PU Europe
Factsheet
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Indoor air quality and polyurethane insulation

Executive summary

People spend about 90 % of their life in buildings. Maintaining a healthy indoor climate, which includes minimising the presence of volatile organic compounds (VOC) and particles (such as fibres) is, therefore, of the utmost importance. This is further accentuated by the need to make building envelopes air-tight in order to avoid thermal losses.

Thermal insulation products have a key role to play in reducing the energy demand of new and existing buildings. They are usually not in direct contact with the indoor air but covered by other building materials such as gypsum/plasterboards, wood, bricks or concrete. Their impact on the indoor air quality (IAQ) is therefore negligible. Even though all construction products put together will only have a very minor impact on the IAQ, industry recognises the need to provide transparent information on VOC emissions from its products.

In the framework of the EU's construction products legislation, CEN develops harmonised test methods for indoor air emissions based on the ISO16000 series. Declarations will probably be done according to national class systems, which will have to be compatible with the European communication format currently under development.

The PU industry has already proactively published VOC/SVOC emission data. They prove that PU insulation is a very low emission product fully suitable for indoor use. As regards MDI, recognised product emission test methods demonstrated that there are no measurable airborne emissions from installed PU insulation products. Even under worst case indoor test conditions, no emissions of monomeric MDI could be identified from cured PU foam after 24 hours.

PU equally shows excellent performance levels regarding other health-related issues. As PU does not provide breeding-ground or food for mould, bacteria or insects, no microbial species/compounds are emitted. The need for air-tight building envelopes may cause problems relating to condensation, which can occur in the insulation layer of walls and roofs if a material with low vapour resistance is used. Thanks to its very low permeability, PU will not be affected.

Looking at the installation phase, there is no evidence of dermal risks when working with PU foam (cutting, placing, etc.). On the other hand, special health and safety requirements must be observed when applying PU in-situ foam and the spraying should only be executed by duly qualified professional applicators.

What is PU?

PU insulation stands for a group of insulation materials based on PUR (polyurethane) or PIR (polyisocyanurate) structures. Their closed cell structure and high cross-linking density give them the characteristics of good heat stability, high compressive strength and excellent insulation properties. PU insulation has a very low thermal conductivity, starting from as low as 0.022 W/mK, making it one of the most effective insulants available today for a wide range of applications.

As PU features very low emission levels and is extremely versatile, it is also widely used in applications outside the construction industry. This includes the food chain, medical devices, clothes, mattresses, car parts and fridges.

PU EUROPE
EXCELLENCE IN INSULATION

Insulation and indoor air climate

"Thermal insulation has a crucial role to play in maintaining indoor comfort while achieving nearly zero energy demand levels..."

Whether in dwellings, schools, offices, factories or shopping centres, people spend about 90 % of their life in buildings. Ensuring a healthy and comfortable indoor climate while meeting highest energy efficiency requirements is therefore of paramount importance.

Thermal insulation has a crucial role to play in maintaining indoor comfort while achieving nearly zero energy demand levels for Europe's new buildings and drastically reducing energy demand in the existing building stock. Thanks to its premium insulation performance and durability, PU (PUR/PIR) is the material of choice to reach these targets. However, thicker insulation layers are required today to achieve highly thermally resistant building envelopes even when the best performing insulation products such as PU is used. This in turn could lead to higher emissions of substances from these products.

One may argue that thermal insulation products are usually not directly exposed to the indoor air but covered by other building materials such as gypsum/plasterboards, wood, bricks or concrete and that potential emissions from the insulation layer cannot get in contact with the indoor air.

However, these covering layers may not be gas-tight or may be perforated for the installation of technical building systems. Furthermore, the building owner/user have the right to be informed about the potential hazards linked to the construction products used in his building.

PU Europe is committed to communicating third party verified test results regarding the effects of using PU insulation in buildings. This factsheet looks at emissions of dangerous substances from PU insulation products and the role PU can play in avoiding humidity and mould problems in low energy buildings.

Emissions of dangerous substances to the indoor air

"...the sum of all construction products represents only a very minor contributor to the burden of disease which quantifies the amount of disease caused by indoor air pollution".

The indoor air quality of a building is determined by multiple factors including its use patterns (human presence, smoking, cooking, fire places, etc.), heating, ventilation rates and emissions from furniture, paints and construction products. As shown in *figure 1*, the sum of all construction products represents only a very minor contributor to the burden of disease which quantifies the amount of disease caused by indoor air pollution. Still, producers of building materials have to ensure that their products cannot cause any harm to the users of buildings.

Essential Requirement n°3 of the Construction Products Directive, replaced by the Basic Requirement for Construction Works n°3 of the Construction Products Regulation, requires works to be designed and built in such a way that they will not pose a threat to the hygiene or health and safety of their occupants [1]. This includes emissions of dangerous substances, volatile organic compounds (VOC), greenhouse gases or dangerous particles into indoor or outdoor air, and dampness in parts of the construction works or on surfaces within the construction works.

Responding to the indoor air part of this provision, the European Commission mandated CEN to develop a harmonised test standard to measure VOC and SVOC emissions from construction products [2].

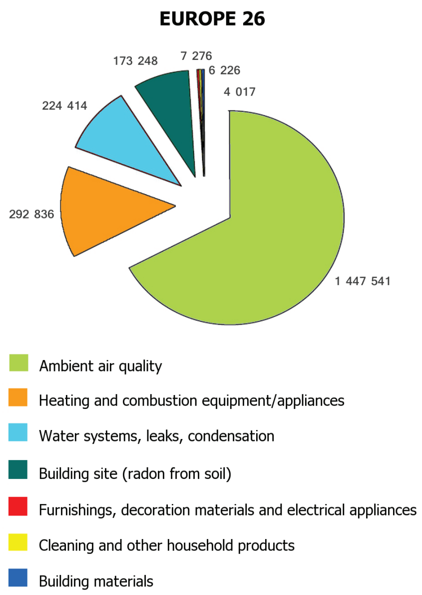

Figure 1: The IAQ associated Burdon of Disease attributed to the key sources of exposure [3]

The method is based on the international standard ISO16000-9. The ISO standard is already used today in a number of Member States including Germany (AgBB scheme), France (decree n°2011-321) and the voluntary Finnish M1 scheme. The CEN test method is currently available as Technical Specification TS 16516. It should be published as CEN standard in 2016 and will replace ISO16000-9.

Towards harmonised European technical classes

"Any new national scheme would probably have to apply the harmonised format".

With a view to harmonising declarations of emissions, the European Commission undertook to combine the German AgBB scheme and the French decree n°2011-321. They represent the first two schemes notified to the Commission. In the meantime, Belgium introduced its own system which features elements of both the German and the French schemes. Also the new Lithuanian scheme should be compatible with the other systems in place.

The harmonisation process for the LCI values (Lowest Concentration of Interest) is not finalised yet. The LCI approach was developed to assess the health effects of compounds from building materials. It was originally part of a basic scheme for the evaluation of VOC emissions.

In late 2014, the Commission presented a revised proposal for harmonised technical classes. If approved, it would be published through a Delegated Act. While France, Belgium, Germany and Lithuania could continue to use their own communication formats, they would have to maintain compliance with the European scheme. Any new national scheme would probably have to apply the harmonised format. For example, the French A+ level would correspond to the European A-f1 or B-f1 classes (see below).

Unfortunately, the proposal is unlikely to be adopted any time soon with Poland having notified another scheme to the Commission. It dates from 1996 and is not compatible with the proposed classes. Also France rejects the communication format as it differs from its own.

EU Class	Individual criteria		
	TVOC [µg/m³]	HCHO [µg/m³]	AR fulfilled
A-f1	< 1 000	< 10	yes
A-f2	< 1 000	< 60	yes
A-f3	< 1 000	< 80	yes
A-f4	< 1 000	< 100	yes
A-f5	< 1 000	< 120	yes
A-f6	< 1 000	< 120	yes
B-f1 to f6	< 1 000	any possible value	no
C-f1 to f6	< 1 500	any possible value	yes or no
D-f1 to f6	< 2 000	any possible value	yes or no
E-f1 to f6	> 2 000	any possible value	yes or no

AR = additional requirements (such as TSVOC emissions < 100 µg/m³, Sum of 'not yet assessed substances' and 'not identified substances' < 100 µg/m³, R-value ≤ 1).

All individual substances to be declared under the French scheme are included in the TVOC class. The worst individual class determines the overall TVOC class.

Table 1: Reference room concentration classes as proposed by the European Commission (December 2014). All values in µg/m³

Emissions from PU insulation products

"...no carcinogenic, mutagenic or reprotoxic substances were detected in any of the emission tests on PU foam".

PU insulation is considered a very low emission product. In fact, emissions from PU products are well below those of most other insulation products. In particular, natural insulants can have VOC emission levels more than 100 times higher than those of PU [4]. Very importantly, no carcinogenic, mutagenic or reprotoxic substances were detected in any of the emission tests on PU foam.

In all existing VOC/SVOC emission classification systems, PU insulation can achieve the best class. This applies to insulation boards, sandwich panels and closed-cell in-situ foam. PU insulation is therefore suitable for indoor use without reservation. The excellent performance of PU insulation is demonstrated by the test results according to the German AgBB diagram.

Most PU insulation products use pentane as blowing agent. This substance is a very volatile compound (VVOC) and emits only in small quantities from the closed-cell foam. Pentane is widely used in cosmetics, presumably leading to the highest possible inhalation exposures, but even in that case, exposure concentrations are considered as being low [5]. Regulators did therefore not identify any adverse health effects and refrained from adopting any restrictions to its use.

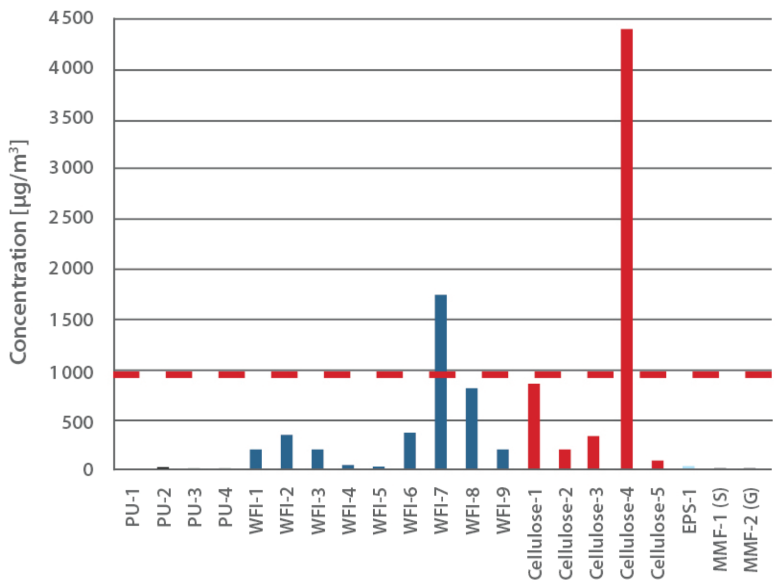

Figure 2: TVOC values of different insulation materials (28 days) – WFI = wood fibre insulation, MMF = man-made mineral fibres (S = stone, G = glass) [6]

Overview of results 28 days	Measured values [µg/m³]
TVOC (C6 – C16)	0-5
Σ VOC excl. NIK (C6 – C16)	0-5
Σ SVOC (C16 – C22)	0-5
Σ cancerogens	0
Σ Ri [-]	<1

Table 2: Reference room concentrations due to emissions from a PU insulation board in accordance with the AgBB diagram using ISO 16000 (28 days) [7]

The question of MDI

"Third parties tested a range of PU insulation products using recognised test methods in order to verify whether any MDI emissions were detectable [...]. They all confirm that there are no MDI emissions from these products."

PU insulation (PUR/PIR) is produced by a reaction of diisocyanates (MDI) with polyols or themselves to create the solid PUR and/or PIR cell structure. MDI (methylene diphenyl diisocyanate) is a respiratory sensitizer and labelled R40 (H351) – suspected of causing cancer.

The MDI is chemically consumed during the foaming process and hence not present in the final rigid foam product [8]. Third parties tested a range of PU insulation products using recognised test methods in order to verify whether any MDI emissions were detectable *(see annex 1)*. They all confirm that there are no MDI emissions from these products.

In order to simulate theoretical worst case scenarios, some of these tests used open cell flexible foam samples, which were compressed in regular intervals. Other tests used closed-cell rigid foam with one using air-tight cubes made of fresh PU boards without facings to ensure extreme case conditions. Ultra-traces of MDI could only be measured for freshly cut PIR foam. With <30 ng/m³, the levels were however far below exposure levels at which any human health effects would be expected. No MDI emissions for PUR/PIR foam could be detected after 24 hours.

The limits of quantification went as low as 1.9 ng/m³ (0.0000019 mg). This is approximately 26 000 times lower than a typical MDI occupational exposure limit (OEL) of 0.05 mg/m³ which is valid in many EU countries for workers. This limit does not seem relevant for indoor air, it is however often used as a basis to derive indoor air limits. For example, Finland applies an OEL of 0.035 mg/m³. According to the Finnish building regulations [9], the indoor air content of "impurities in normal areas may normally be no more than 1/10 of the OEL". When applying an exposure limit of 0.0035 mg/m³, indoor air concentration under extreme case conditions would be at least 1 800 times below this threshold.

Several other national schemes apply a general threshold value of OEL/100 or OEL/1 000 for substances which are classified as carcinogenic and for which there is no specific indoor air limit. Even then the reported detection limit is well below these thresholds. Another source for assessing the exposure risks for the general population is the "Californian Reference Exposure Limit [10], a community safe airborne level" which applies a public health limit of 0.0007 mg/m^3 (0.07 pb v/v). This is the most stringent threshold currently applied world-wide. Even in this case, the quantification limit is more than 350 times lower than the public health limit [11].

Based on the above, it can be concluded beyond any doubt that there is no relevant exposure of building users to MDI used to make PU insulation products. The above-mentioned test results are summarised in *annex 1*.

The question of microbial pollution

Apart from chemical substances, mould spores and so-called microbial volatile organic compounds can lead to serious health risks. The latter can be produced by fungi or through the metabolism of bacteria and can be toxic or causing allergenic reactions. Unlike several other construction products, PU insulation does not provide breeding-ground or food for mould, bacteria or insects and, because it is a closed cell product, it cannot contain spores.

The question of 'breathability'

"Condensation can indeed occur in the insulation layer of walls or roofs if a material with low vapour resistance is used. Thanks to its very low permeability, PU will not be affected".

Low and zero energy buildings cannot be achieved without air-tight building envelopes. Efficient natural or mechanical ventilation systems are becoming indispensable with a view to maintaining comfortable and healthy indoor air humidity levels.

There are claims in the market regarding the benefits of 'breathable' constructions in general and in particular of 'breathable' insulation. The supporters of such claims warn that moisture would build up in 'non-breathable' structures or buildings leading to surface condensation. This in turn would lead to microbial growth (mould, dust mite) with all its negative consequences.

First of all, most scientists reject the term 'breathability'"as it does not describe a specific physical characteristic but stands for several phenomena which must be assessed at the building level.

Condensation can indeed occur in the insulation layer of walls or roofs if a material with low vapour resistance is used. Thanks to its very low permeability, PU will not be affected.

Furthermore, even in the worst case scenario (0.5 air changes an hour), ventilation accounts for 95 % of the vapour transfer from a house with 'breathable' walls [12]. Bulk air-exchange (intended ventilation plus air-leakage) is at least 19 times more important than 'breathability' in controlling air-borne moisture, surface condensation, mould growth, dust mites and consequent health problems.

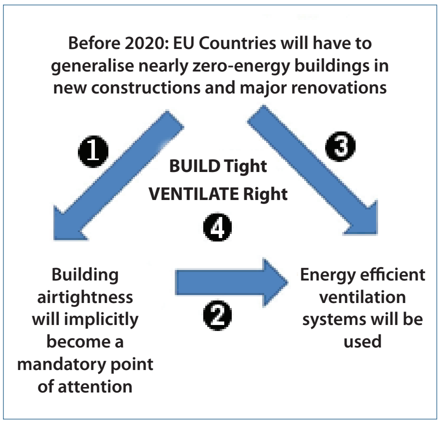

Figure 3: Impact of the Energy performance of buildings directive on the building air tightness (Source: TightVent)

The same applies to the moisture buffering effect of building elements. Research has shown that thermal insulation has only a marginal role to play, as the buffering effect is principally limited to the covering layer in direct contact with the indoor air [13].

Working with PU insulation

Are there dermal risks when working with PU foam?

Contractors cutting factory-made PU boards to size and installing them come in direct contact with PU foam. It is therefore important to verify whether this could lead to dermal contact with MDI.

A test was conducted during which filters were placed in contact with flexible foam pieces on both sides for 5 days at 22 °C and the foam was compressed to 75 % of the original height. There was no MDI-derivative detectable in the filter extracts with a detection limit of 44 ng/cm^2 over five days or – continuous migration assumed – 9 ng/cm^2 per day [14]. This detection threshold is 80 lower than the Acceptable Daily Exposure Level (AEL) of 740 ng/cm^2.

Figure 4: MDI-based polyurethane foam in the dynamic fatigue test chamber with air sampling pumps and sampling filters

The question of PU in-situ foam

"Once the foam has cured, as with other forms of PU used in buildings [...], it is considered chemically inert. VOC and SVOC emission levels are then comparable to those of factory-made PU insulation."

Special health and safety requirements must be observed when installing in-situ foam and the spraying should be exclusively executed by duly qualified professional applicators. When the two liquid chemical components PMDI and the foam 'resin' are mixed together and dispensed, the PMDI can reach concentrations in the air above current exposure limit values, and special safety measures are to be observed. During non-spray applications at or below room temperature, PMDI levels are below the workplace exposure limit for MDI of 0.050 mg/m^3, as set in many EU countries.

When in-situ foam is installed, the applicators must respect the required health & safety protection measures which include the segregation of the immediate application area from occupants and members of the general population.

In order to minimise exposure to vapours, aerosols, and particulates of PMDI and other chemicals during the spray application and subsequent operations, applicators should wear proper personal equipment such as powered air systems or air supply systems, gloves, coveralls (e.g. Tyvek), boots, etc. As to masks, instructions from the supplier should be followed.

PU Europe has developed industry guidelines for the safe installation of spray foam. National associations and suppliers can provide detailed safety measures based on these industry-wide recommendations [15].

Once the foam has cured, as with other forms of PU used in buildings for insulation, seating, mattresses, wall coverings, etc., it is considered chemically inert. VOC and SVOC emission levels are then comparable to those of factory-made PU insulation.

Disclaimer

While all the information and recommendations in this publication are to the best of our knowledge, information and belief accurate at the date of publication, nothing herein is to be construed as a warranty, express or otherwise.

[1] Construction Products Directive (89/106/EEC)

[2] WI 351009 – Construction products – Assessment of emissions of regulated dangerous substances from construction products – Determination of emissions into indoor air

[3] European Commission, DG Health and Consumers: *Promoting actions for healthy indoor air (IAIAQ)*, 2011

[4] See sections 9 (Nachweise) in the EPDs at **http://bau-umwelt.de/hp545/Daemmstoffe.htm**

ANNEX 1 MDI emission tests

Source	Test sample	Detection limit	Results (partially) as quotation
Emission chamber test on rigid PU foam Phase 1: Emission measurements, PO number: 304-EU-ANA, Dr Stephan Konrad, Currenta GmbH&Co KG, 2011	Sealed box of 64 l made of freshly cut PIR boards (without facing); Edges sealed with emission-free tape; swept with nitrogen gas flow	1.9 ng/m³ (limit of quantification) • Most sensitive analytical techniques currently available	Air sampling: glass fibre filters impregnated with dibutylamine (DBA) and acetic acid. "The investigations showed measurable concentrations of monomeric MDI (28 ng/m³) for the first measurement point" (0:00 hours)". "Samples taken after several hours show no significant concentration for 4,4'-MDI and no measurable signal for 2,4'-MDI compared to blank measurements. A repetition after three month of storage of the PIR cube showed no significant values".
Emission chamber test on rigid PU foam Phase 1: Emission measurements, PO number: 304-EU-ANA, Dr Stephan Konrad, Currenta GmbH&Co KG, 2011	Sealed box of 64 l made of freshly cut PUR boards (without facing); Edges sealed with emission-free tape; swept with nitrogen gas flow	1.9 ng/m³ (limit of quantification) • Most sensitive analytical techniques currently available	Air sampling: glass fibre filters impregnated with dibutylamine (DBA) and acetic acid. "Except the value of 1.3 ng/m³ for 4,4'-MDI after 24 h, there are no detectable concentrations of monomeric MDI". The value of 1.3 ng/m³ is below the limit of quantification and is therefore not significant.
Evaluation of Consumer Risk Resulting from Exposure Against Diphenylmethane-4,4'-Diisocyanate (MDI) from Polyurethane Foam, Hans-Dieter Hoffmann, Thomas Schupp, EXCLI Journal 2009;8:58-65, ISSN 1611-2156 (page 60)	Five days old MDI-based cold-cure flexible foam	5.4 ng/m³	"The cushion was periodically compressed with 1.2 Hz." "The MDI analysis was performed according to OSHA 47 (United States Occupational Safety and Health Administration, 1989), with some modifications." "No detectable amounts of MDI could be found in the air samples, with a detection-limit of 5.4 ng/m³."
European Union Risk Assessment Report METHYLENEDIPHENYL DIISOCYANATE (MDI) CAS No: 26447-40-5, EINECS No: 247-714-,0 European Commission JRC, 2005 (page 81)	Open cell flexible foam	6 ng/m³ (emission) 1 µg/25 cm² for contact test	"During a dynamic fatigue test, run over 135 minutes at 40 °C and 50 % relative humidity, there was no MDI detectable in the air of the closed chamber (detection limit 6 ng/m³)." "During a contact test, where filters containing derivatisation agent were contacted with the foam surface for 5 days at 22 °C while compressed to 75 % of the original foam-height, no MDI was extractable (detection limit 1 µg per filter, which is 1 µg/25 cm²)."
Institut Bauen und Umwelt e.V.: Environmental Product Declaration – Factory-made polyurethane insulation products (Declaration number: EPD-IVP-20140207-IBE1-DE), 2015 (page 8)	Closed cell rigid foam (insulation board)	10 ng/m³	"*Isocyanate exhalation* • Measuring agency: Fraunhofer Institut für Holzforschung, Wilhelm Klauditz Institute WKI • Test report, date: Test report number 861/98 dated 7 December 1998 /IVPU • Result: No release of isocyanates was detected in the test in the 1 m³ test chamber • SUPELCO cartridges impregnated with 1-(2-Pyridyl)-piperazine were used for determining the MDI. Extraction was via the OSHA Method No. 47; analysis was via • HPLC with fluorescence detection. The limit of detection is 10 ng/m³."
Survey and health assessment of selected respiratory sensitizers in consumer products, Danish Ministry of the Environment, Survey of Chemical Substances in Consumer Products, No. 82 2007	• Foam mattress (open cell flexible foam) • Spring mattress (open cell flexible foam)	0.2 µg/m³	"The mattress was placed on the floor, and air was collected 25 cm above the surface for 7 hours. During this time the mattress was sat on and walked on every half hour." "All samples were therefore reanalysed with HPLC method 2, which showed that there was no MDI in any of the samples."

[5] Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE), Opinion on the results of the Risk Assessment of: n-PENTANE, Human Health Part (17 December 2002)

[6] Fachagentur Nachwachsende Rohstoffe e. V. for Bundesministeriums für Ernährung, Landwirtschaft und Verbraucherschutz „Untersuchungen zur Optimierung und Standardisierung von Dämmstoffen aus nachwachsenden Rohstoffen" (IBP-Bericht BBHB 01/2008)

[7] Institut Bauen und Umwelt e.V.: *Environmental product declaration in accordance with ISO 14025: Factory-made polyurethane insulation products* (2010)

[8] REACH use descriptors

[9] D2 – Indoor Climate and Ventilation of Buildings Regulations and Guidelines 2010

[10] **http://www.oehha.ca.gov/air/Allrels.html**

[11] California is currently considering a proposal to lower this value to 0.00008 mg/m³ or 0.08 µg/m³ or 0.008 ppb. Even in this case, the detection limit would be 40 times below this proposed limit

[12] Cambridge Architectural Research Ltd. (CAR): *Moisture transfer and the significance of breathability in buildings*

[13] VTT: *A survey of the breathable building structure concept – Effect of insulation materials* (2012)

[14] Evaluation of Consumer Risk Resulting from Exposure Against Diphenylmethane-4,4'-Diisocyanate (MDI) from Polyurethane Foam, Hans-Dieter Hoffmann, Thomas Schupp, EXCLI Journal 2009;8:58-65, ISSN 1611-2156

[15] PU Europe: *Health and Safety Product Stewardship Workbook for Spray Foam* (2012)