ACADEMIA | Letters

PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries?

Gianluca Sarti, Reagens S.p.A.
Marco Piana, PVC4Cables

PVC is an extraordinary and versatile resin, used in a large range of articles in building and construction (B&C), such as profiles, pipes, flooring, cables etc. One of the keys of the success of PVC articles in B&C along the sixties and the seventies has been its remarkable fire performance. In fact, PVC has a low ignitability, a low flammability, a high ease of extinction, a low tendency to spread fire, but moreover a low heat release rate (HRR). Particularly the heat released by the article and its peak can be considered a measure of the intensity of the fire, and this can make the difference if people can escape unharmed before the fire becomes too large [1,2,3]. Thus, flame retardants and polymers with an intrinsic flame retardancy as PVC, CPVC, PEF, PTFE etc. play a fundamental role in fire safety. Often halogenated polymers are used where other polymers fail. Despite these extraordinary properties, in the European Union (EU) some PVC articles suffered the competition of other "plastics". Particularly PVC compounds for cables lost 26% of market share, from 65% in 2000 down to 39% in 2019, with an estimated 35% in 2023 [4]. This happened mainly because PVC compounds have been under attack for some of its "claimed negative issues": PVC emits black dense smokes, its combustion products are toxic, and its fumes are acidic.

Smoke kills in fires more than fire itself. In fact, most of the fatalities in fires are caused by the inhalation of toxic smoke. But the "big toxic killer in smokes" is carbon monoxide (CO) and, after flashover (i.e., when the fire becomes too big to be extinguished), every polymer releases about 20% of its weight as CO [1, 5, 6]. Therefore, PVC burning does not release more toxic fumes than other polymers. Furthermore, the fatalities due to inhalation are a direct

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.

consequence of the fact that the fire has reached the flashover. Therefore, deaths due to smoke inhalation are an indirect consequence of an elsewhere failure.

The smoke obscuration impedes people to escape uninjured from the fire scenario and to be found by rescuers. Therefore, the measure of the smoke production from articles is another key factor in fire safety. But does PVC release more smoke than other polymers? Not really. PVC burns less and it has in its chemistry all the weapons to reduce smokes, easily reaching the best classes in terms of smoke emission [7, 21].

Regarding the smoke acidity, most "fire scientists" consider it an ancillary measure in fire safety. In fact, studies show clearly that tenability is driven mostly by narcoleptic substances like CO or HCN rather than by HCl [7, 8]. This means that CO or HCN reach the concentration impeding you to exit unharmed from the fire scenario before HCl or other irritant gases. That is because PVC articles burn later and in a real fire scenario HCl decays quickly, absorbed by surrounding materials, washed away by water or trapped by fillers in the PVC compound [5, 9].

Despite all these considerations, in the European Union (EU), according to Regulation (EU) N°305/2011 (Construction Product Regulation, or CPR), cables permanently installed in buildings must be classified also for the acidity of the gases released during their combustion (table 1 and 2).

Reaction to fire Class	Additional classification for smoke	Additional classification for flaming droplets
Aca (best)	s1a (best)	d0 (best)
B1ca	s1b	d1
B2ca	s2	d2
Cca	s3	
Dca		
Eca		
Fca		

Table 1: main classes and additional classification for smoke and flaming droplets according to EN 13501-6.

PVC cables are in the worst class for acidity, a3, because no PVC compound has been found capable of reaching the best classes a1 or a2 yet (table 2). Therefore, halogen free cables have replaced them in those locations where the class a1 or a2 are required. Furthermore, in the EU in 2017 there were some attempts to introduce the additional classification for toxicity for all building and construction products [10]. When adopted, the acidity classification can lead to a priori exclusion of PVC, just because PVC. The strategy of our competitors' plastics has been precise: R&D, innovation, new products, the use of the innovation "up" inside technical committees, and the dissemination of the innovation "down" to the public opinion. This strategy has been a winning strategy and it reflects the success of the new halogen-free

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.

cables in the EU market in the period 2000 – 2019. In the past the research on PVC fire behaviour and on novel additives for getting down smoke and smoke acidity has been scarce. This kind of research and its dissemination "up" and "down" can avoid the decline of PVC in some specific fields. In this context, some Italian compounders, supported by PVC4cables, are carrying out a new research in low smoke acidity PVC cables. PVC4cables is the European Council of Vinyl Manufacturers' (ECVM) platform dedicated to the PVC cables value chain. Some data of this research have been presented in several conferences between 2017 and 2022, particularly in AMI cables 2019, AMI cables 2020, 2021 and 2022 and AMI formulation 2021 [11-21]. CPR requires that acidity is indirectly assessed performing the technical standard EN 60754-2. The test apparatus of EN 60754-2 is a tube furnace where the sample is introduced and burnt for 30 minutes in isothermal conditions at temperatures between 935 °C and 965 °C. The smokes are collected in two bubbling devices and pH and conductivity are measured. Table 2 gives the additional classification for acidity according to EN 13501-6, indirectly assessed by pH and conductivity measurements, performing EN 60754-2: a1 is the best class, a3 is the worst.

Class	Requirement performing EN 60754-2
a_1 (best)	pH > 4,3, Conductivity < 2.5 [μS/mm]
a_2	pH > 4,3, Conductivity < 10 [μS/mm]
a_3	not a_1, not a_2

Table 2: additional classification for acidity and requirements according to EN 13501-6.

What has emerged from this research is that new PVC cables with an extremely low smoke acidity are available on the market and they are capable to reach the best classes in terms of reaction to fire and flaming droplets, B2ca and d0 and one of the best in term of smoke emission, s1b [19, 21].

The critical point remains the additional classification for acidity. Even though the new cables reach an extremely low level of acidity, 3.80 pH and 13,6 microS/mm [18, 20], these values are not enough to match the class a2 or a1. But the research of Italian compounders has shown that the introduction of a different thermal profile in EN 60754-2 can bring values close to a1 [11-15, 17-19]. In fact, the severe thermal profile of EN 60754-2, isothermal at temperature between 935 °C and 965 °C, mimicking the condition of a fully developed fire after flashover, hinders acid scavengers in PVC compounds in their action to trap HCl. Introducing the thermal profile of the EN 60754-1 in EN 60754-2 (heating regime, 40 minutes to 800°C and 20 minutes in isothermal at 800°C), we can get higher pH and lower conductivities. In fact, the speed of evolution of HCl during the combustion of the cables affects a

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.

lot the behaviour of acid scavengers, commonly used in low smoke acidity compounds. HCl is a gas and acid scavengers are solid substances trying to trap it. Therefore, acid scavengers must be particularly quick in their interaction before HCl flies away. Consequently, the test temperature and the presence or absence of heating regimes are the main causes affecting the "efficiency" of HCl scavengers. In figure I the dramatic loss of efficiency of a potent acid scavenger AS1-6B is reported [15]. The higher the temperature, the lower the efficiency. Al(OH)3 (ATH), as inert acid scavenger, does not show any variation. Picture 2 [20] shows how big the discrepancies can be in pH and conductivities, when we perform EN 60754-2 and EN 60754-2 with the thermal profile of EN 60754-1. The compound not containing acid scavengers behaves "bad" at both thermal profiles. This concept was highlighted in the past by other research teams. In fact, Chandler and others, in 1987 noted how different temperature regimes affected the quantity of released HCl [9]. We need to highlight how this research is an applied research, and therefore not available yet to the fire community.

All these considerations point out how it is necessary to change the standard EN 60754-2 with the introduction of the thermal profile of the EN 60754-1 for reaching the class a1 and a2 using PVC compounds, but, as we know, any change of standards will not be simple and immediate.

So the conclusion is the following and we come back to the question in the title of the article: can the "European approach" be considered a good example for other countries? The answer is obviously not, because the introduction of acidity classification, performing a small-scale test, cannot predict the actual concentration of HCl in a real fire scenario, and acidity classification has brought and will bring to a reduction of the use of PVC cables in B&C.

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.

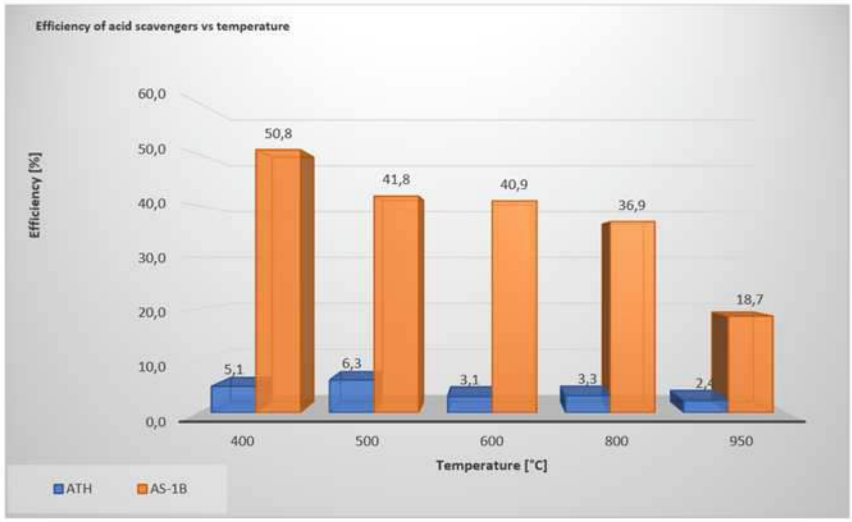
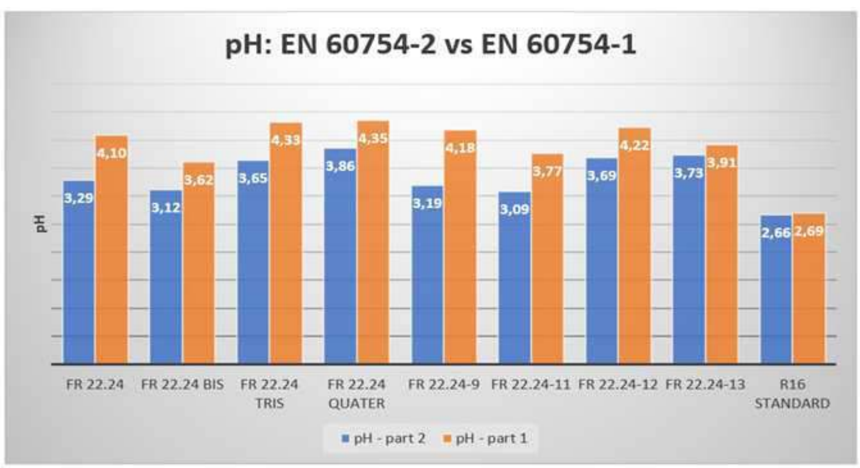


Figure I: efficiency decay of acid scavenger AS-1B and ATH as temperature increases: after 800° the drop of efficiency is quite severe [15].



Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.

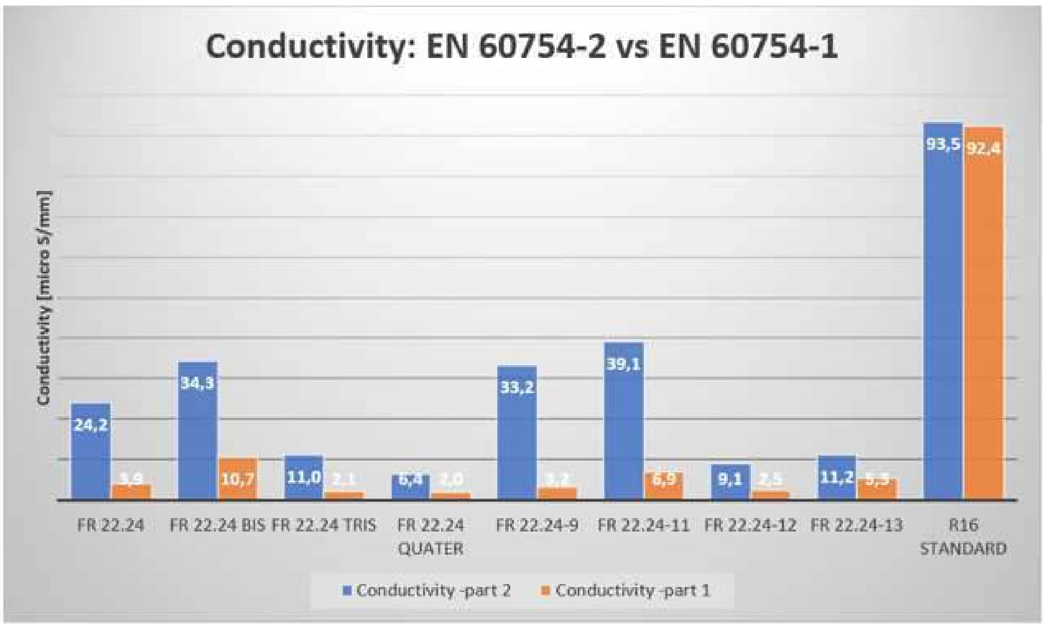


Figure 2: pH and conductivities of some PVC compounds performing EN 60754-2 and EN 60754-2 with the thermal profile of EN 60754-1 [15]. R16 is a type of not harmonized compound produced according to Italian standard, not containing acid scavengers at high temperatures.

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453. https://doi.org/10.20935/AL5453.

References

[1] M. Hirschler, "Poly(vinyl chloride) and its fire properties", Fire and Materials, Volume 41, Issue 8, 993-1006, 2017, https://doi.org/10.1002/fam.2431

[2] C. E. Wilkes, J. W. Summers, C. A. Daniels, Mark T. Berard, PVC Handbook, Hanser, ISBN 1378-1569903797,2005, https://books.google.it/books/about/PVC_Handbook.html?id=YUkJNI9QYsUC&redir_esc=y

[3] V. Babrauskas, R. D. Peakock, «Heat release rate: The single most important variable in fire hazard», Fire Safety Journal, Volume 18, Issue 3, pp 255 – 272, 1992, https://doi.org/10.1016/0379-7112(92)90019-9

[4] Astrid Aupetit, " Overview of the Global Cable Industry , Chapter 1: Markets and Materials", Book Editor(s): Günter Beyer, 2021, https://doi.org/10.1002/9783527822263.ch1

[5] M. Hirschler, "Fire safety, smoke toxicity and acidity", Flame Retardants 2006, February 14-15, 2006, London, pp. 47-58, Interscience Communications, London, UK (2006).

[6] V. Babrauskas et al., "A methodology for obtaining and using toxic potency data for fire hazard analysis", Fire Safety Journal, Volume 31, Issue 4, pp. 2345 – 358, 1998, https://doi.org/10.1016/S0379-7112(98)00013-7

[7] ISO/TR 20118:2019: "Plastics — Guidance on fire characteristics and fire performance of PVC materials used in building applications", ISO, 2019, https://www.iso.org/standard/67071.html

[8] E. Guillaume et al., "Real-scale fire tests of one-bedroom apartments with regard to tenability assessment", Fire Safety Journal, Volume 70, pp.81-97, 2014, https://doi.org/10.1016/j.firesaf.2014.08.014

[9] Chandler L.A., Hirschler, Smith G. F., "A heated tube furnace test for the emission of acid gas from PVC wire coating materials: effects of experimental procedures and mechanistic considerations", European Polymer Journal, 23 (1), 51-61, 1987, https://doi.org/10.1016/0014-3057(87)90098-X

[10] Study to evaluate the need to regulate within the Framework of Regulation (EU) 305/2011 on the toxicity of smoke produced by construction products in fires, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2017, https://ec.europa.eu/docsroom/documents/27346

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.

[11] G Sarti, "How formulations can influence the PVC cables fire behavior", 1st PVC4cables conference, 2017, conference proceeding. http://dx.doi.org/10.13140/RG.2.2.19480.03849

[12] M. Piana, G Sarti, "New formulations and test comparison for the classification of PVC cables under EU regulation n° 305/2011 for construction products", AMI Cables 2019, conference proceeding; http://dx.doi.org/10.13140/RG.2.2.21736.11528

[13] M. Piana, G Sarti, "Construction Products Regulation (CPR) and Acidity Test", 2nd PVC4 cables conference, 2019, conference proceeding.

[14] M. Piana, G Sarti, "PVC cables and smoke acidity: a review comparing performances of old and new compounds", AMI Cables 2020, conference proceeding; http://dx.doi.org/10.1 31 40/RG.2.2.15672.26881

[15] M. Piana, G Sarti, "Performances and innovations of PVC in cables and evaluation of their adaptability to specific needs: the experience and case study of Italian Compounders", Global PVC compounding & production cycle, 2020, Düsseldorf, Germany, conference proceeding.

[16] C. Cardelli, "New formulations of low smoke, low acidity, no dripping, flame retardant PVC", AMI Cables 2021, conference proceeding.

[17] I. Bassi "Characterization of PVC compounds and evaluation of their fire behavior focusing on the comparison between EN 60754-1 and EN 60754-2 in the assessment of the smoke acidity", UNIBO, master degree thesis, 2021, https://www.pvc4cables.org/images/assessment_of_the_smoke_acidity.pdf

[18] M. Piana, G Sarti, "Smoke acidity and a new generation of PVC formulation for cables", AMI Formulation 2021, conference proceeding.

[19] C. Cardelli, "Comparative testing of cables in EN 50399 (CPR). An overview of current properties of PVC and fillers with regards to fire safety and flame retardancy", Future of PVC Compounding, Production & Recycling, 24-25th February 2022, conference proceeding.

[20] G Sarti, "Developing and improving fire performance and safety in PVC", Future of PVC Compounding, Production & Recycling, 24-25th February 2022, conference proceeding, http://dx.doi.org/10.13140/RG.2.2.30678.32322

[21] C. Cardelli, "CPR classification of cables and fire safety: contribution of innovative PVC

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453. https://doi.org/10.20935/AL5453.

and Halogen free compounds", AMI Cables 2022, conference proceeding.

Corresponding Author: Gianluca Sarti, gianluca.sarti@fastwebnet.it
Citation: Sarti, G., Piana, M. (2022). PVC in cables for building and construction. Can the "European approach" be considered a good example for other countries? *Academia Letters*, Article 5453.
https://doi.org/10.20935/AL5453.