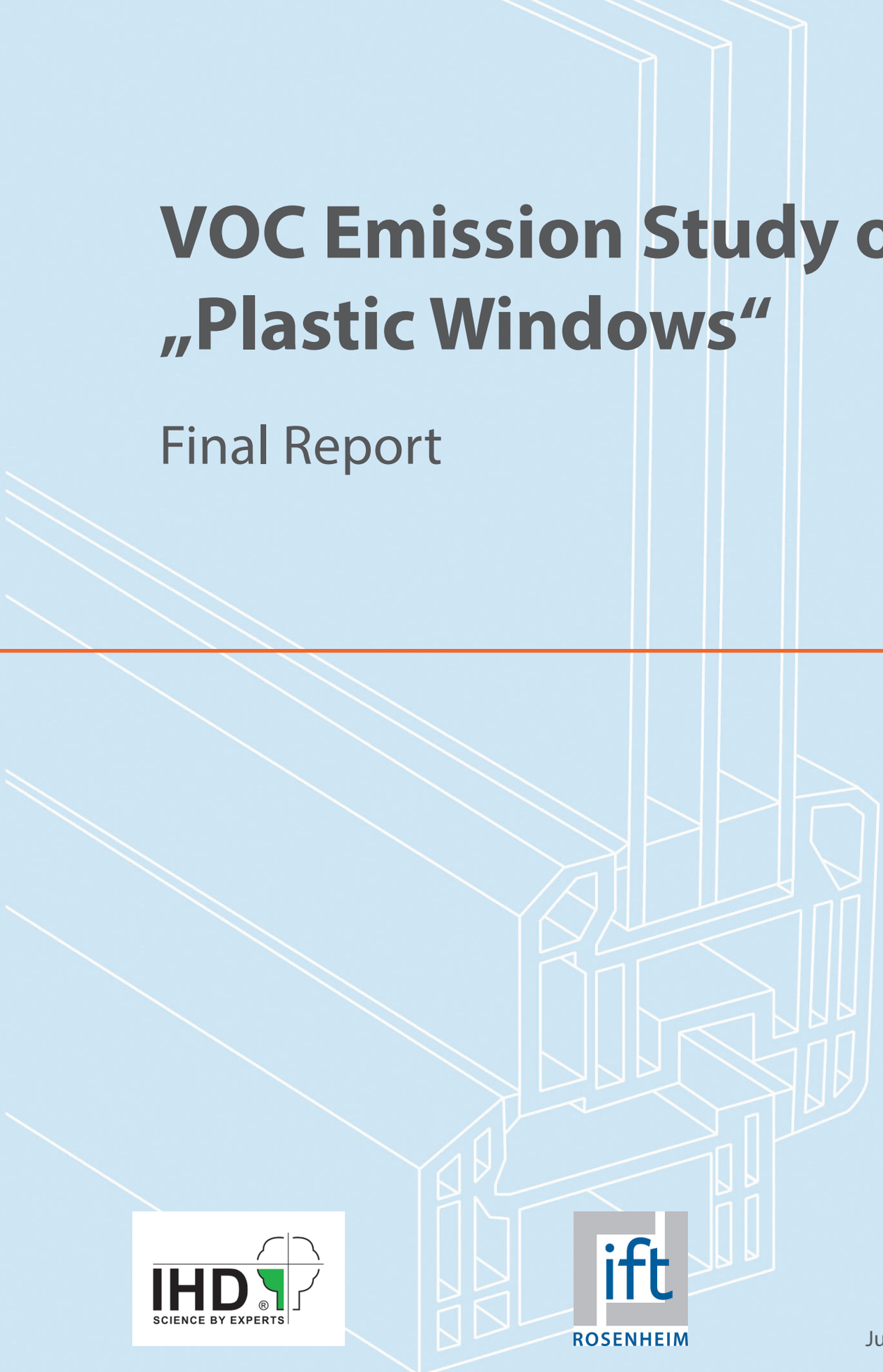
VOC Emission Study on „Plastic Windows“

Final Report



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Gütegemeinschaft Kunststoff-Fensterprofilsysteme e.V.

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July 2017

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VOC Emission Study „Plastic Windows“
No. 1516009

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1 Scope

REGULATION (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products has defined among others a basic requirement on Hygiene, health and the environment. The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition, in particular as a result of any of the following: (b) the emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air.
In order to provide an answer RAL-Gütegemeinschaft Kunststoff-Fensterprofilsysteme e.V. Bonn, Germany as representative of European plastic window profile suppliers (herein called “the industry”) initiated a study on five representative PVC windows aiming to assess whether these windows do have an impact on the indoor climate. The collective consisted of basic constructions, bonded-glazed windows, with and without decorative films, wet paint and different gasket materials to cover the current range of plastic windows on the market.
Two competent bodies (ift-Rosenheim and EPH Dresden) have been commissioned to realize measurements from different perspectives.
The present report summarizes the results of related test reports and shall provide an expert opinion, which can be used for verification purposes.

2 Investigations and results

2.1 Investigations IFT

The content of the chapter 2.1 based on the report “VOC emissions of plastic windows” [1].

2.1.1 Sampling, sample description, sample preparation

Representative selection

The purpose of the projects assigned and ordered is meant to obtain a detailed overview of VOC emissions of plastic windows. In the process, to keep the number of fest specimens as low as possible, special attention has been paid to the representative selection of test specimens.
At present, there are very versatile constructions of plastic windows that vary especially with respect to basic construction, profile design, surfaces and variants of the sealing profiles. The plastic market is dominated by a few system providers who are responsible for an additional variation in terms of the manufacturing processes and system specifications.
In the course of the project 5 systems have been selected. Based on the variation in the parameters mentioned, this selection can be considered to be representative for the market of plastic windows. Table 1 summarizes the selection and assignment of the respective parameters.

Table 1 Representative selection

Internal designation		**System 1**	**System 2**	**System 3**	**System 4**	**System 5**
Basic construction	„Standard“ glazing (triple IGU)	**X**	**X**	**X**	**X**	
	Bonded glazing					**X**
Frame profile design	„Standard“ with reinforced steel		**X**	**X**		
	Reinforced profile GRP					**X**
	Insulation material PUR				**X**	
	Recycling share	**X**				
Surface frame profile	„Standard“ PVC white		**X**			**X**
	Decorative film (on PVC white)	**X**				
	Decorative film (imbued on PVC)				**X**	
	Wet paint			**X**		
Glazing gasket	TPE inserted or rolled in		**X**			
	EPDM inserted or rolled in			**X**		**X**
	PVC-P extrusion joined	**X**			**X**	
Rebate stop seal	TPE inserted or rolled in		**X**			
	EPDM inserted or rolled in			**X**		**X**
	TPE extruded	**X**			**X**	

From all the systems shortlisted, 1-sash window elements with turn-tilt hardware and triple layer IGU were selected. The total width of the viewing surface area of the frame material was limited to 125 mm ± 5 mm. The size of the window elements ordered out was 1.23 m x 1.48 m (outer dimensions of built-in frame). This size represents a standard dimension pertaining to the product Standard EN 14351-1 [8] and is used as the basis for determining several other properties of a window.

Sampling

There is the possibility of a large impact on subsequent measured values by the manner in which the test specimen is sampled and the previous history of the components processed. In order to receive comparable, reproducible and transparent test results, hence, a detailed specification of the procedure for the sampling was necessary. The test specimens are manufactured directly by the system providers at their facility. The manufacturing process was compliant with the technical specifications, which were also specified to those processing the systems (window manufacturers). The test specimens were manufactured as far as possible just prior to the agreed test date and packed and dispatched after

completing the manufacture. The total chronological sequence from the supply of individual window components to the manufacture and right up to delivery in the test laboratory was documented in detail and the report on the specimen removal was certified. Special sampling bags made of composite aluminum material were used for dispatch in order to preserve the fresh manufacturing condition until the commencement of the laboratory analysis and to protect the specimen against contamination (see figure 1). However, longer storage periods in the packed condition should be avoided as far as possible.

Figure 1 Packed test specimen

The customary protective film used for plastic windows was initially left as it is even on the profiles of the test specimens and should be removed only just prior to starting the analyses. Over and above this, no other cleaning or similar was undertaken on the surfaces.

The detailed specifications on the procedures for sampling are documented in the IFT Final Report.

2.1.2 Chamber testing, analysis

The window elements were analysed in an emission test chamber having a volume of 20 m^3. In order to achieve the conditions of the reference room in accordance with prEN 16516 [3] the air exchange rate was adjusted slightly and also taking the limits specified into consideration. Table 2 presents the test parameters configured compared to the conditions of the reference room. Based on the identical area-specific air exchange rate, the measured values obtained can be used as input data for the evaluation method without any further conversion.

Table 2 Test Specifications and conditions of reference room

	Test chamber specification	**Reference room**
Standard	DIN EN ISO 16000-9/-11	prEN 16516:2015
Temperature	23 °C	23 °C
rel. humidity	50 %	50 %
Volume	20 m³	30 m³
Sample size	1.82 m²	2.0 m²
Loading	0.091 m²/m³	0.067 m²/m³
Air exchange rate	0,68 h^{-1}	0,5 h^{-1}
area specific air exchange rate	7.5 m³/m²h	7.5 m³/m²h

As far as emissions in the indoor air are concerned, only the surfaces inside the room can be considered for windows. This is why the reveal sides of the window and the outer surface were covered with a steel tray and sealed with aluminum adhesive tape (see figure 2). Figure 3 illustrates one of the test specimens with the stainless steel tray mounted in the test chamber.

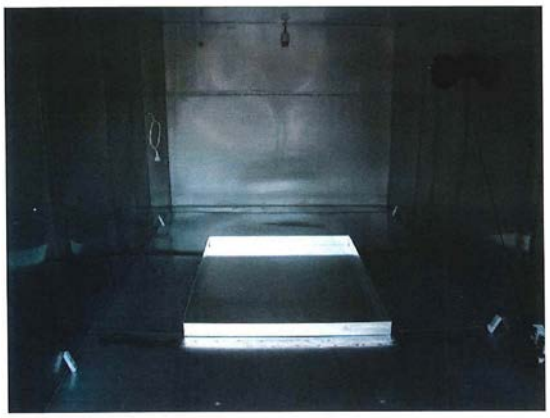

Figure 2 Stainless steel tray

Figure 3 Test specimen with stainless steel tray in the emission test chamber

Air samples were removed from the emission test chamber after 3, 7 and 28 days. In order to enable the subsequent evaluation of the measured values in accordance with the AgBB scheme and the French evaluation method (Emissions dans l air interieur), the parameters specified by the standard have been applied. Table 3 illustrates the procedure of air sample removal with the relevant parameters.

Table 3 Air sampling

Air sampling after 3, 7 and 28 days				
Parameter	**Standard**	**Sorbens**	**sampling volume**	**sampling time**
VOC	DIN ISO 16000-6	Tenax TA	5 l	50 min
Aldehydes	DIN ISO 16000-3	DNPH	50 l	25 min

2.1.3 Results

Table 4 summarizes the results with respect to an evaluation in accordance with the German AgBB scheme [10].

Table 4 Results and evaluation in accordance with AgBB scheme

	Parameter	**Unit**	**AgBB requirement**	**System 1**	**System 2**	**System3**	**System 4**	**System 5**
3 days	TVOC	µg/m³	≤ 10000 (≤ 10 mg/m³)	0	66	10	33	31
	SVOC	µg/m³		0	31	0	0	0
	R			0.000	8.674	0.000	0.009	0.011
	VOC without LCI	µg/m³		0	0	0	0	0
	Carcinogens	µg/m³	≤ 10 (≤ 0,01 mg/m³)	0	0	0	0	0
7 days	TVOC	µg/m³		0	84	7	19	30
	SVOC	µg/m³		0	113	0	0	0
	R			0.000	8.687	0.001	0.006	0.012
	VOC without LCI	µg/m³		0	0	0	0	0
	Carcinogens	µg/m³		0	0	0	0	0
28 days	TVOC	µg/m³	≤ 1000 (≤ 1,0 mg/m³)	0	536	0	23	70
	SVOC	µg/m³	≤ 100 (≤ 0,1 mg/m³)	0	0	0	0	0
	R			0.000	94.381	0.000	0.006	0.028
	VOC without LCI	µg/m³	≤ 100 (≤ 0,1 mg/m³)	0	0	0	0	0
	Carcinogens	µg/m³	≤ 1 (≤ 0,001 mg/m³)	0	0	0	0	0

System 1, system 3, system 4 and system 5 lie considerably below the requirements in all evaluation criteria. The respective substance classes cannot be verified at all to a large extent. It was very apparent that even the criteria for cancellation of measurement after 7 days were clearly met. In Germany at present, no approval according to the AgBB scheme is necessary for windows, and thus, the evaluation system is not obligatory for this product category. However, if the AgBB scheme would have been used for the evaluation, system 1, system 3, system 4 and system 5 would have been suitable for use indoors. The four window systems show only extremely low or ignorable emissions.

The requirement criteria were clearly met after 3 days for system 2. The cancellation criteria after 7 days were clearly missed with respect to the SVOC emissions and the R value; however, this does not play any decisive role for the final evaluation. While most of the requirement criteria after 28 days are still clearly met to a large extent, the R value is very clearly exceeded. In Germany at present, no approval according to the AgBB scheme is necessary for windows, and thus, the evaluation System is not binding for this product category. However, if the AgBB scheme had still been used for evaluating the measured values, then according to it, System 2 would not have been suitable for use indoors. In order to find the root cause for the unexpected and unusual emission behavior of system 2, post analyses were initiated for this purpose, which are described in Chapter 2.1.4.

French evaluation system

The results pertaining to evaluation in accordance with the French evaluation system (Emissions dans l' air Intérieur) [11] are summarized in Table 5.

Table 5 Results and evaluations in accordance with the French evaluation System (Emissions dans l' air intérieur)

French evaluation System (Emissions dans l'air interieur)			**System 1**	**System 2**	**System 3**	**System 4**	**System 5**
28 days'[1]	Formaldehyde	≤ 10	< 2	< 2	< 2	< 2	< 2
	Acetaldehyde	≤ 200	5	< 2	< 2	< 2	< 2
	Toluene	≤ 300	0	34	0	0	0
	Tetrachlorethene	≤ 250	0	0	0	0	0
	Xylene	≤ 200	0	24	0	0	52
	1,2,3-trimeliticacid	≤ 1.000	0	0	0	0	0
	1,4-dichlorbenzene	≤ 60	0	0	0	0	0
	Ethylbenzene	≤ 750	0	6	0	0	0
	2-Butoxyethanol	≤ 1.000	0	0	0	0	0
	Styrol	≤ 250	0	0	0	0	0
	TVOC	≤ 1.000	2	587	0	23	79

*[1] Limit values for the best possible class A+.

System 1, system 3, system 4 and system 5 very clearly meet the requirements of the best possible class A+. The respective individual substances cannot be verified at all to a large extent.
Even system 2 early meets the requirements of the best possible class A+. Compared to the other systems, however, with system 2, more than 50% of the TVOC limit value specified in France is already reached. As already established with the AgBB evaluation, compared to the other systems, however, even in the course of the French evaluation, a considerably different pattern of system 2 is identifiable compared to the other systems analysed.

2.1.4 Post analysis

Detail analysis of the measured values

While the emissions of system 1, system 3, system 4 and system 5 can definitely be assessed as negligible, system 2 revealed a considerably different emission pattern. Comprehensive follow-up investigations were conducted to analyse the circumstances in detail. For a more accurate analysis and assessment, the detailed emissions of the test conducted on system 2 are itemised once again in Table 6.

Table 6 Detected substances of System 2

Detected substances	**CAS No.**	**Retention range**	**Measured value in µg/m³**		
			3 days	**7 days**	**28 days**
Satured aliphatic hydrocarbons higher than C9		VOC	40	41	144
Satured aliphatic hydrocarbons higher than C16		SVOC	31	113	-
Decanal	112-31-2	VOC	1	-	-
BHT	128-37-0	VOC	4	4	8
2-Methoxyethanol	109-86-4	VOC	26	26	282
Ethylmethylketone	78-93-3	VOC	2	2	3
Bis(2-ethylhexyl) phthalate	117-81-7	SVOC	1	-	-
Other aliphatic hydrocarbon		VVOC	8	9	11
Acetone	67-64-1	VVOC	26	6	13
Formaldehyde	50-00-0	VVOC	-	-	-
n-Undecane	1120-21-4	VOC	-	3	2
n-Dodecane	112-40-3	VOC	-	3	1
n-Tridecane	629-50-5	VOC	-	4	1
n-Tetradecane	629-59-4	VOC	-	1	-
n-Hexadecane	544-76-3	VOC	-	2	-
n-Octadecane	593-45-3	SVOC	-	1	-
Octanal	124-13-0	VOC	-	1	-
Nonanal	124-19-6	VOC	-	5	-
Decanal	112-31-2	VOC	-	12	-
Benzaldehyde	100-52-7	VOC	-	2	4

2-Ethyl-1-hexanol	104-76-7	VOC	-	1	4
Toluene	108-88-3	VOC	-	-	34
Ethylbenzene	100-41-4	VOC	-	-	6
Xylene	1330-20-7	VOC	-	-	24
Isopropylbenzene	98-82-8	VOC	-	-	1
n-Propylbenzene	103-65-1	VOC	-	-	2
1,3,5-Trimethylbenzene	108-67-8	VOC	-	-	2
1,2,4-Trimethylbenzene	95-63-6	VOC	-	-	9
1,2,3-Trimethylbenzene	526-73-8	VOC	-	-	2
2-Ethyltoluene	611-14-3	VOC	-	-	2
1,2,4,5-Tetramethylbenzene	95-93-2	VOC	-	-	1
Styrene	100-42-5	VOC	-	-	1
n-Hexane	110-54-3	VOC	-	-	17
Cyclohexane	110-82-7	VOC	-	-	3
n-Heptane	142-82-5	VOC	-	-	4
n-Octane	111-65-9	VOC	-	-	1
n-Decane	124-18-5	VOC	-	-	2
3-Caren	498-15-7	VOC	-	-	1
Alpha-Pinen	80-56-8	VOC	-	-	3
Pentanal	110-62-3	VOC	-	-	1
Hexanal	66-25-1	VOC	-	-	3
Octanal	124-13-0	VOC	-	-	1
1-Butanol	71-36-3	VOC	-	-	5
Phenol	108-95-2	VOC	-	-	2
Benzylalcohol	100-51-6	VOC	-	-	1
Diethylenglycol monobutylether	112-34-5	VOC	-	-	1
Acetophenone	98-86-2	VOC	-	-	1
1-Butylacetate	123-86-4	VOC	-	-	1

In the course of the AgBB evaluation and evaluation according to the French evaluation system, the unexpectedly high TVOC values were noticeable. This summation of the VOC substances found is primarily attributable to 4 substances or substance classes:

- Satured aliphatic hydrocarbons higher than C9,
- 2-Methoxyethanol,
- Toluene and
- Xylene.

The AgBB criteria being missed are, however, attributable to the substance 2-methoxy-ethanol. Based on a very low LCI-value for this substance, there is an enormous contribution to the R value. In the French evaluation method (Emissions dans l' air intérieur), this substance is, in fact, also involved in the summation of the TVOC value, but special evaluation based on the low LCI-values does not take place in this evaluation method.

After clarifying with the manufacturer of System 2 as well as the associated suppliers, no source could be assigned at first within the window system.

A few original areas of application could be identified. These as well as interfaces to system 2 that can possibly be assigned are listed in Table 7.

Table 7 Areas of application and interface substances

Application 2-Methoxyethanol	**Possible interfaces to System 2**	**Notes**
Products made of natural rubber and plastic	Adhesive protective film	- The protective film is removed prior to the test and any adhesive residues on the profile - Protective films were there on all systems, but this substance was found only with system 2
	Sealing profile	- According to information from the manufacturers, not a constituent of the formulation or not used in production - Until now, not detected in connection with sealing profiles
Production and Processing of plastics	Plastic profile	- According to information from the manufacturers, not a constituent of the formulation or not used in production - Until now, not detected in connection with plastic profiles
Industrial solvents for lacquers and cleaning agents for surfaces	Use in production	- Difficult to track if used only sporadically and not regularly
Lubricants or auxiliary materials	Use in production	- Difficult to track if used only sporadically and not regularly
Solvents for lacquers and paints	None	- No use of lacquers or paints with system 2
Solvents for PCB manufacture	None	- No relation to system 2
Dyeing of leather	None	- No relation to system 2

<u>Emissions from the protective film</u>

A few areas of application of the substance could be ruled out from the very beginning. Queries and clarifications sought from the manufacturer regarding cleaning agents or other auxiliary materials remain inconclusive. Hence, in a follow-up analysis the protective film used, the sealing profile as well as the plastic profiles from the window element were analyzed separately.

The protective film used originally on the test specimen was no longer available at the time of the follow-up analysis. Hence, the protective film was ordered out in new condition from

the manufacturer and tested in an emission chamber. The actual adhesive surface was kept exposed in the process and kept in the emission test chamber with considerably increased load. This is why the measured values cannot be used for evaluations or comparisons of the individual components, but can only be understood as a general statement on the emission pattern.

The substances found for the protective film are summarized in Table 8. However, the substance 2-methoxyethanol was not found. The emissions also show no indication that the protective film or possible residues of the adhesive on the plastic profile could be responsible for the present emission pattern of system 2.

Table 8 Detected substances follow-up analysis protective film

Detected Substances	**CAS No.**	**Retention range**	**results after 3 days in µg/m³**	**results after 7 days in µg/m³**
Naphthaline	91-20-3	VOC	1	-
n-Undecane	1120-21-4	VOC	1	-
n-Dodecane	112-40-3	VOC	5	-
n-Tridecane	629-50-5	VOC	11	2
n-Tetradecane	629-59-4	VOC	2	-
other Terpene		VOC	5	-
1-Butanol	71-36-3	VOC	25	4
Propylene carbonate	108-32-7	VOC	88	47
Acetic acid	64-19-7	VOC	3	-
Dipropylene glycol monomethylether	34590-94-8	VOC	-	1
2-Methyl-4-isothiazolin-3-one	2680-20-4	VOC	-	1

Substances in profiles

As far as the sealing profile and the plastic profile of system 2 are concerned, specimens were removed directly from the original test specimen and used for further analysis. The small specimens were not analysed for emissions at room temperature, but with reference to the contents of relevant substances. For this purpose, the specimens were subjected to an extract and headspace analysis with subsequent evaluation using gas chromatography. This is why the results cannot be used for evaluations or comparisons of the individual components, but can only be understood as a general statement on the possible emission.

The substances found for the sealing profiles and the frame profile are summarized in Table 9. As expected, substances were found in all 3 specimens analysed that can also occur as VOC emissions. Only extremely minor traces of the substance 2-methoxyethanol were found in the glazing gasket. The scale of the quantity found near the verification limit, does not permit any complete verification on the content of the substance within the specimen. Possibly, this was brought on the surface of the specimen in the form of contamination (e.g. by cleaning agents or other manufacturing influences).

Table 9 Detected substances of the post analysis of sealing profile and plastic profile in mg/kg

Detected substances	**CAS no.**	**Retention range**	**sealing profile glazing**	**sealing profil stop seal**	**plasic profile**
2-Methoxyethanol	109-86-4	VOC	< 5	-	-
Diisononyl phtalate (DINP)	28553-12-0	-	4	-	-
Diisodecyl phthalate (DIDP)	26761-40-0	-	-	130000	-
Aliphatic hydrocarbons	-	-	-	1100	21000
Butylated hydroxytoluene (BHT)	128-37-0	VOC	-	8000	
a-Pinene	80-56-8	VOC	-	-	8
Carene	-	-	-	-	10
Terpenoid hydrocarbons	-	-	-	-	7
Bis(butyl)-(chorbenzo-triazolyl)-phenol	-	-	-	-	160
Octyladipat-Isomer	-	-	< 1		
Aromatic Ester	-	-	-	30	
Long-chained alkylbenzene	-		-	-	31
Non-allocatable hydrocarbons	-	--	2	300	230

In the course of the post analysis conducted, no clear evidence for the source of the emissions of 2-Methoxyethanol and thus, the AgBB requirements not being met, could be found. The low quantity of the substance in the gasket of the glazing permits suspicion of contamination in the course of the production chain. No other follow-up tests or repetition of the analysis on system 2 could be conducted in the course of this project.

2.2 Investigations EPH

The tests are described in the reports 2514534 parts 1 and 2 dated 2015-06-11 and 2015-07-21. [12], [13].

2.2.1 Sampling, sample description, sample preparation

The windows were sent by the producer to the test Laboratory directly.

Product description

Window 1:

Product name:	Plastic window
Producer:	company A (company is known)
Production date:	2015-02-03
Dimension:	1480 mm x 1230 mm
Sample receipt:	2015-02-23

Window 2:

Product name:	Plastic window
Producer:	company B (company is known)
Production date:	2015-03-31
Dimension:	1480 mm x 1230 mm
Sample receipt:	2015-04-09

2.2.2 Chamber tests

The windows were placed into a test chamber according to ISO 16000-9 (figure 4) after unpacking under the following conditions:

Chamber size:	6 m³
Temperature:	23 °C ± 2 K
Air humidity:	50 % ± 5 %
Air exchange rate:	0.5 / h ± 3
Loading without glass:	0.13 m²/m³
Loading with glass:	0.30 m²/m³
Emission area without glass	0.77 m²
Emission area with glass	1.82 m²

Figure 4 Window position in the 6 m³ test chamber (left: windows 1, right: window 2)

The following measurements were carried out:

	measurement 1	measurement 2	measurement 3	measurement 4
window 1	2015-03-02	2015-03-06	2015-03-13	2015-03-27
window 2	2015-04-23	2015-04-27	2015-05-06	2015-05-18

Before the tests started the not emission relevant areas were sealed with aluminum foil.

2.2.3 Analysis

Volatile organic compounds (VOC) – ISO 16000 part 6

The determination of the VOC was carried out by gaschromatography after previous adsorption on tenax and following thermodesorption with cryo focussion (GC-MS).

Sample air volume: 3 – 5 L
Volume flow rate: 0.1 L/min
Detection limit: 1 to 3 µg/m³ (2 L sample volume)

Formaldehyde/aldehydes – ISO 16000 part 3

The determination of formaldehyde and other aldehydes was carried out by DNPH-method.

Sample air volume: 90 - 120 L
Volume flow rate: 1 L/min
Detection limit: 1 to 3 µg/m³

2.2.4 Results

The conditions of the technical specification DIN CEN TS 16516 are taken as basis for the evaluation of the results according to the requirements of the AgBB scheme and the French VOC regulation as well for the normalization of measured results regarding loading.

In DIN CEN TS 16516 Point 4.2.2, a loading in the test chamber of 0.05 m^2/m^3 is designated for building products with small surfaces. Under the prevailing test conditions, the loading in the 6 m^3 test chamber is 0.30 m^2/m^3 regarding the surface that emits into the room.

The following results were determined under the conditions stated in point 2.2.2.

Window 1

Table 10: VOC emission in [µg/m^3] – window 1

Compound	**concentration [µg/m^3]**			
	3. day	**7. day**	**14. day**	**28. day**
1-Propanol	3	6	n.d.	n.d.
2-Methoxyethanol	164	136	124	117
Toluene	2	5	6	4
Hexamethylcyclotrisiloxan	n.d.	4	4	5
Benzaldehyde	4	3	4	5
Acetophenon	2	n.d.	n.d.	2
Butylhydroxytoluen (BHT)	4	4	3	4
Sum VOC	**179**	**158**	**141**	**137**

n.d. not detected

Table 11: Aldehyde emission in [µg/m^3] – window 1

Compound	**concentration [µg/m^3]**			
	3. day	**7. day**	**14. day**	**28. day**
Formaldehyde	3	4	2	3
Acetaldehyde	9	8	8	7
Acroleine	n.d.	n.d.	n.d.	n.d.
Propionaldehyde	n.d.	n.d.	n.d.	n.d.
Crotonaldehyde	n.d.	n.d.	n.d.	n.d.
Methacroleine	n.d.	n.d.	n.d.	n.d.
Butyraldehyde	n.d.	n.d.	n.d.	n.d.
Benzaldehyde	n.d.	n.d.	n.d.	n.d.
Valeraldehyd	n.d.	n.d.	n.d.	n.d.
Tolualdehyde	n.d.	n.d.	n.d.	n.d.
Hexanal	n.d.	n.d.	n.d.	n.d.

n.d. not detected

Table 12: VOC emission in [µg/m³], measured values normalized to a loading factor of 0.05 m²/m³ window 1

Compound	**LCI value* [µg/m³]**	**concentration [µg/m³] 3. day**	**R_i value**	**concentration [µg/m³] 28. day**	**R_i value**
**Formaldehyde	-	n.d.	--	n.d.	-
**Acetaldehyde	1200	1	0.001	1	0.001
2-Methoxyethanol	3	27	9.000	20	6.667
Toluene	1900	n.d.	-	1	0.001
Hexamethylcyclotrisiloxan	without LCI	n.d.	-	1	-
Benzaldehyde	90	1	0.011	1	0.011
Acetophenon	490	n.d.	-	1	0.002
Butylhydroxytoluen (BHT)	100	1	0.010	1	0.010
Sum VOC		**29**		**26**	
TVOC		**27**		**20**	

* LCI list 2012 TVOC - compounds starting 5 µg/m³

** formaldehyde and acetaldehyde are listed in table 13 because they are to be evaluated according to French VOC regulation

Evaluation according to AgBB scheme – Window 1

Table 13: Evaluation according to AgBB scheme 2012; measured values normalized to a loading factor of 0.05 m²/m³ – window 1

	unit	**requirement**		**result**	
		3d	**28d**	**3d**	**28d**
TVOC	mg/m³		≤ 1.0	0.027	0.020
TSVOC	mg/m³	-	≤ 0.1	n.d.	n.d.
R value		-	≤ 1	**9.022**	**6.692**
VOC without LCI	mg/m³	-	≤ 0.1	n.d.	0,001
cancerogene	mg/m³	≤ 0.01	≤ 0.001	n.d.	n.d.
formaldehyde	mg/m³	-	≤0.12	n.d.	n.d.
requirements fulfilled?					**NO**

Window 2

Table 14: VOC emission in [µg/m³] – window 2

Compound	**concentration [µg/m³]**			
	3. day	**7. day**	**14. day**	**28. day**
Hexane	35	2	1	1
Cyclohexane	5	5	1	3
Hexanal	7	1	n.d.	n.d.
o,m,p Xylene	3	2	n.d.	n.d.
Benzaldehyde	12	4	1	2
Octanal	6	1	n.d.	n.d.
Acetophenone	8	3	1	1
Nonanal	12	3	1	n.d.
Decanal	10	2	1	n.d.
n.i.	3	n.d.	n.d.	n.d.
Sum VOC	101	23	6	7

n.i. not identified
n.d. not detected

Table 15: Aldehyde emission in [µg/m³] – window 2

Compound	**concentration [µg/m³]**			
	3. day	**7. day**	**14. day**	**28. day**
Formaldehyde	7	8	8	2
Acetaldehyde	7	5	11	13
Acroleine	n.d.	n.d.	n.d.	n.d.
Propionaldehyde	3	3	3	n.d.
Crotonaldehyde	n.n.	n.d.	n.d.	n.d.
Methacroleine	5	5	4	n.d.
Butyraldehyde	n.d.	n.d.	n.d.	n.d.
Benzaldehyde	4	3	n.d.	n.d.
Valeraldehyde	n.d.	n.d.	3	n.d.
Tolualdehyde	n.d.	n.d.	n.d.	n.d.
Hexanal	4	3	3	n.d.

n.d. not detected

Table 16: VOC emission in [µg/m³], measured values normalized to a loading factor of 0.05 m²/m³ window 2

Compound	**LCI value* [µg/m³]**	**concentration [µg/m³] 3. day**	**R_i value**	**concentration [µg/m³] 28. day**	**R_i value**
**Formaldehyde	-	3	-	n.n.	-
**Acetaldehyde	-	3	-	1	-
Hexane	72	13	0,181	n.d.	n.c.
Cyclohexane	7000	2	n.c.	n.d.	n.c.
Hexanal	890	3	n.c.	n.d.	n.c.
o,m,p Xylene	2200	1	n.c.	n.d.	n.c.
Benzaldehyde	90	5	0,056	n.d.	n.c.
Octanal	1100	2	n.c.	n.d.	n.c.
Acetophenone	490	3	n.c.	n.d.	n.c.
Nonanal	1300	5	0,004	n.d.	n.c.
Decanal	1400	4	n.c.	n.d.	n.c.
not identified	-	1	-	n.d.	-
Sum VOC		**45**		**n.d.**	
TVOC		**23**		**n.d.**	

* LCI list 2012 TVOC - compounds starting 5 µg/m³ n.c.-not calculated, due c ≤ 5 µg/m³
** formaldehyde and acetaldehyde are listed in table 15 because they are to be evaluated according to French VOC regulation

Evaluation according to AgBB scheme – Window 2

Table 17: Evaluation according to AgBB scheme 2012; measured values normalized to a loading factor of 0.05 m²/m³ – window 2

	unit	requirement		result	
		3d	**28d**	**3d**	**28d**
TVOC	mg/m³	≤ 10	≤ 1.0	0.023	n.d.
TSVOC	mg/m³	-	≤ 0.1	n.d.	n.d.
R value		-	≤ 1	0.241	0.000
VOC without LCI	mg/m³	-	≤ 0.1	n.d.	n.d.
cancerogene	mg/m³	≤ 0.01	≤ 0.001	n.d.	n.d.
formaldehyde	mg/m³		≤0.120	0.003	0.003
requirements fulfilled?					**Yes**

Within the testing task, the changes in the LCI value list between 2015 and 2012 concern only the following compounds:
- formaldehyde, for which a LCI value of 100 µg/m³ was specified
- toluene (only window 1), whose LCI value was increased from 1900 µg/m³ (2012) to 2900 µg/m³

These changes have practically no influence on the evaluation of the examination results according to the AgBB scheme.

Evaluation according to the French VOC regulation

Table 18: Requirement and VOC emission in [µg/m³], normalized to a loading factor of 0.05 m²/m³ windows 1 und 2

Parameter	**Class**				**window 1**	**window 2**
	C	B	A	A+		
Formaldehyde	> 120	< 120	< 60	< 10	1	n.d.
Acetaldehyde	> 400	< 400	< 300	< 200	3	1
Toluene	> 600	< 600	< 450	< 300	2	n.d.
Tetrachlorethylen	> 500	< 500	< 350	< 250	n.d.	n.d.
Xylol	> 400	< 400	< 300	< 200	n.d.	n.d.
1,2,4-Trimethylbenzene	> 2000	< 2000	< 1500	< 1000	n.d.	n.d.
1,2-Dichlorbenzene	> 120	< 120	< 90	< 60	n.d.	n.d.
Ethylbenzene	> 1500	< 1500	< 1000	< 750	n.d.	n.d.
2-Butoxyethanol	> 2000	< 2000	< 1500	< 1000	n.d.	n.d.
Styrene	> 500	< 500	< 350	< 250	n.d.	n.d.
TVOC value	> 2000	< 2000	< 1500	< 1000	70	n.d.
classification					**A+**	**A+**

n.d. not detected

Table 19: Compliance with the requirements or classification in emission classes regarding several regulations, normalized to 0.05 m²/m³

evaluation base	window 1	window 2
AgBB scheme 2012	No	Yes
AgBB scheme 2015	No	Yes
French VOC Regulation	A+	A+
Belgian VOC Regulation	No	Yes

2.2.5 Additional tests – window 1

Within the examinations of window 1, 2-Methoxyethanol was found in a concentration that impedes the compliance with the R-value which is one of the evaluation criteria of AgBB scheme and Belgian VOC regulation

The tests and results are descripted in the report 2514534 part 1 dated 2015-06-11 [12].

Emission tests of the sealing and the frame materials were carried out in a µ-test chamber in order to identify the emission source.

Sample name

Sample 1	PVC profile
Sample 2	sealing glazing/frame
Sample 3	sealing casement/frame

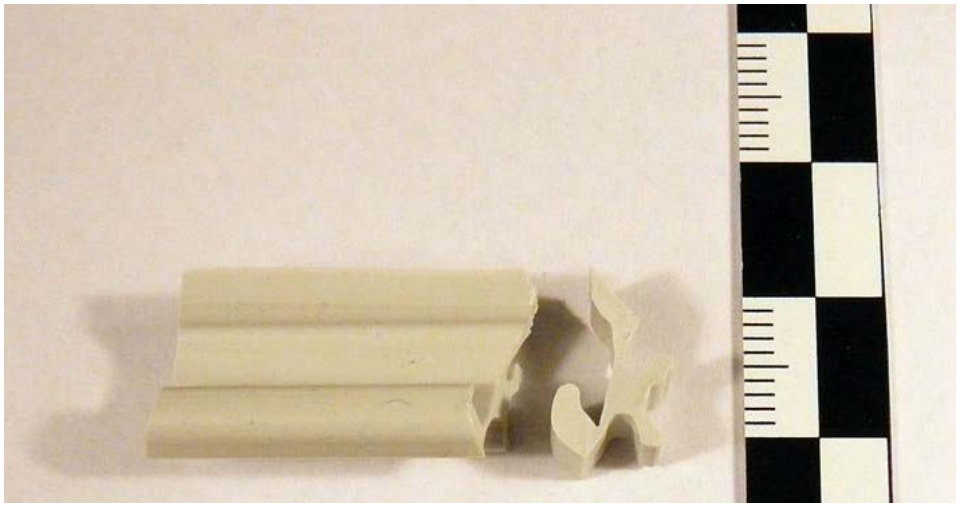

Figure 5: Sealing glazing/frame (sample 2)

Test method

Approximately 0.5 g of the sample material were placed in the µ-test chamber and conditioned for 10 min at 30 °C. Afterwards the sampling was started. Sampling was carried out on TENAX TA adsorption tubes during 30 min. 3 L of sample air are conducted through the tube within this sampling time. Subsequently the adsorption tube is analyzed according to ISO 16000-6. The identification of 2-Methoxy ethanol was carried out substance-specifically by retention time and device-specific mass spectrum.

Test conditions in the µ-chamber

Temperature	30 °C
Air humidity	< 10 % (cleaned compressor air)
Air volume flow	100 mL/min
Air exchange rate	125 per hour

Results

Table 20: Release of 2-Methoxyethanol from window materials

	concentration of 2-Methoxyethanol [µg/m³]
sample 1 - PVC profile	not detected
sample 2 - sealing glazing/frame	784
sample 3 - sealing casement/frame	28

The results show, that:

- There is no 2-Methoxy ethanol contained in the PVC.
- Significant amounts of 2-Methoxy ethanol emit from the sealing glazing/frame. Therefore this material is a possible source for this critical compound.
- Small amounts of this compound are emitting from the sealing casement/frame. This is caused with a high degree of probability by a secondary contamination by the source.

2.2.6 Additional tests – plastic granulate material and sealing material

The tests and results are descripted in the report 2515264 dated 2015-06-23 [14].

The release of 2-Methoxyethanol from plastic granulate material and profile sample with sealing material was determined with a µ-chamber.

The following samples were tested:

Sample 1: Granulate material
Sample 2: Sealing material, taken from the profile sample
Sample 3: piece of profile with sealing material

The test method is equivalent to the method descripted in point 2.2.5.

Results

Table 21: Release of 2-Methoxyethanol from window materials

	concentration [µg/m³]
Sample 1 Granulate material	not detected
Sample 2 Sealing material	not detected
Sample 3 profile	not detected

2-Methoxyethanol was not detected from the tested materials.

2.2.7 Additional tests – insulated glazing sample

The tests and results are descripted in the report 2515381 dated 2015-07-22 [15].

The release of 2-Methoxyethanol from an insulated glazing sample was determined by use of an emission test chamber.

Product description

Product:	insulated glazing sample
Producer:	company A (company is known)
Production date:	2015-07-14
Size:	400 mm x 250 mm

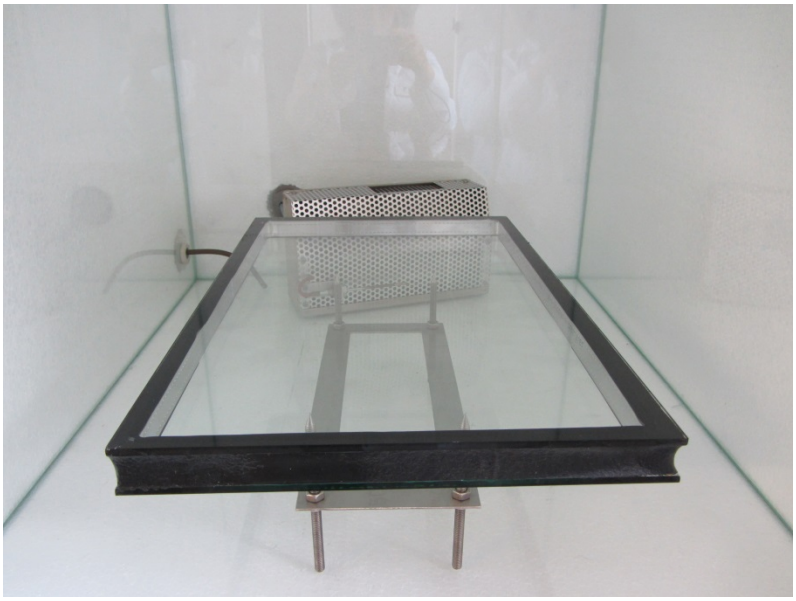

Figure 6: Position of the sample in a 225 L emission test chamber

Test conditions

Chamber size:	225 L
Temperature:	23 °C ± 2 K
Air humidity:	45 % ± 5 %

Air exchange rate:	1.0 / h ± 3
Loading without glass:	0.09 m²/m³
Loading with glass:	0.89 m²/m³
Emission area without glass	0.0208 m²
Emission area with glass	0.200 m²

The following measurements were carried out.

2015-07-17	3 hour after test start
2015-07-20	3 days after test start

Analysis is descripted in Point 2.2.3.

Table 23: 2-Methoxyethanol concentration in the chamber air, measured value and normalized to a loading of 0.05 m²/m³ and an air change rate of 0.5 per hour

	concentration [µg/m³]	
	measured value	**normalised value**
3 hour after test start	409	454
3 days after test start	1165	1294

The emission tests show:

- High 2-Methoxyethanol concentrations in the chamber air,
- a significant increase of the concentration in the chamber air within of 3 days,
- The material of the insulating glass edge sealing is the source of the 2-Methoxyethanol release.

VOC emission tests of plastic windows performed by ift Rosenheim show a critical emission of one window. In the emission of this sample the compound 2-Methoxyethanol was found with the result that the requirements according AgBB scheme were not met. In addition to the emission tests of complete products window components (sealing profile glazing, sealing profile stop seal and plastic profile) were tested separately. No 2-Methoxyethanol content was found in the tested materials.

Further on tests were carried out by EPH to find the emission source of 2-Methoxyethanol. The investigations started with the VOC emission test of two complete windows and continued with single material tests. One window showed a high 2-Methoxyethanol emission level so that the DIBt requirements were not met too. In the next steps single materials were tested. The following tests were performed:

Test series A Emission test of material of window 1 (PVC profile, sealing glazing/frame, sealing casement/frame) using µ-chamber

Test series B Emission tests of separate plastic raw material (plastic granulate, profile sample with sealing material)

Test series C Emissions tests of an insulated glazing sample using test chamber (3 day test)

The tests of series A and B showed no release of 2-Methoxyethanol. Therefore the tested materials could be excluded as sources of the 2-Methoxyethanol emission of the investigated windows.

In the chamber air of the insulated glazing sample (test series C) a high emission of 2-Methoxyethanol was detected. It can be therefore concluded that the insulating glass edge sealing of this sample is the source of this compound.

2-Methoxyethanol (CAS 109-86-4)

Other names are: e.g. Methyl glycol, Ethylene glycol monomethyl ether, EGME, Methyl cellosolve,
Used e.g. as solvent for lacquers and paints, in cleaning agents for surfaces, was replaced from 1980 on by e.g. 1-Methoxy-2-propanol (CAS 107-98-2)

Selected properties	
Boiling point:	124 °C
Vapour pressure:	8 hPa
Density:	0.97 g/cm³
Solubility:	miscible with water
Classification/labelling:	According to the harmonised classification and labelling approved by the European Union, this substance may damage fertility and may damage the unborn child, is a flammable liquid and vapour, is harmful if swallowed, is harmful in contact with skin and is harmful if inhaled.
MAK	3.2 mg/m³
LCI value (AgBB)	3 µg/m³

Attention should be paid to the fact that 2-Methoxyethanol is a substance of very high concern (SVHC) and is included in the candidate list of ECHA (European Chemicals Agency).

3 Summary/Conclusions

The research institute ift Rosenheim and the developmental and testing laboratory EPH performed extensive investigations to determine VOC emissions from plastic windows. In one product the emission of 2-Methoxyethanol was found.

In summary it can be said that PVC-U windows do not significantly emit VOC. The fact that 2-Methoxyethanol has been identified in a component of one of the windows could be regarded as an isolated incident.

Especially in view of the classification of 2-Methoxyethanol as SVHC (substance of very high concern) the use of this substance should be prevented in window materials. It is therefore recommended that the industry implements quality control measures along the value chain.

4 Literature

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