Save more energy with new windows

May 2021 update of the study "In a new light: Energetic modernisation of old windows"

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1. Foreword: Potential, process and objectives

This study of the German window market is the latest in a series of surveys published jointly by the VFF and BF at regular intervals over many years.[1] It contains the latest statistical information from the associations, and the resulting calculations for potential energy savings from replacing old windows in Germany's existing buildings.[2] As in previous editions, this study divides the existing window stock into different types. This means we can measure the true energy efficiency of the country's current windows reliably. When we calculate the energy-saving potential of renovations, we also consider solar gain from using transparent building materials. The study continues to contain information on measuring cost-effectiveness based on the full cost of the windows, but also considers the current 20 % subsidy for new windows as 'individual measures' under the Federal funding for efficient buildings (BEG).[3] We compare the cost-effectiveness of high-quality replacement against replacement with the minimum quality standard.

The cost-effectiveness calculation uses the cost of saving 1 kWh by means of new windows, which can then be compared to the expected cost of purchasing energy if the windows are not replaced. The energy price used for comparison is 0.075 €/kWh. This is slightly higher than the current energy price, and assumes the carbon price has been introduced; this price is set to rise in increments until 2025, and will raise the price of natural gas by 0.01 €/kWh.[4] If the cost per kilowatt hour of energy saved is lower than the energy price used for comparison, then the replacement measure is said to be cost-effective.

Thus the present study intends to supply all stakeholders with baseline data on the renovation potential in existing German windows. Given the increasing importance of renovating Germany's building stock, this will allow a serious look at the question: 'When is it financially worthwhile to replace my windows?

[1] See VFF (2002), VFF-BF (2005), VFF-BF (2007), VFF-BF (2008), VFF-BF (2010), VFF-BF (2011), VFF-BF (2014) and VFF-BF (2017).

[2] The study was compiled and revised by Univ.-Prof. Dr.-Ing. Gerd Hauser, Technical University of Munich and Dr. Rolf-Michael Lüking in cooperation with the Verband Fenster + Fassade (VFF) and the Bundesverband Flachglas (BF).

[3] For details, see RTG (2021)

[4] First Act Amending the Law on Fuel Emissions Trading of 3 November 2020, www.bgbl.de

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2. Summary

Three outdated types of windows are present in large numbers in current German residential buildings: Single-glazed windows (Type 1, 11 million window units), double or coupled windows (Type 2, 39 million window units), and windows with uncoated insulating glass (Type 3, 185 million window units). If all three categories, totalling 235 million window units, are replaced with modern windows, some 53 billion kilowatt hours of energy could be saved and around 12.3 million tonnes less CO_2 emitted each year.[5]

Replacing outdated windows not only makes environmental sense, it is also very cost-effective. The cost of saving energy by replacing windows, when converted to kWh of energy, already usually works out lower than the cost of purchasing that amount of energy at current prices.

If a window is going to be replaced anyway, for example because it no longer meets functional requirements, then there are two arguments for the planner and client to consider which favour 'doing the job properly, if you are going to do it at all'. High-quality, energy-efficient windows should be fitted, with a U_W-value of 0.95 W/(m^2K) or above. Firstly, because the environment will benefit as emissions are reduced: this is climate protection in action. Secondly, because their finances will benefit, as energy costs are reduced; the Federal funding for efficient buildings (BEG) and the tax deductible nature of the renovation are worth serious money.

Investing in new windows saves energy, but it also improves comfort, convenience, soundproofing and security. New windows increase the value of the property too.

3. Existing windows: The energy efficiency of different types

The Federal Republic of Germany has witnessed four phases of window construction, closely linked to overall economic developments and changes relating to thermal insulation. From 1950 to 1978, the market was dominated by single-glazed windows and double or coupled windows.
The Insulation Act (WSchVO) was passed in 1978, which brought more insulating glass windows onto the market. From 1995 coated thermal-insulation glass (low-E) gained in popularity. Windows with triple thermal-insulation glass (2 low-E coatings) were introduced in 2005 and their market share has been growing strongly since 2009.

[5] Calculation includes solar gain.

Totals for windows in Germany

Window stock in Germany		2016 million WU	2020 million WU
Type 1	Single-glazed window	17	11
Type 2	Double or coupled windows	44	39
Type 3	Window with uncoated insulating glass	205	185
Type 4	Double-glazed window with thermal-insulation glass (low-E)	289	309
Type 5	Triple-glazed window with thermal-insulation glass (2 x low-E)	55	90
Total		**610**	**634**

Window stock in units (1 WU = 1.3 x 1.3 m = 1.69 m^2). Figures rounded. Source: VFF / BF, 2021

The energy properties of a window are defined by its thermal transmittance[6] (U-value or U-factor) which gives its transmission heat loss, and by its overall heat gain (solar factor or g-value) which gives its solar energy gain. Over the past 50 years, the U-value of windows has improved by around 75 % as the table below illustrates. The lower the transmittance, the lower the heat loss.

[6] The thermal transmittance is measured in W/(m^2K). It is generally true that the lower the thermal transmittance, the better the window is insulated.

Thermal transmittance U_W and and solar factor in existing buildings, by window type

Window type	Mainly installed	Average U_W-value in W/(m²K)	Average solar factor in %
1 Single-glazed window	Up to 1978	4.7	87
2 Double or coupled windows	Up to 1978	2.4	76
3 Window with uncoated insulating glass	1978-1995	2.7	76
4 Double-glazed window with thermal-insulation glass (low-E)	From 1995	1.5	60
5 Triple-glazed window with thermal-insulation glass (2 x low-E)	From 2005	1.1	50

The figures are averages for the windows installed in these years. The stock consists of windows with frames of different depths and with different insulating properties and of glazing with different thermal transmittances and solar factors (see table in Appendix 1). Source: VFF / BF

Modern insulating windows are made from three panes of thermal-insulation glass, two of which are coated ('low-E glazing'). In conjunction with the advanced insulating and sealing technology used for the frames, they achieve four times the thermal insulation of single-glazed windows. The coatings reduce the solar factor compared to old, poorly insulating glass; this effect is advantageous in summer but leads to reduced solar heat gain in the winter when the heating is on. We have usually taken these solar energy gains – which are free of charge – into account in the calculations for the present study. The window stock comprises windows of various sizes, with frames of different depths and constructions. The insulating glass panes have different thermal transmittances. The calculation of average U_W-values is therefore based on the thermal transmittances of glass and frame, taking into account the proportions of different glass and frame types (see Appendix 1).

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4. Modernisation potential in Germany

Considering Germany's current environmental policy objectives, both new construction and potential energy savings in existing buildings – whether residential or commercial – are more important than ever.

The present study examines the effects of replacing windows in residential buildings from an economic point of view, as well as in terms of energy savings and CO_2 reduction. The calculations are based on replacing the window types described above with modern, triple-glazed windows using thermal-insulation glass, which have a U_W-value of 0.95 W/(m²K) and a solar factor of 62 %.[7] The potential energy savings are illustrated in detail in the following overview. It shows that replacing single-glazed windows (Type 1) is particularly effective. However, replacing the large number of windows with outdated, uncoated insulating glass (Type 3) is also cost-effective. The greatest savings can be achieved in these two areas.

Type 1 single-glazed windows, of which there are still around 11 million window units according to VFF and BF figures, are particularly worthwhile targets for rapid replacement. Taken as an average across all ages of window, these have a very high thermal transmittance (U-value): 4.7 W/(m²K) and above. The comparisons are made with modern, triple-glazed windows using low-E glass (Type 5), which have a U_W-value of 0.95 W/(m²K) and a solar factor of 62 %. Replacing single-glazed windows would save around 491 kWh of energy, or 49 m³ of natural gas, per window unit each year.

The total energy-saving potential through replacing single-glazed windows is therefore around 5 billion kWh and 1.2 million tonnes of CO_2 a year.

However, replacing outdated, uncoated insulating glass windows (Type 3) is also recommended. Replacing these would save around 222 kWh of energy, or 22 m³ of natural gas, per window unit each year. Projections for replacing the vast pool of these window units – 185 million – give an energy-saving potential of around 41 billion kWh and 9.5 million tonnes of CO_2 a year.

[7] The U_W-value was chosen based on the requirements in the Federal funding for efficient buildings (BEG) to support individual energy-saving renovation measures. In some cases, glass doors that allow disabled people access do not need to meet the given U_W-value.

Energy-saving potential of windows, Germany 2020

	Window types in existing buildings						
Energy-saving potential of windows, Germany 2020	**Type 5 Triple-glazed thermal-insulation glass**	**Type 4 Double-glazed thermal-insulation glass**	**Type 3 Uncoated insulating glass**	**Type 2 Double or coupled windows**	**Type 1 Single-glazed window**	**Total worth renovating Types 1 to 3**	**Units**
Stock in Window Units, or WU (1 WU = 1.69 m^2)	90	309	185	39	11	235	million WU
Mainly installed from…to…							
U_W-value before 1978 solar factor					4.7 87		W/(m^2K) %
U_W-value before 1978 solar factor				2.4 76			W/(m^2K) %
U_W-value 1978-1995 solar factor			2.7 76				W/(m^2K) %
U_W-value since 1995 (double-glazed) solar factor		1.8 - 1.3 58 - 63					W/(m^2K) %
U_W-value since 2005 (triple-glazed) solar factor	0.8 - 1.1 45 - 60						W/(m^2K) %
Given a degree day factor of 75 kKh and an annual heating system usage factor of 85 % (e_g = 1.2), and including solar gains, the energy savings in kWh per WU (1.69 m^2) will be:	Replacement not effective in terms of energy savings		222.0	176.0	491.0		kWh (WU*a)
Converted into m^3 of natural gas			22.2	17.6	49.1		m^3 (WU*a)
Energy-saving potential in billion kWh			41.0	6.9	5.4	53.3	bn. kWh/a
Converted into billion cubic metres of natural gas			4.1	0.7	0.5	5.3	billion cubic metres of natural gas/a
Converted into million tonnes CO_2			9.48	1.59	1.25	12.32	million tonnes CO_2/a

Source: Univ.-Prof. Dr.-Ing. Gerd Hauser, Technical University of Munich / Dr. Rolf-Michael Lüking

5. The cost-effectiveness of new windows

Cost-effectiveness is calculated using dynamic annuity calculations that establish the cost of energy savings per kWh, which can then be compared to the expected cost of purchasing energy. This comparison determines the cost-effectiveness of a measure: when the cost of the energy saved is lower than that of the energy that would otherwise have been purchased, the measure is said to be cost-effective.

The calculations result in a price per kilowatt-hour of energy saved (in €/kWh). Assumptions regarding the depreciation period for the investment, the interest rate and the rate of inflation are applied when calculating this price (see Appendix 2 for the methodology).

The energy price used for comparison is 0.075 €/kWh. This is slightly higher than the current energy price, and assumes the carbon price has been introduced; this increases in increments until 2025, and will increase the price of natural gas by 0.01 €/kWh. If the cost per kilowatt hour of energy saved is lower than the energy price used for comparison, then the measure is cost-effective. The present study leaves it to the reader to judge how energy prices will change in future.

The calculations are based on modern windows made of PVC, wood, wood-aluminium and aluminium, with average, standard features and without extra options such as locks, special safety features, mechatronic controls, glazing bars. The average market price for a new, modern triple-glazed window measuring 1.3 x 1.3 m using thermal-insulation glass was applied for all materials (PVC, wood, wood-aluminium and aluminium). An average price for 2020 was derived, and weighted according to the market shares for these types of frame. Because aluminium is rarely used for frames in residential buildings, a weighted average price excluding aluminium was also calculated. The price calculation included installation costs (without removal and disposal) and VAT (currently 19 % in Germany).[8]

Given that the current Federal funding for efficient buildings (BEG) subsidises the cost of new windows as a standalone measure at 20 %, the table below shows the prices with this reduction and the resulting prices for energy saved.

Shaded in green are all cases which meet the cost-effectiveness criteria (i.e. where the cost of energy saved is lower than the cost of purchasing that energy at 0.075 €/kWh).

[8] Average prices rounded to whole euros. As at May 2021.

Cost of energy saved by window replacement (full cost calculation)

Replacement with a triple-glazed thermal-insulation glass window (U_W = 0.95 W/(m²K) and g = 62 %)

				Window types in existing buildings							
Frame material	Market share in %	Price per window in €	Price per window in €	Type 5 Triple-glazed thermal-insulation glass	Type 4 Double-glazed thermal-insulation glass	Type 3 Uncoated insulating glass		Type 2 Double or coupled windows		Type 1 Single-glazed window	
		without subsidy	./. 20 % subsidy	Cost of energy saved in €/kWh without / ./. 20 % subsidy							
						without	with	without	with	without	with
Wood	15.1	645 €	516 €	Replacement not effective in terms of energy savings		0.071	0.057	0.090	0.072	0.032	0.026
Wood-aluminium	9.1	750 €	600 €			0.083	0.066	0.104	0.084	0.037	0.030
PVC	58.5	490 €	392 €			0.054	0.043	0.068	0.055	0.024	0.020
Aluminium	17.3	930 €	744 €			0.103	0.082	0.130	0.104	0.046	0.037
Weighted average residential window, excluding aluminium	82.7	547 €	438 €			0.061	0.048	0.076	0.061	0.027	0.022
Weighted average for all frame materials	100	613 €	490 €			0.068	0.054	0.085	0.068	0.031	0.025

Comparison cost for energy purchased: 0.075 €/kWh. Shaded in green: cost-effective
Source: VFF, average market prices for windows. As at May 2021. Univ.-Prof. Dr.-Ing. Gerd Hauser, Technical University of Munich/Dr. Rolf-Michael Lüking.

Replacing old, Type 1 windows (single-glazed) clearly makes economic sense, even without the 20 % subsidy, as for all common residential frame materials the cost of energy purchased is higher than the cost of the energy savings. Considering the 20 % subsidy, it also makes economic sense to replace Type 2 windows (double or coupled windows) with frames made from most materials, and for Type 3 windows (uncoated insulating glass) with frames made from all materials.

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6. Investing in higher quality vs the minimum standard

So far, we have presented the full cost of replacing windows. Besides this, we are also interested in the economic viability of investing in the high-quality modern windows described. These have a U_W-value 0.95 W/(m²K) and a solar factor of 62 %. They are compared with a minimum standard window – such as one being replaced for functional reasons other than saving energy, e.g. breakage, malfunction, wear and tear. For comparison, the minimum window standard required under the 2020 Energy Act for Buildings (GEG) is: U_W-value 1.3 W/(m²K), in practice this means double-glazing with thermal-insulation glass, with a solar factor of 60 %.

The market price for one such standard window to meet the minimum requirements, measuring 1.3 x 1.3m and including installation and VAT, was calculated as described above. A weighted average price was determined taking into account the market shares for the various frame materials.[9] Where windows need to be replaced anyway for functional reasons, investing in a high-quality modern window (U_W-value 0.95 (W/(m²K); solar factor 62 %) instead of meeting only the minimum requirements means an additional cost per 1.3 m x 1.3 m window of between € 70 and € 76, including installation and VAT, depending on the frame material.

The cost per kilowatt hour of energy saved will be between 0.029 and 0.031 €/kWh, as shown in the table below. This is far below the comparison price for purchasing energy (0.075 €/kWh). In the case of window replacement that is due to take place anyway, deciding to invest in the high-quality modern windows described therefore makes economic sense in all cases. Indeed, when the 20 % subsidy is deducted from the price of the high-quality, modern window, the subsidised prices are consistently lower than the prices for windows meeting the minimum requirements, so higher-quality replacement actually saves money.

[9] Average prices rounded to whole euros. As at May 2021.

Cost of energy saved compared to a minimum-standard window

Replacement with a triple-glazed thermal-insulation glass window (U_W = 0.95 W/(m²K) und g = 62 %) instead of a window meeting the minimum Building Energy Act (GEG) requirements (U_W = 1.3 W/(m²K) and g = 60 %)

Frame material	Market share in %	Price per triple-glazed window with thermal-insulation glass, in €		Price per minimum GEG-standard window, in €	Cost of additional energy saved, in €/kWh	
		without subsidy	./. 20 % subsidy		without subsidy	./. 20 % subsidy
Wood	15.1	645 €	516 €	569 €	0.031	-0.022
Wood-aluminium	9.1	750 €	600 €	678 €	0.030	-0.032
PVC	58.5	490 €	392 €	420 €	0.029	-0.012
Aluminium	17.3	930 €	744 €	856 €	0.030	-0.046
Weighted average residential window, excluding aluminium	82.7	547 €	438 €	476 €	0.029	-0.016
Weighted average for all frame materials	100	613 €	490 €	541 €	0.030	-0.021

Comparison cost for energy purchased: 0.075 €/kWh. Shaded in green: cost-effective

7. Replacing windows makes sense

It makes financial sense to replace windows, due to the energy savings. These in turn prevent CO_2 emissions and help achieve climate policy objectives, which is why the Federal funding for efficient buildings (BEG) subsidise replacements.

High-quality, modern windows also make for more modern buildings than outdated, existing windows. They improve:

- User comfort (because better-insulated glass surfaces have higher surface temperatures)
- Ease of operation
- Ease of care (e.g. surfaces)
- Security
- Noise protection

and, more broadly:

- Sustainability/environmental properties
- The asset value of the property
- Its attractiveness to tenants.

If these effects were quantified, they would certainly improve the cost-effectiveness of replacing windows even further. It would be possible to quantify them, but this would require making assumptions, some of which may be debatable. In any case, it is clear that investing in new windows will bring the modern benefits described above. From an environmental policy perspective, it is necessary to replace all single-glazed windows in any case; it also brings clear advantages to owners of both residential and non-residential buildings.

For windows dating from before 1995 which have frames and seals that are still in good condition, replacing the uncoated insulating glass with modern, low-E thermal-insulation glass is a worthwhile option. Generally the replacement will be with double-glazing using thermal-insulation glass, because the existing window frames and rebates are not wide enough for triple-glazing.

Since 1 January 2021, the Federal funding for efficient buildings (BEG) has combined many existing support programmes under a single umbrella, and it is therefore now easier to apply for support. The BEG has also expanded the horizons for support: new, attractive proposals have been added which better meet the needs of individual property owners. In addition to the BEG, tax incentives and the support for energy consultants also remain in place.

Appendix 1

Windows sold in Germany[10] U-values, as at 06-2021			1971	1972	1973	1974	1975	1976	1977	1978
Figures for the window market										
Wood	In millions of units*		5.6	6.8	7.0	7.6	7.0	6.7	6.4	6.3
PVC			1.0	1.3	1.7	2.0	2.5	3.0	3.6	4.2
Aluminium	* 1 Unit = 1.69 m^2		5.7	6.3	6.1	6.0	5.5	4.9	5.1	4.8
Wood-aluminium			0	0	0	0	0	0	0	0
Total market			**12.3**	**14.4**	**14.8**	**15.6**	**15.0**	**14.6**	**15.1**	**15.3**
* Source: VFF										
Market share of glass types										
Single glazing	U_g= 5.8	W/(m^2K)	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	20.0 %
Double or coupled windows	U_g= 2.8	W/(m^2K)	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %
Insulating glass 4/12/4 (uncoated)	U_g=2.8	W/(m^2K)								10.0 %
Double-glazed thermal-insulation glass 1st generation	U_g= 1.4	W/(m^2K)								
Double-glazed thermal-insulation glass 2nd generation	U_g= 1.2	W/(m^2K)								
Double-glazed thermal-insulation glass 3rd generation	U_g= 1.1	W/(m^2K)								
Triple-glazed thermal-insulation glass	U_g= 0.7	W/(m^2K)								
Glass types in millions of m^2										
Single glazing			4.4	5.1	5.3	5.5	5.3	5.2	5.4	3.6
Double or coupled windows			10.2	11.9	12.3	12.9	12.4	12.1	12.5	12.7
Insulating glass 4/12/4 (uncoated)			0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
Double-glazed thermal-insulation glass 1st generation			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Double-glazed thermal-insulation glass 2nd generation			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Double-glazed thermal-insulation glass 3rd generation										
Triple-glazed thermal-insulation glass										
Proportion of 'warm-edge' glazing (Psi value of 0.06)										
	Average U_g-value	**W/(m^2K)**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**	**3.4**
U-values for frame types										
Wooden single window (hardwood)	U_f= 1.9	W/(m^2K)	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %	30.0 %
Wooden single window (softwood)	U_f= 1.5	W/(m^2K)	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Wooden double window (hardwood)	U_f= 1.4	W/(m^2K)	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %
Wooden single window (Type 1)	U_f= 1.1	W/(m^2K)								
Wooden single window (Type 2)	U_f= 0.9	W/(m^2K)								
	Average U_f-value	**W/(m^2K)**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**
PVC window (two-chamber)	U_f= 2.2	W/(m^2K)	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
PVC window (three-chamber)	U_f= 1.8	W/(m^2K)								
PVC window (multi-chamber, Type 1)	U_f= 1.4	W/(m^2K)								
PVC window (multi-chamber, Type 2)	U_f= 1.1	W/(m^2K)								
PVC window (multi-chamber, Type 3)	U_f= 0.9	W/(m^2K)								
	Average U_f-value	**W/(m^2K)**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**	**2.2**
Aluminium window, "Rahmenmaterialgruppe" 3	U_f= 7.0	W/(m^2K)	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Aluminium window, "Rahmenmaterialgruppe" 2.3	U_f= 5.0	W/(m^2K)								
Aluminium window, "Rahmenmaterialgruppe" 2.2	U_f= 3.8	W/(m^2K)								
Aluminium window, "Rahmenmaterialgruppe" 2.1	U_f= 3.0	W/(m^2K)								
Aluminium window, "Rahmenmaterialgruppe" 1	U_f= 2.2	W/(m^2K)								
Aluminium window, today (Type 1)	U_f= 1.9	W/(m^2K)								
Aluminium window, today (Type 2)	U_f= 1.4	W/(m^2K)								
Aluminium window, today (Type 3)	U_f= 1.1	W/(m^2K)								
Aluminium window, today (Type 4)	U_f= 0.9	W/(m^2K)								
	Average U_f-value	**W/(m^2K)**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**	**7.0**
Wood-metal window (Type 1)	U_f= 1.7	W/(m^2K)	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Wood-metal window (Type 2)	U_f= 1.3	W/(m^2K)								
Wood-metal window (Type 3)	U_f= 1.1	W/(m^2K)								
Wood-metal window (Type 4)	U_f= 0.9	W/(m^2K)								
	Average U_f-value	**W/(m^2K)**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
All window frame materials	**Average U_f-value**	**W/(m^2K)**	**4.1**	**4.0**	**3.9**	**3.7**	**3.7**	**3.5**	**3.5**	**3.4**
Average U_W-value, all windows as per table		W/(m^2K)	3.8	3.8	3.8	3.7	3.7	3.6	3.7	3.4
Average U_W-value 1971 - 1978			3.7							
Average U_W-value 1979 - 1994										

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	7.0	7.1	6.2	5.5	5.3	5.5	5.2	5.1	5.3	5.4	6.6	7.3	7.3	7.6	8.0	7.6
	5.5	6.3	5.7	5.2	5.0	4.9	5.1	5.4	5.5	5.3	5.7	6.6	8.5	9.3	10.0	11.7
	5.0	4.7	3.2	2.7	2.3	2.3	2.1	2.7	3.1	3.5	3.8	4.2	4.4	4.7	4.8	5.2
	0	0	0	0	0	0	0	0.1	0.2	0.2	1.0	0.4	0.5	0.7	0.6	0.7
	17.5	**18.1**	**15.1**	**13.4**	**12.6**	**12.7**	**12.4**	**13.3**	**14.1**	**14.4**	**17.1**	**18.5**	**20.7**	**22.3**	**23.4**	**25.2**
	0.0 %															
	5.0 %															
	95.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	90.0 %	89.0 %	88.0 %	83.0 %	66.0 %
												10.0 %	11.0 %	12.0 %	17.0 %	34.0 %
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	19.7	21.4	17.9	15.9	14.9	15.0	14.7	15.7	16.7	17.0	20.2	19.7	21.8	23.2	23.0	19.7
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.7	3.2	4.7	10.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.8	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.8**	**2.7**	**2.6**	**2.6**	**2.6**	**2.3**
	95.0 %	100.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	80.0 %	60.0 %	60.0 %	60.0 %
	0.0 %	0.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	20.0 %	40.0 %	40.0 %	40.0 %
	5.0 %															
	1.9	**1.9**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**	**1.7**	**1.7**	**1.7**
	100.0 %	100.0 %	100.0 %	100.0 %	90.0 %	80.0 %	70.0 %	60.0 %	50.0 %	40.0 %	30.0 %	20.0 %	10.0 %			
					10.0 %	20.0 %	30.0 %	40.0 %	50.0 %	60.0 %	70.0 %	80.0 %	90.0 %	95.0 %	90.0 %	85.0 %
														5.0 %	10.0 %	15.0 %
	2.2	**2.2**	**2.2**	**2.2**	**2.2**	**2.1**	**2.1**	**2.0**	**2.0**	**2.0**	**1.9**	**1.9**	**1.8**	**1.8**	**1.8**	**1.7**
	90.0 %															
	10.0 %	100.0 %	100.0 %	90.0 %	70.0 %	50.0 %	30.0 %	10.0 %								
				10.0 %	30.0 %	50.0 %	70.0 %	90.0 %								
									100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
	6.8	**5.0**	**5.0**	**4.9**	**4.6**	**4.4**	**4.2**	**3.9**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
	1.7	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
	3.4	**2.8**	**2.6**	**2.6**	**2.5**	**2.4**	**2.3**	**2.3**	**2.1**	**2.2**	**2.1**	**2.1**	**2.1**	**2.0**	**2.0**	**2.0**
	3.0	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.6	2.6	2.4
									2.8							

[10] Figures up to 1990 for the Federal Republic of Germany (West Germany)

Appendix 1

Windows sold in Germany, U-values, as at 06/2021			1995	1996	1997	1998	1999	2000	2001	2002	2003
Figures for the window market											
Wood	In millions of units*		7.4	6.8	6.5	5.9	5.4	4.6	3.5	3.5	2.8
PVC			12.3	12.1	12.6	12.1	12.1	10.7	8.6	8.1	7.2
Aluminium	* 1 Unit = 1.69 m²		5.2	5.1	4.4	3.9	3.5	3.5	3.1	2.6	2.6
Wood-aluminium			0.7	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6
Total market			**25.5**	**24.7**	**24.3**	**22.6**	**21.8**	**19.5**	**16.0**	**14.7**	**13.2**
* Source: VFF											
Market share of glass types											
Single glazing	U_g= 5.8	W/(m²K)									
Double or coupled windows	U_g= 2.8	W/(m²K)									
Insulating glass 4/12/4 (uncoated)	U_g= 2.8	W/(m²K)	41.0 %	20.0 %	17.0 %	15.0 %	9.0 %	5.0 %	5.0 %	4.0 %	
Double-glazed thermal-insulation glass 1st generation	U_g= 1.4	W/(m²K)	59.0 %	80.0 %	83.0 %	85.0 %	45.0 %	30.0 %	20.0 %	6.0 %	
Double-glazed thermal-insulation glass 2nd generation	U_g= 1.2	W/(m²K)					46.0 %	65.0 %	75.0 %	90.0 %	100.0 %
Double-glazed thermal-insulation glass 3rd generation	U_g= 1.1	W/(m²K)									
Triple-glazed thermal-insulation glass	U_g= 0.7	W/(m²K)									
Glass types in millions of m²											
Single glazing			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Double or coupled windows			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insulating glass 4/12/4 (uncoated)			12.4	5.8	4.9	4.0	2.3	1.2	0.9	0.7	0.0
Double-glazed thermal-insulation glass 1st generation			17.8	23.4	23.9	22.7	11.6	6.9	3.8	1.0	0.0
Double-glazed thermal-insulation glass 2nd generation			0.0	0.0	0.0	0.0	11.9	15.0	14.2	15.7	15.7
Double-glazed thermal-insulation glass 3rd generation											
Triple-glazed thermal-insulation glass											
Proportion of 'warm-edge' glazing (Psi value of 0.06)											
	Average U_g-value	**W/(m²K)**	**2.0**	**1.7**	**1.6**	**1.6**	**1.4**	**1.3**	**1.3**	**1.3**	**1.2**
U-values for frame types											
Wooden single window (hardwood)	U_f= 1.9	W/(m²K)	60.0 %	60.0 %	60.0 %	60.0 %	60.0 %	40.0 %	40.0 %	40.0 %	40.0 %
Wooden single window (softwood)	U_f= 1.5	W/(m²K)	40.0 %	40.0 %	40.0 %	40.0 %	40.0 %	60.0 %	60.0 %	60.0 %	60.0 %
Wooden double window (hardwood)	U_f= 1.4	W/(m²K)									
Wooden single window (Type 1)	U_f= 1.1	W/(m²K)									
Wooden single window (Type 2)	U_f= 0.9	W/(m²K)									
	Average U_f-value	**W/(m²K)**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
PVC window (two-chamber)	U_f= 2.2	W/(m²K)									
PVC window (three-chamber)	U_f= 1.8	W/(m²K)	80.0 %	70.0 %	60.0 %	50.0 %	40.0 %	30.0 %	20.0 %	10.0 %	5.0 %
PVC window (multi-chamber, Type 1)	U_f= 1.4	W/(m²K)	20.0 %	30.0 %	40.0 %	50.0 %	60.0 %	70.0 %	80.0 %	90.0 %	95.0 %
PVC window (multi-chamber, Type 2)	U_f= 1.1	W/(m²K)									
PVC window (multi-chamber, Type 3)	U_f= 0.9	W/(m²K)									
	Average U_f-value	**W/(m²K)**	**1.7**	**1.7**	**1.6**	**1.6**	**1.6**	**1.5**	**1.5**	**1.4**	**1.4**
Aluminium window, "Rahmenmaterialgruppe" 3	U_f= 7.0	W/(m²K)									
Aluminium window, "Rahmenmaterialgruppe" 2.3	U_f= 5.0	W/(m²K)									
Aluminium window, "Rahmenmaterialgruppe" 2.2	U_f= 3.8	W/(m²K)									
Aluminium window, "Rahmenmaterialgruppe" 2.1	U_f= 3.0	W/(m²K)	100.0 %	95.0 %	90.0 %	85.0 %	80.0 %	70.0 %	65.0 %	45.0 %	30.0 %
Aluminium window, "Rahmenmaterialgruppe" 1	U_f= 2.2	W/(m²K)	0.0 %	5.0 %	10.0 %	15.0 %	20.0 %	30.0 %	35.0 %	50.0 %	55.0 %
Aluminium window, today (Type 1)	U_f= 1.9	W/(m²K)								5.0 %	15.0 %
Aluminium window, today (Type 2)	U_f= 1.4	W/(m²K)									
Aluminium window, today (Type 3)	U_f= 1.1	W/(m²K)									
Aluminium window, today (Type 4)	U_f= 0.9	W/(m²K)									
	Average U_f-value	**W/(m²K)**	**3.0**	**3.0**	**2.9**	**2.9**	**2.8**	**2.8**	**2.7**	**2.5**	**2.4**
Wood-metal window (Type 1)	U_f= 1.7	W/(m²K)	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Wood-metal window (Type 2)	U_f= 1.3	W/(m²K)									
Wood-metal window (Type 3)	U_f= 1.1	W/(m²K)									
Wood-metal window (Type 4)	U_f= 0.9	W/(m²K)									
	Average U_f-value	**W/(m²K)**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**	**1.7**
All window frame materials	**Average U_f-value**	**W/(m²K)**	**2.0**	**2.0**	**1.9**	**1.9**	**1.8**	**1.8**	**1.8**	**1.7**	**1.7**
Average U_W-value, all windows as per table		W/(m²K)	**2.2**	**2.0**	**1.9**	**1.9**	**1.7**	**1.7**	**1.7**	**1.6**	**1.5**
Average U_W-value 1995 - 2001						**1.9**					
Average U_W-value 2001 - 2007											
Average U_W-value 2008 - 2016											
Average U_W-value 2017 - 2020											

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
																Preliminary
2.8	2.3	2.5	2.1	2.0	2.1	2.1	2.1	2.1	2.1	2.0	2.0	2.1	2.1	2.2	2.2	2.3
7.2	6.5	7.2	6.4	6.4	6.8	7.1	7.4	7.5	7.6	7.7	7.7	8.0	8.2	8.3	8.4	8.8
2.4	2.2	2.3	2.4	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.5	2.6	2.7	2.8	2.9
0.6	0.6	0.6	0.7	0.8	0.8	0.8	0.9	1.0	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4
13.1	**11.6**	**12.6**	**11.6**	**11.7**	**12.1**	**12.5**	**12.9**	**13.0**	**13.1**	**13.4**	**13.4**	**13.8**	**14.2**	**14.4**	**14.8**	**15.3**
90.0 %	75.0 %	26.0 %	10.0 %													
10.0 %	20.0 %	65.0 %	80.0 %	85.0 %	75.0 %	60.0 %	55.0 %	50.0 %	45.0 %	44.0 %	42.0 %	41.0 %	40.4 %	40.1 %	39.7 %	39.5 %
	5.0 %	9.0 %	10.0 %	15.0 %	25.0 %	40.0 %	45.0 %	50.0 %	55.0 %	56.0 %	58.0 %	59.0 %	59.6 %	59.9 %	60.3 %	60.5 %
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13.9	10.3	3.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.5	2.7	9.7	11.0	11.8	10.7	8.9	8.4	7.7	7.0	7.0	6.7	6.7	6.8	6.8	7.0	6.9
	0.7	1.3	1.4	2.1	3.6	5.9	6.9	7.7	8.5	8.9	9.2	9.6	10.0	10.2	10.6	10.6
			3 %	8 %	16 %	30 %	40 %	50 %	55 %	58.0 %	62.0 %	62.7 %	62.8 %	66.2 %	70.0 %	74.0 %
1.2	**1.2**	**1.1**	**1.1**	**1.0**	**1.0**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**
40.0 %	40.0 %	40.0 %	40.0 %	30.0 %	25.0 %	10.0 %										
60.0 %	60.0 %	60.0 %	60.0 %	65.0 %	60.0 %	74.0 %	84.0 %	84.0 %	84.0 %	80.0 %	76.0 %	74.0 %	72.0 %	70.0 %	68.0 %	66.0 %
										4.0 %	8.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %
				5.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	12.0 %	14.0 %	16.0 %	18.0 %
					5.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %	6.0 %
1.7	**1.7**	**1.7**	**1.7**	**1.6**	**1.5**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**
5.0 %																
95.0 %	100.0 %	100.0 %	100.0 %	95.0 %	88.0 %	60.0 %	55.0 %	51.0 %	48.0 %	46.0 %	45.0 %	44.0 %	43.0 %	42.0 %	41.0 %	40.0 %
				5.0 %	8.0 %	32.0 %	35.0 %	40.0 %	41.0 %	45.0 %	46.0 %	47.0 %	48.0 %	48.0 %	49.0 %	50.0 %
					4.0 %	8.0 %	8.0 %	9.0 %	9.0 %	9.0 %	9.0 %	9.0 %	9.0 %	10.0 %	10.0 %	11.0 %
1.4	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
15.0 %																
65.0 %	50.0 %	30.0 %	30.0 %	24.0 %	14.0 %											
20.0 %	50.0 %	70.0 %	70.0 %	70.0 %	70.0 %	70.0 %	50.0 %	40.0 %	10.0 %	5.0 %						
				5.0 %	10.0 %	22.0 %	39.0 %	46.0 %	74.0 %	82.0 %	84.0 %	84.0 %	82.0 %	80.0 %	77.0 %	75.0 %
				1.0 %	5.0 %	7.0 %	10.0 %	13.0 %	15.0 %	12.0 %	15.0 %	15.0 %	16.0 %	17.0 %	19.0 %	20.0 %
					1.0 %	1.0 %	1.0 %	1.0 %	1.0 %	1.0 %	1.0 %	1.0 %	2.0 %	3.0 %	3.0 %	4.0 %
2.3	**2.1**	**2.0**	**2.0**	**1.9**	**1.8**	**1.7**	**1.6**	**1.6**	**1.4**	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	**1.3**	**1.3**
100.0 %	100.0 %	100.0 %	100.0 %	86.0 %	69.0 %	38.0 %	25.0 %	15.0 %								
				10.0 %	20.0 %	44.0 %	53.0 %	59.0 %	70.0 %	68.0 %	67.0 %	66.0 %	60.0 %	54.0 %	48.0 %	42.0 %
				4.0 %	8.0 %	12.0 %	15.0 %	18.0 %	20.0 %	22.0 %	23.0 %	24.0 %	30.0 %	36.0 %	42.0 %	48.0 %
					3.0 %	6.0 %	7.0 %	9.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %	10.0 %
1.7	**1.7**	**1.7**	**1.7**	**1.6**	**1.5**	**1.4**	**1.3**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
1.6	**1.6**	**1.6**	**1.6**	**1.6**	**1.5**	**1.4**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.2**	**1.2**
1.5	**1.5**	**1.4**	**1.4**	**1.4**	**1.3**	**1.3**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**
	1.5															
							1.3				**1.2**					
															1.1	

Appendix 2

Explanation of the calculations

a) Assumptions for heating period and total solar radiation

- Heating period according to DIN 4108-2; degree-day factor 75 kKh (assumption for partially renovated building stock: updated values for specific CO_2 emissions from energy sources observed, in accordance with GEMIS 5.0)
- Calculation method: simplified (heating period balance method according to EnEv).
  Annual heating requirement:
  $Q_h = F_{GT} * (H_T + H_V) - \eta_{HP}(Q_s + Q_i)$ [kWh/a]
- The useful heat gains (Q_s) from solar radiation are dependent on window orientation and are derived from the total solar radiation ($I_{s,HP}$) during the heating period, taking into account reduction factors such as the frame (30 % of the window) and dirt and shading per m² of window surface:
  $Q_s = 0.567 * I_{s,HP}$
- Degree of use of heat gain $\eta_{HP} = 0.9$
- Average value of total solar radiation in the heating period per square metre
- window surface facing north, south, east and west:
  $I_{s,HP,on\ average} = 306$ kWh/(m²a)

b) Assumptions about heating systems

- Equipped with low-temperature or condensing boilers: ratio of primary energy to domestic energy consumption 1.20
- Thus the reduction in heating required due to window replacement yields a reduction in heating energy demand as follows:
  $\Delta Q_E = 1.2 * \Delta Q_h = 1.2 * (F_{GT} * \Delta U_W - \Delta g * \eta_{HP} * Q_s)$ [kWh/(m²FFa)]
- Energy source for heating: natural gas with specific emissions of 0.231 kg/(kWh) CO_2-equivalent [GEMIS 5.0]. The Energy Act for Buildings (GEG) makes slightly different calculations for natural gas, with specific emissions of 240 g/(kWh) CO_2-equivalent.

c) Basis of the cost-effectiveness calculation

- The cost of energy saved (P_{Ein} in e/kWh) is derived from the energy saved (ΔQ_E) and the annuity costs (K) of the investment:
  $P_{Ein} = K/\Delta Q_E$
- The annuity costs of the measure are the product of the annuity factor a and the investment costs I: $K = a * I$
- The annuity factor a depends on the real interest rate p and the lifetime n of the investment, according to this formula:
  $a = p/(1-(1+p)-n)$
- The nominal interest rate $p_N = 2{,}0$ %
- The rate of inflation $i = 1{,}3$ %
- The lifetime $n = 48$ years
- The resulting effective interest rate $p = 0.69$ %

Literature

BF (2009), In Glas steckt Potenzial, information for professionals, published by the Bundesverband Flachglas (BF), Troisdorf

BMWi (2020), German Federal Ministry of Economics and Energy: Directive on Federal funding for efficient buildings – Residential buildings (BEG WG), Directive on Federal funding for efficient buildings – Non-residential buildings (BEG NWG), Directive on Federal funding for efficient buildings – Individual measures (BEG EM), www.bundesanzeiger.de

First Act Amending the Law on Fuel Emissions Trading of 3 November 2020, www.bgbl.de

VFF (2002), Aufschwung schaffen – Gesamtwirtschaftliche und ökologische Wirkungen der Förderung von Investitionen zur Verbesserung der Wärmedämmung von Fenstern, report by B. Meyer and M.I. Wolter, Gesellschaft für Wirtschaftliche Strukturforschung mbh, specialists in empirical economic research (GWS Osnabrück). Published by the Verband der Fenster- und Fassadenhersteller (VFF), Frankfurt am Main

VFF (2004), Grunddaten zum Fenstermarkt, Arbeitstabellen des Verbandes der Fenster- und Fassadenhersteller, unpublished. Published by the Verband der Fenster- und Fassadenhersteller (VFF), Frankfurt am Main

VFF-BF (2005), Wirtschaftlichkeit von neuen Fenstern bei Nachrüstverpflichtung, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

VFF-BF (2007), In neuem Licht: Energetische Modernisierung von alten Fenstern, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

VFF-BF (2008), Amortisation von neuen Fenstern – Aktualisierung, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

VFF-BF (2010), Mehr Energie sparen mit neuen Fenstern – Aktualisierung, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

VFF-BF (2011), Mehr Energie sparen mit neuen Fenstern – Aktualisierung, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

VFF-BF (2014), Mehr Energie sparen mit neuen Fenstern – Aktualisierung, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

VFF-BF (2017), Mehr Energie sparen mit neuen Fenstern – Aktualisierung, published by the Verband der Fenster- und Fassadenhersteller (VFF) and the Bundesverband Flachglas (BF), Frankfurt am Main and Troisdorf

GEMIS 5.0, – As at April 2019, Download from iinas.org, IINAS GmbH – International Institute for Sustainability Analysis and Strategy, Darmstadt

RTG (2021), Information sheet, Förderung der energetischen Gebäudesanierung 2021: "Die neue 'BEG' und weitere Optionen", published by the Repräsentanz Transparente Gebäudehülle

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