving the stringent certification criteria of the Passive House Institute.

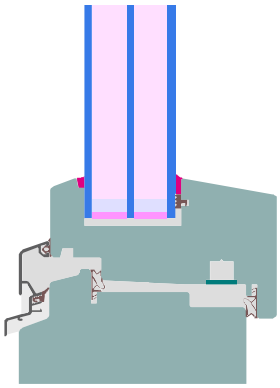
Product description | Produktbeschreibung
Slim, uninsulated timber frame (0.11W/(mK)) | Schlanker, ungedämmter Fensterrahmen aus Fichte/Tanne (0,11 W/(mK)).

Spacer | Abstandhalter: SWISSP. Ultimate

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,54	0,50	0,67	-0,3	15,6	351	396	22

* Average values over all windows of the building| Mittelwert über alle Fenster des Reference building
** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





2.4.2 Timber Category 2nd prize: OPTIWIN | Freisinger, AUSTRIA: Holz2Holz

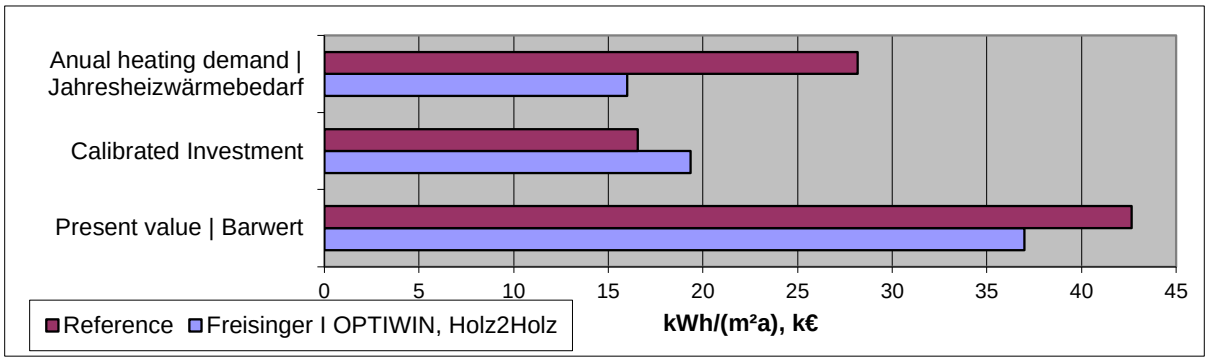
OPTIWIN is an international cooperation of medium-size window manufacturers. It has set itself the goal of developing and marketing innovative construction elements and energy efficient windows in particular, under consideration of ecological and economic aspects. The company Freisinger forms the core and mainstay of the OPTIWIN Group.
The window Holz2Holz consists of an inner layer of timber which assumes the actual function of the window. This sustainable system utilises the advantages of various types of timber in an optimal manner. OPTIWIN mainly uses timber types such as oak or larch for the outer layer as they are highly resistant against the effects of weather. The Holz2Holz is certified as a thermal bridge free window connection.

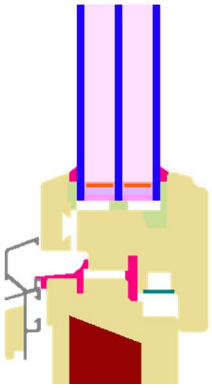
Product description | Produktbeschreibung
Timber frame (0.11 W/(mK)), certified as window connection, insulated by wood fibre board (0.04 W/(mK)) | Holz-Alu Rahmen (0,11 W/(mK)), zertifiziert als Fensteranschluss, gedämmt mit Holzweichfaserplatte (0,04 W/(mK)).

Spacer | Abstandhalter: SuperSp. Tri-Seal

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,53	0,52	0,71	4,9	16,0	0	452	13

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes
** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





3.4.7 Timber/Aluminium Category 1st Prize: proPassive House window | LORBER Fensterbau, AUSTRIA: smartwin compact

proPassivhausfenster is a cooperation of small European window manufacturers with the objective of producing high-performance and cost-effective Passive House windows through cooperation in development and acquisition as well as transfer of expertise, in order to support the promulgation of Passive Houses and thus contribute to a reduction in energy consumption. The company Lorber is a small innovative family enterprise located in Styria, and is a founding member of proPassivhausfenster. In addition to the smartwin compact, proPassivhausfenster also holds certificates for its windows smartwin arctic, smartwin classic and smartwin historic, and its doors smartwin sliding and smartwin entrance.

Product description | Produktbeschreibung

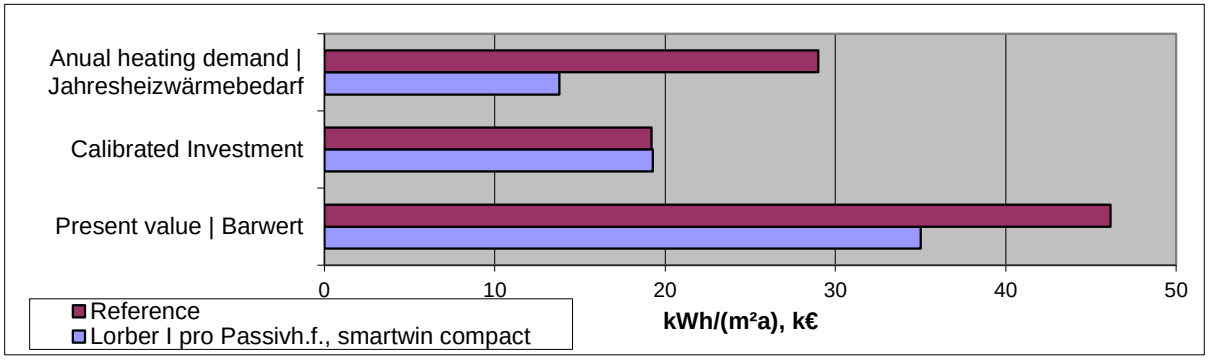
Timber-alu frame (0.11 W/(mK)), insulated by wood fibre board (0.04 / 0.05 W/(mK)) and PU-foam (0.07 W/(mK)) | Holz-Alu Rahmen (0,11 W/(mK)), isoliert mit Holzweichfaserplatten (0,04 / 0,05 W/(m²K)) und PU-Schaum (0,027 W/(mK)).

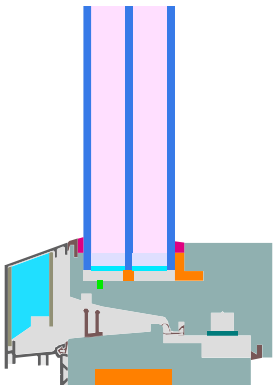
Spacer | Abstandhalter: Ultimate Swisspacer PU

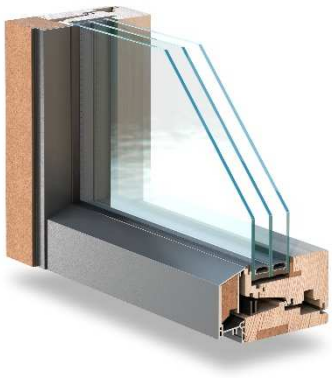
U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,60	0,61	0,68	-13,5	13,8	382	451	24

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude







3.4.8 Timber/Aluminium Category 1st Prize: OPTIWIN | Bieber, FRANCE: Futura

OPTIWIN is an international cooperation of medium-size window manufacturers. It has set itself the goal of developing and marketing innovative construction elements and energy efficient windows in particular, under consideration of ecological and economic aspects. The company Bieber represents the OPTIWIN Group in France.

The special construction of the window OPTIWIN Futura opens up new perspectives and creative opportunities for building owners and designers. The window frame is almost invisible on account of its slender frame and minimalist puristic design. Only the glazing is visible. The individual components are recyclable; special attention was given to energy conservation in the choice of materials and during production, making the OPTIWIN Futura state-of-the-art in terms of sustainability as well.

Product description | Produktbeschreibung

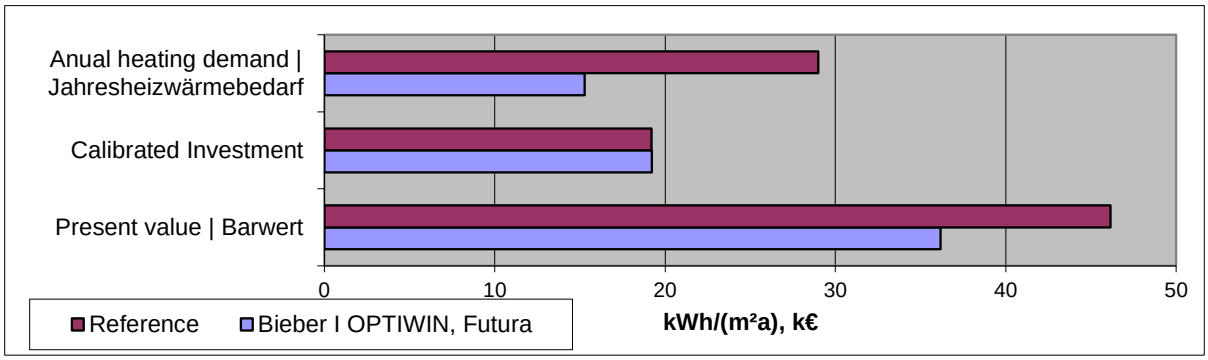
Timber-alu frame (0.11 W/(mK)), insulated by wood fibre board (0.04 W/(mK)) | Holz-Alu Rahmen (0,11 W/(mK)), gedämmt mit Holzweichfaserplatte (0,04 W/(mK)).

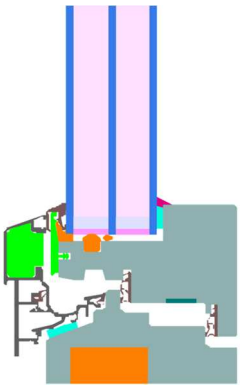
Spacer | Abstandhalter: Ultimate Swisspacer

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,64	0,62	0,75	-3,1	15,3	0	450	22

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





3.4.9 Timber/aluminium Category 2nd Prize: OPTIWIN | Freisinger, AUSTRIA: Alu2Holz

OPTIWIN is an international cooperation of medium-size window manufacturers. It has set itself the goal of developing and marketing innovative construction elements and energy efficient windows in particular, under consideration of ecological and economic aspects. The company Freisinger forms the core and mainstay of the OPTIWIN Group. The window Alu2Holz consists of an inner layer of timber which assumes the actual function of the window. The removable outer layer consists of weather-resistant aluminium. The window frame is no longer visible on the outside due to which extremely small facing frame widths are possible compared with a conventional aluminium window. OPTIWIN achieves this through extremely narrow casement and window frames which can be completely covered with insulation on the outside during installation. The Alu2Holz is certified as a thermal bridge free window connection.

Product description | Produktbeschreibung

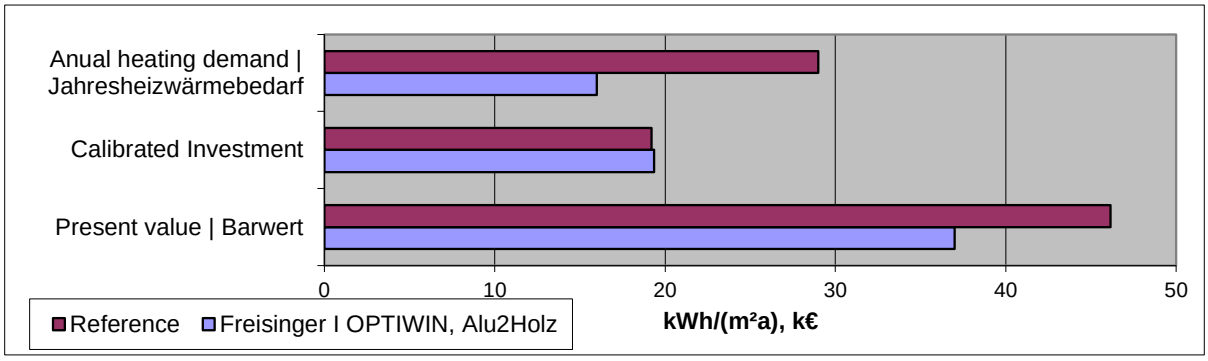
Timber-alu frame (0.11 W/(mK)), certified as window connection, insulated by wood fibre board (0.04 W/(mK)) | Holz-Alu Rahmen (0,11 W/(mK)), zertifiziert als Fensteranschluss,

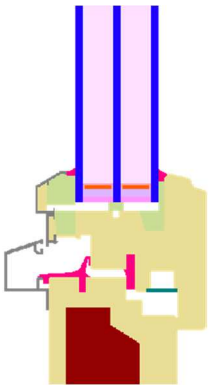
Spacer | Abstandhalter: Super Spacer Triseal

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,53	0,52	0,71	4,9	16,0	0	452	20

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





3.4.10 Aluminium Category 1st Prize: RAICO: Bautechnik, GERMANY: FRAME+ 90 WI

As a system manufacturer, the company RAICO Bautechnik GmbH develops and markets glazing systems for aluminium windows and doors, facades and conservatories. With its extensive portfolio of innovative products and services, the company can meet the most diverse requirements of its clients.
With the new System FRAME+ 90 WI/WB, RAICO has completed its FRAME+ series of aluminium windows with this module which has an installation depth of 90 mm and is certified by the Passive House Institute in Darmstadt. Consistent thermal optimisation and innovative system components such as the THERMORIT material for I-beams guarantee a high potential for saving energy.

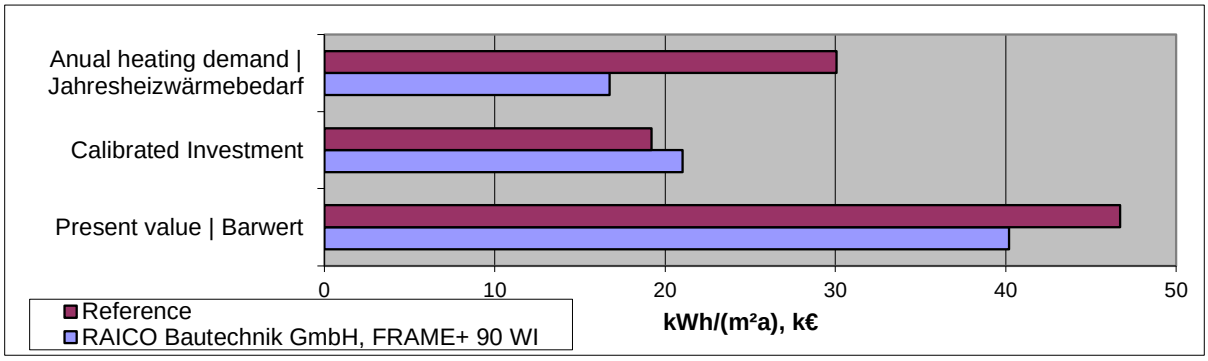
Product description | Produktbeschreibung
Thermally broken aluminum window system, insulated by PU-foam | Thermisch getrenntes Aluminiumfenstersystem mit PU-Dämmung.

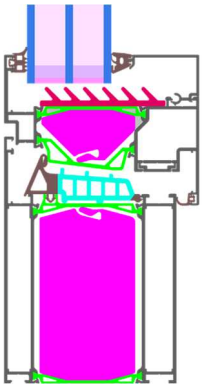
Spacer | Abstandhalter: SWISSP. Ultimate

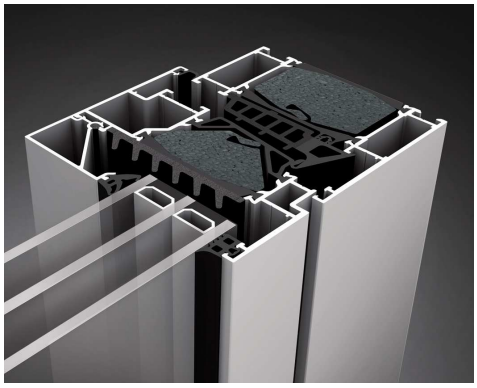
U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,58	0,53	0,79	16,6	16,7	411	492	14

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude







3.4.11 Aluminium Category 1st Prize: PURAL, GERMAY: eco90

In the window Pural eco90, thermal insulation is achieved by means of a polyurethane thermal block and a large-volume seal consisting of foamed EPDM in the frame rebate. Inserts in hollow spaces are not necessary. The system can be processed using conventional machines that are used for window installation. The hardware system with standard Euro groove is constructed based on commercially available fittings from well-known manufacturers. Due to this, the window can be repaired in a cost-saving way even decades after installation without completely replacing the window.

Product description | Produktbeschreibung

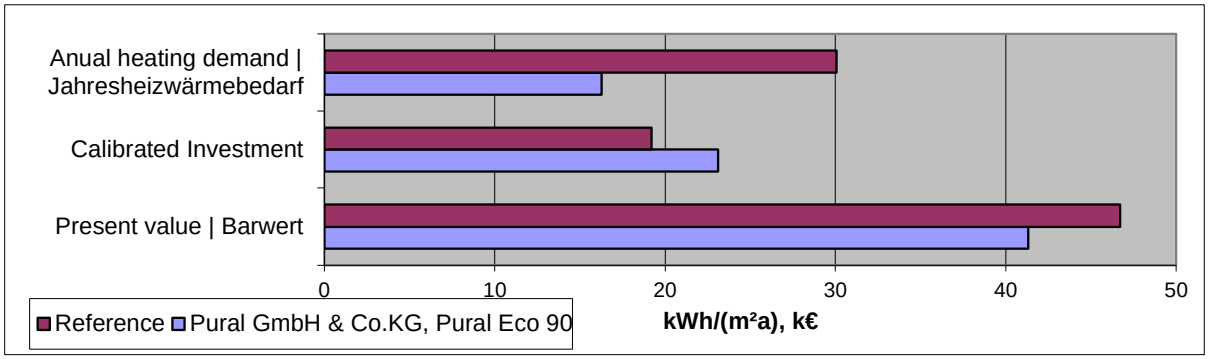
Aluminum window profile with rigid PU-foam block (0.051 W/(mK)) in the insulation layer | Aluminium Fensterprofil mit Polyurethan Wärmeblock (0,051 W/(mK)) in der Dämmebene.

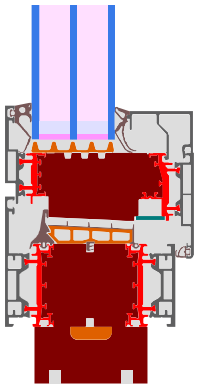
Spacer | Abstandhalter: SWISSP. Ultimate

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,62	0,59	0,77	5,5	16,3	419	540	12

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





3.4.12 PVC Category 1st Prize: Hilzinger FBS GmbH, GERMANY: VADB plus 550

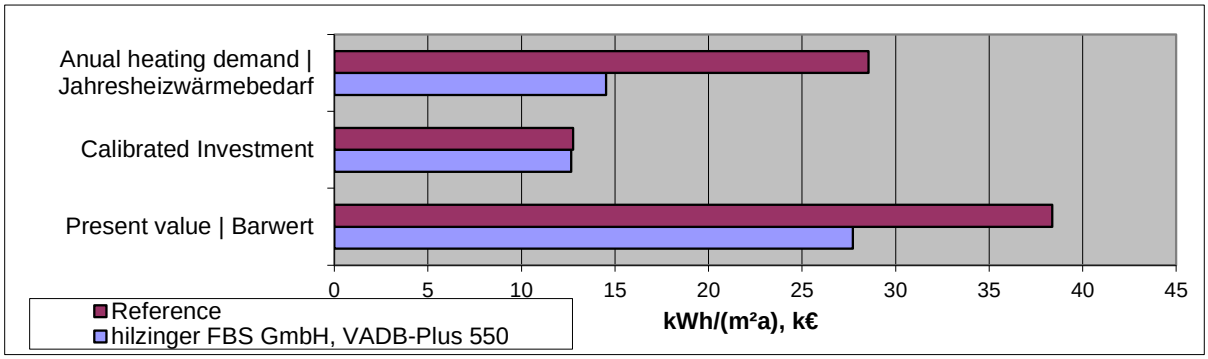
The Hilzinger group of enterprises with around 1000 employees produces windows and doors made of PVC, timber, timber/aluminium and aluminium. The innovative window Hilzinger VADBplus 550 was developed due to the growing requirements for optimal use of daylight, thermal insulation, and utilisation of free solar energy during the heating period.
In addition to the VADBplus 550, the window VADBplus 550+ was also submitted; this has a better frame U-value due to more insulated chambers and therefore has lower heat losses. However, the 550+ also had higher investment costs which could not be compensated by the lower energy demand; under the given boundary conditions, the 550 therefore proved to be the more cost-effective variant.

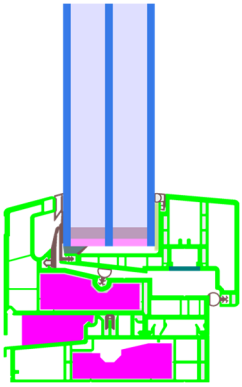
Product description | Produktbeschreibung
Slim multichamber-integral-frame with EPS Insulation (0,031 W/(mK)) | Schmaler Mehrkammer-Kunststoff-Integralrahmen mit Einschubdämmung aus EPS (0,031 W/(mK)).

Spacer | Abstandhalter: TPS

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0.57	0.57	0.68	-7.5	14.5	208	296	28

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes
** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





3.4.13 Special prize for innovative glazing: Wiegand, GERMANY: DW-plus

The company Wiegand Fensterbau has been producing certified Passive House windows as timber/aluminium constructions since 1998, and installation is carried out nationwide by its own specialists. In the last 15 years, DW-plus Passive House windows were installed in over 1000 properties.

Due to continuous further development by Wiegand, the company now has three Passive House products: DW-plus integral, öko Vision and XPS. The products are characterised by their energy efficiency, visual appeal and comprehensive verification (suitability for use, protection against break-ins and noise, environmental compatibility).

The glazing which received a Passive House Award not only exhibits impressively high solar gains (g-value = 65%) and low heat losses (U_g-value = 0.62 W/(m²K)), but are also 25 % lighter than previously available triple-glazing due to the use of 3 mm thin glass.

Product description | Produktbeschreibung

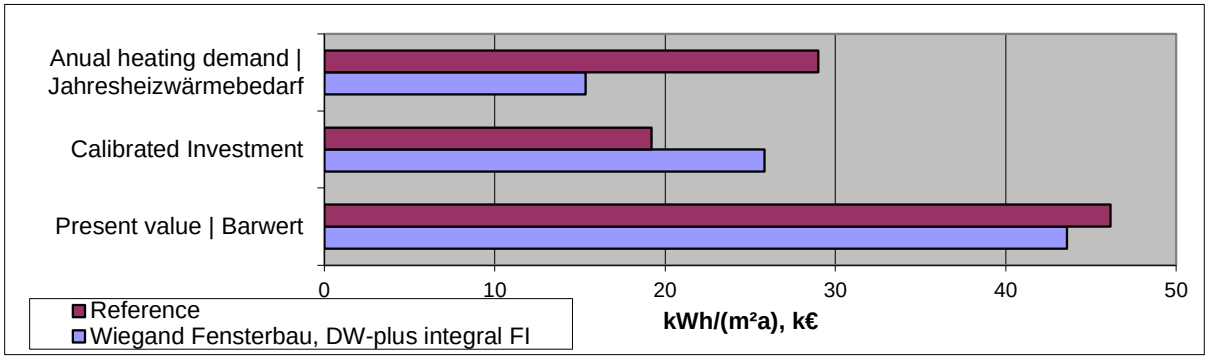
Timber-aluminum (0.11 W/(mK)) frame, insulated by an outside multichamber vinyl profile | Holz-Alufenster (0,11 W/(mK)), außenseitig durch ein Mehrkammer PVC-Profil isoliert.

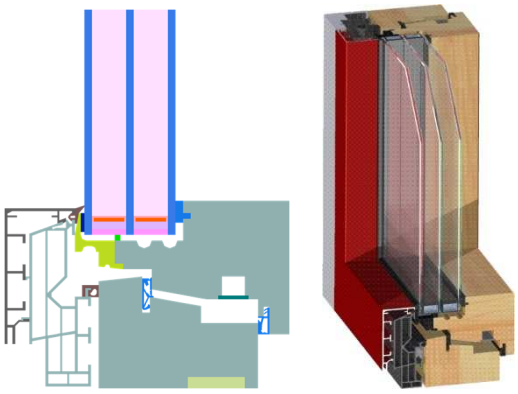
Spacer | Abstandhalter: SWISSP. Ultimate

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,62	0,65	0,77	-4,7	15,3	453	604	6

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude





3.4.14 Special prize for thermal protection: Pazen Fenster und Technik, GERMANY: ENERsign arctis*

Pazen Fenster und Technik is one of the first manufacturers of certified Passive House windows. The latest ENERsign line of products represents the consistent further development of those first Passive House windows. Because of a low frame U-value and narrow facing frame widths (94 mm) the first ENERsign achieved as first ever window efficiency class phA, long before this classification system was introduced in 2011. With the ENERsign arctis*, a suitable alternative is available for the cold climate, requiring minimal changes to the frame compared with the standard ENERsign plus variant. Moreover, the ENERsign product family includes entrance doors, sliding doors, and shading and blind systems.

Product description | Produktbeschreibung

Timber-aluminum itegral frame (0,11 W/(mK)), insulated by XPS (0.028 W/(mK)). The glass is varied by ENERcell (0.06 W/(mK)) | Holz-Aluminium Integralrahmen (Fichte/Tanne 0,11 W/(mK)) mit Dämmung aus XPS (0,028 W/(mK)). Das Glas wird durch ENERcell (0,06 W/(m²K)) getragen.

Spacer | Abstandhalter: SWISSP. Ultimate, PU secondary seal

U_g [W/(m²K)]*	**g** [-]*	**$U_{W,installed}$** [W/(m²K)]*	**Net. window losses** [kWh/m²a]*	**Heating demand** [KWh/(m²a)]	**Calibrated investment Window** [€/m²]*	**Calibrated investment installed window** [€/m²]*	**Savings** comp. to building with ref. window [%]**
0,34	0,46	0,46	-10,4	13,2	499	599	8

* Average values over all windows of the building | Mittelwert über alle Fenster des Referenzgebäudes

** Life-cycle: Energy costs and energy saving investments of the whole building | Lebenszyklus: Energiekosten und Investition in Energiesparmaßnahmen für das gesamte Gebäude