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Ljubljana, Slovenia

SFPE 2023 ENGINEERING SOLUTIONS SYMPOSIUM

Fire Safety and Sustainable Building Design | 29-30 November

SFPE

Fire Safety of BAPV and BIPV – from Testing to Implementation in Standards

Introduction

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Giombattista Traina is the Head of Reaction to Fire laboratory and a Senior Lead Research at Instituto Giordano Spa, a Certification and Research company in Italy, Notified Body n. 0407 under the Construction Product Regulation.

He has been with Istituto Giordano since 2005.

He seats on different technical committees: CEN/TC 127 - FIRE SAFETY IN BUILDINGS, WG 4 - Reaction to fire and WG 5 - Roofs; GNB-SH02 (Horizontal sector group for Fire) and Sector group 22 (SG22) for cables under the Construction Product Regulation; He is the EGOLF Contact person for Istituto Giordano.

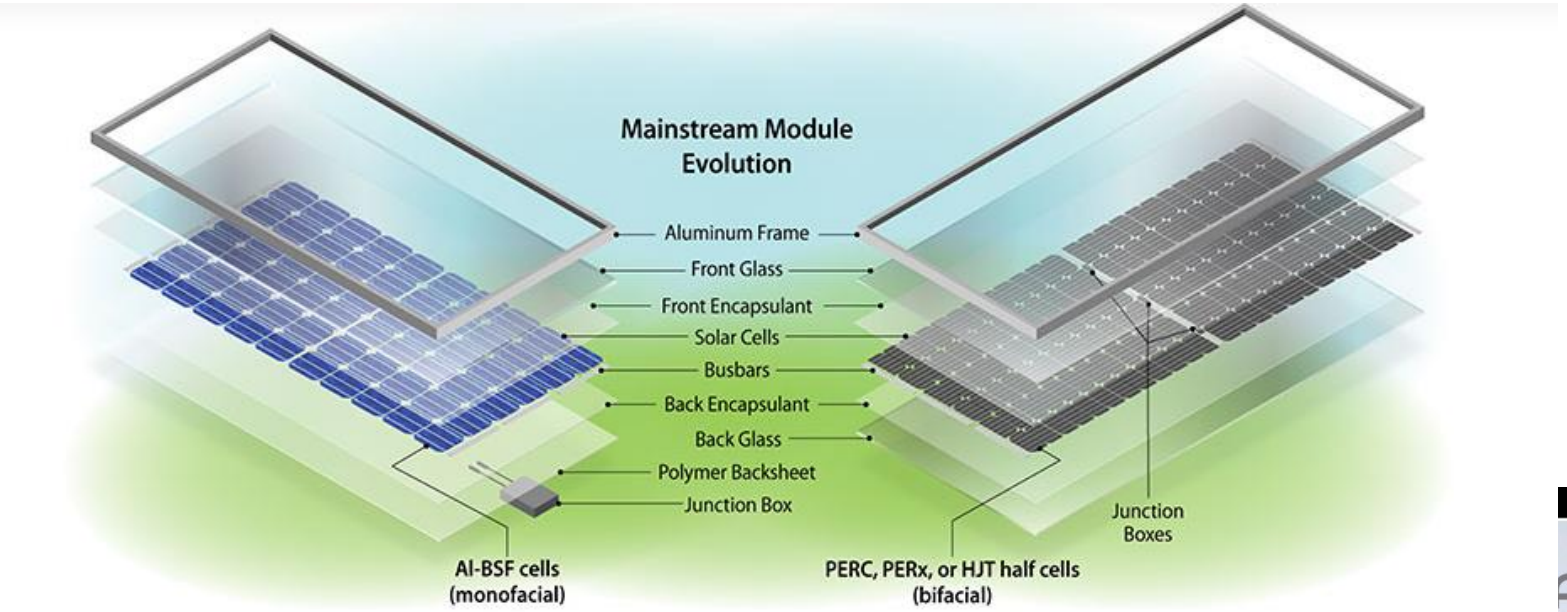
He is also a co-author of the new test method to assess the fire behaviour of BAPV when combined with different types of Roof coverings in Italy, the CEI TS 82-89 "

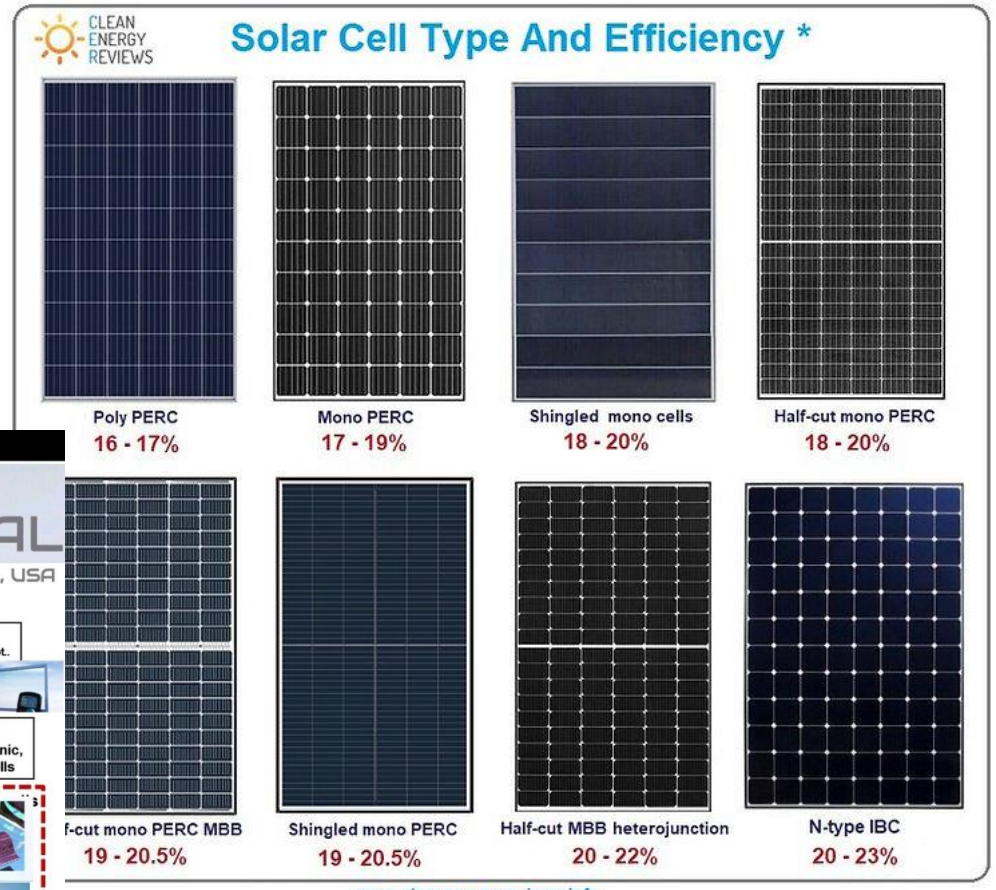
Introduction

- Definitions of PV, BIPV vs BAPV
- Standards, test methods and regulations
- How can we estimate the fire behaviour of PV?
- Possible solutions to test BIPV
- Possible solutions to test BAPV
- Examples of mitigation of the fire risk
- Conclusions
- Annex for further readings

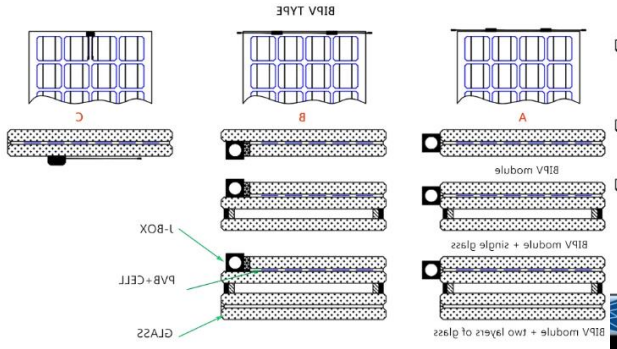
PVs are not the Same!

highly innovative sector with continuous changes in materials and technologies (faster than standardization)

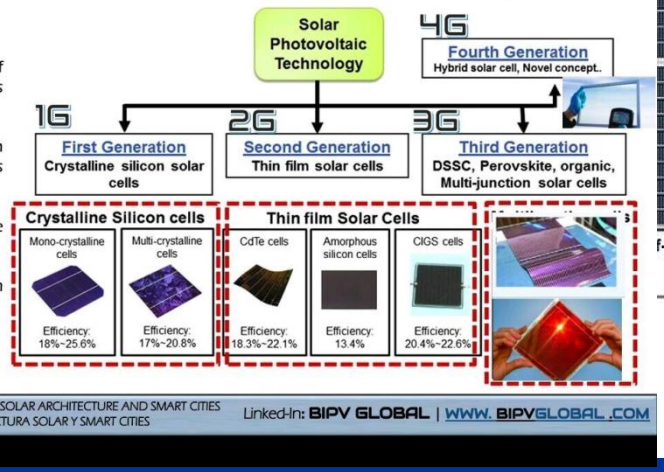




https://cleantechnica.com/2022/04/22/working-out-the-details-of-a-circular-solar-economy/



- Photovoltaics have 4 generations
- **FIRST GENERATION:** It consists of mono and poly crystalline silicon. It is the oldest.
- **SECOND GENERATION:** It is called thin film, since it uses less material. It is mainly composed of CdTe, Si-a, CIGS.
- **THIRD GENERATION:** For example organic solar cells, perovskites, tandem.
- **FOURTH GENERATION:** Quantum glass, hybrid cells, etc.



https://www.solarkobo.com/post/types-of-solar-panel-designs

Certification of PV Product standards (CE marking - LVD)

Terrestrial photovoltaic (PV) modules - Design qualification and type approval

Part 1: Test requirements - IEC 61215-1:2021

Photovoltaic (PV) module safety qualification

- Part 1: Requirements for construction - IEC 61730-1:2023

Requirements for the materials, e.g plastics (connectors, junction box) with V-1 class according to IEC 60695-11-10 (similar to UL94)

BAPV and BIPV are subject to specific fire-related safety requirements originating from national building codes. Fundamental requirements for fire safety are not yet internationally harmonized. It is therefore not possible to define general requirements on this topic in this document

- Part 2: Requirements for testing - IEC 61730-2:2023

MST 23 - Fire Test- National/Local code*

it shall be noted that fundamental requirements for fire safety are not internationally harmonised. It is therefore not possible to define general requirements for fire safety of PV modules as recognition of test results is commonly not practiced.

MST 24 - Ignitability test - EN ISO 11925-2

BAPV vs BIPV

Aftermath of Delanco, NJ, Warehouse Fire. Source: New Jersey State Fire Marshal, 2013

Sonnekraft solar shed roof
Solarstrasse 1, 9300 St. Veit an der Glan, Austria
Fonte: SONNENKRAFT Gmbh

iliad Store - Milano
Viale Francesco Restelli 1/A, Milano

Definitions BAPV vs BIPV (IEC 63092-1:2020 or EN 50583 & IEA PVPS T15)

Building-Integrated Photovoltaic modules
BIPV modules

photovoltaic modules are considered to be building-integrated, if the PV modules form a construction product **providing a function as defined in** the European Construction Product Regulation **CPR 305/2011**. Thus the **BIPV module is a prerequisite for the integrity of the building's functionality**. If the integrated PV module is dismounted (in the case of structurally bonded modules, dismounting includes the adjacent construction product), the PV module would have to be replaced by an appropriate construction product.

The building's functions in the context of BIPV are one or more of the following:

mechanical rigidity or structural integrity , primary weather impact protection: rain, snow, wind, hail, energy economy, such as ading, daylighting, thermal insulation, fire protection, noise protection, separation between indoor and outdoor environments, security, shelter or safety

Inherent electro-technical properties of PV such as antenna function, power generation and electromagnetic shielding etc. alone do not qualify PV modules as to be building-integrated.

Building-Attached Photovoltaic Modules
BAPV modules

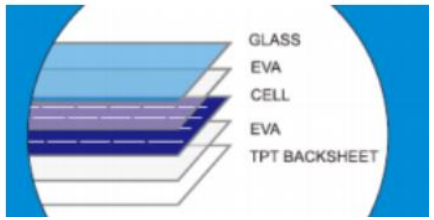
photovoltaic modules are considered to be building-attached, if the PV modules are mounted on a building envelope and do not fulfil the above criteria for building integration

(Negation: **The integrity of the building functionality is independent of the existence of a building-attached photovoltaic module**.)

BAPV - BIPV - CPR and other directives

- **The definition of CP according to the** CPR 305/2011 is only one point then we need a Harmonized product standard or an EAD
- Regulation and Directives deal mainly with **PLACING ON THE MARKET**, for the CPR we have to declare the performance…also class F (the worst, for highly flammable products)
- **CE mark is not a safety mark**
- Fire Safety aspects will be defined in the national Building/fire Codes

PVs made of 2 Construction products



https://solar.kamtexindustries.com/Articles/types-of-commercial-solar-panels-and-their-structures/Frameless-Glass-Laminated-Solar-panel.html

CPR

EN 14449 Glass in building Laminated glass and laminated safety glass

EN 13501-1 (B,s1-d0)

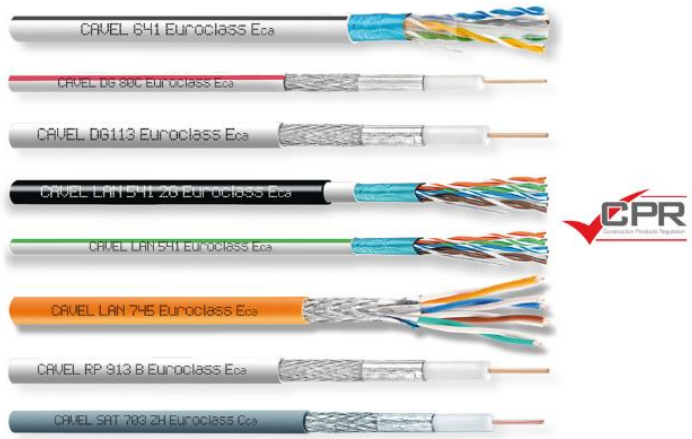
https://couleenergy.net/double-glass-solar-panels-half-cell-mono-perc-panel/

NO Hps EN 50583 CPR

(May be with a lot of doubts

EN 13830 Curtain walling, EN 14351-1 roof windows)

Class EN 13501-1 (not part6)



https://www.sistemi-integrati.net/regolamento-cpr-ue-305-11-introduzione-e-gestione-id-51-ida-2916-htm/

CPR

EN 50575 Power, control and communication cables — Cables for general applications in construction works subject to reaction to fire requirements

EN 13501-6 ($B2_{ca}$-s1, d0, a1)

CE marking Vs safety regulation

BAPV and BIPV need to be CE marked according to Electrical Directives/Regulations, but what about Construction Product Regulation?

CPR with harmonized product standard

GAP

NO harmonized product standard

Clear requirement in the national building/fire code

GAP

NO specifc requirement in the national building/fire code

All the performances are covered by actual testing methods

GAP

NOT All the performances are covered by actual testing methods

Fire Safety Risk Assessment (DGPS in the GAP)

https://retail-focus.co.uk/warning-retailers-mind-the-gap-before-your-customers-fall-through-it

DGPS: Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on General Product Safety

REGULATION (EU) 2023/988 from 2025

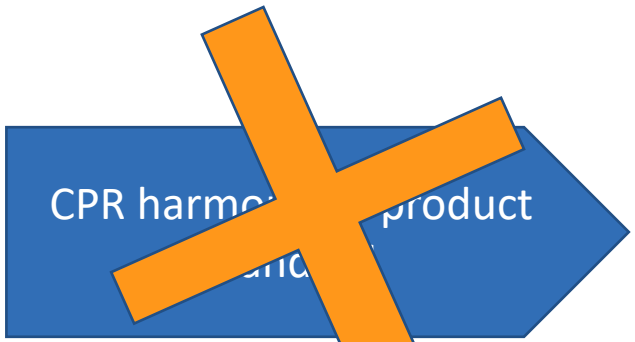
- (b) "safe product" shall mean any product which, under normal or reasonably foreseeable **conditions of use including duration** and, where applicable, putting into service, **installation and maintenance requirements**, **does not present any risk or only the minimum risks** compatible with the product's use, considered to be acceptable and consistent with a high level of protection for the safety and health of persons….

Directive 2001/95/EC of the European Parliament and of the Council of 3 December 2001 on general product safety

Article 3

- 1. Producers shall be obliged to place **only safe products** on the market.
- 2. A product shall be deemed safe, as far as the aspects covered by the relevant national legislation are concerned, when, in the absence of specific Community provisions governing the safety of the product in question, it conforms to the specific rules of national law of the Member State in whose territory the product is marketed, such rules being drawn up in conformity with the Treaty, and in particular Articles 28 and 30 thereof, and laying down the health and safety requirements which the product must satisfy in order to be marketed.
- A product shall be presumed safe as far as the risks and risk categories covered by relevant national standards are concerned when it conforms to voluntary national standards transposing European standards, the references of which have been published by the Commission in the Official Journal of the European Communities in accordance with Article 4. The Member States shall publish the references of such national standards.
- 3. **In circumstances other than those referred to in paragraph** 2, **the conformity of a product to the general safety requirement shall be assessed** by taking into account the following elements in particular, where they exist:
- (a) voluntary national standards transposing relevant European standards other than those referred to in paragraph 2;
- (b) the standards drawn up in the Member State in which the product is marketed;
- (c) Commission recommendations setting guidelines on product safety assessment;
- (**d) product safety codes of good practice in force in the sector concerned;**
- **(e) the state of the art and technology;**
- **(f) reasonable consumer expectations concerning safety**

Examples NO DOP for CPR, but ok for the rest



GAP

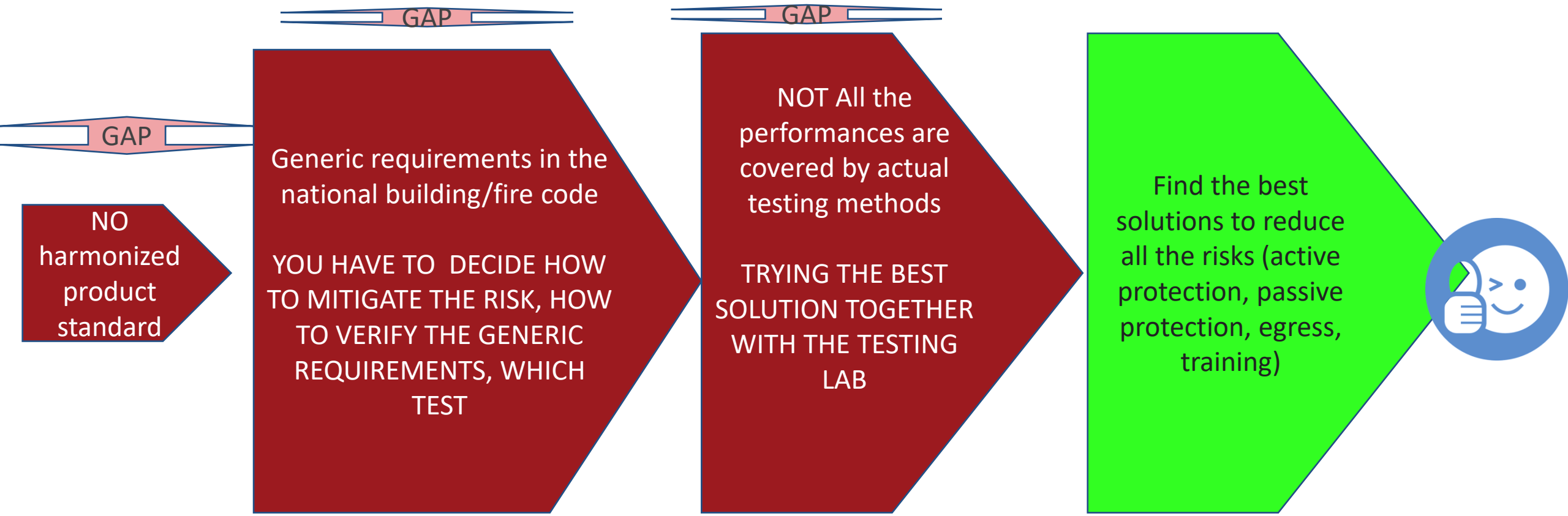
NO harmonized product standard

National building/fire code

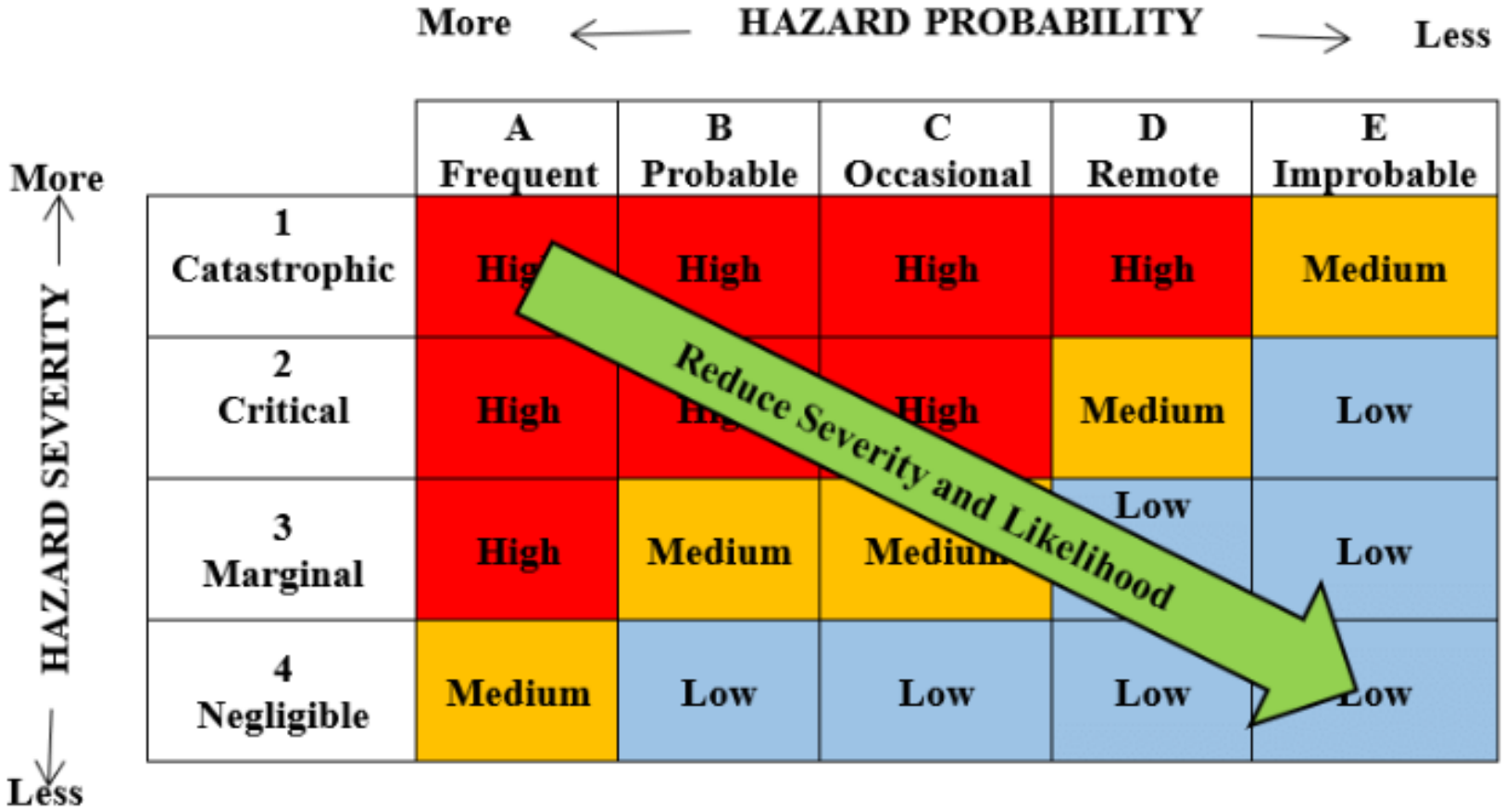
- BIPV needs class Bs1d0
- test for Facade BS 8414
- Cables B2ca s1 d0 a2

Guidelines on how to test and Mount these products

Example: Risk assessment and custom decision

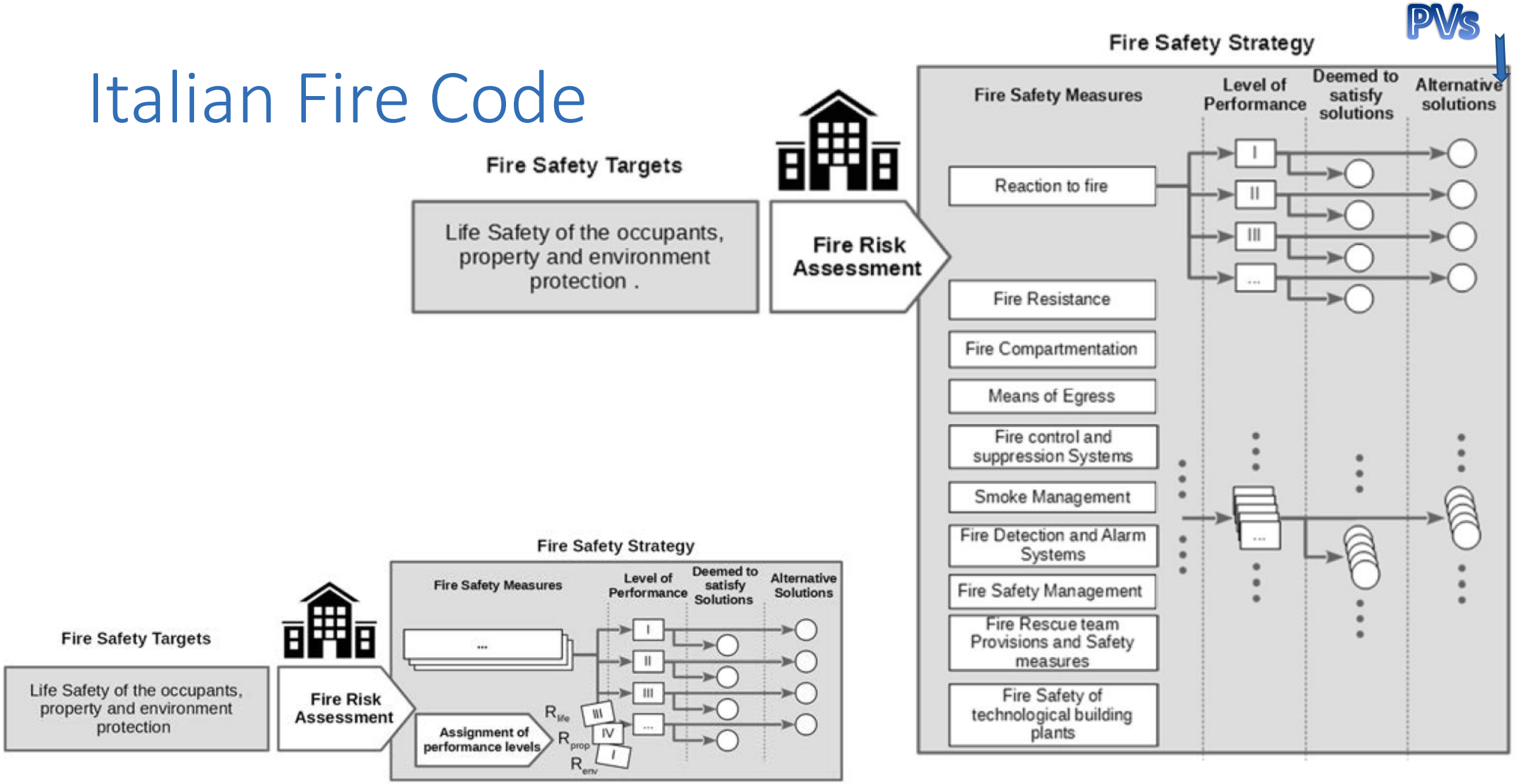


We need the best testing methods to estimate the severity of the hazard, trying to reduce it as much as possible, and then proceed by reducing the probability of its occurrence



The generalized risk scale – a scalar integrated tool for developing risk criteria by consensus, in the field of explosives for civil uses January 2020 MATEC Web of Conferences 305:00078

Italian Fire Code



BIPV - working with these targets (CPR)

Safety in case of fire – claims that a construction work must be designed and built in such a way that in the event of an outbreak of a fire,

(1) The load-bearing capacity of the construction can be assumed for a specific period of time;

(2) The generation and spread of fire and smoke within the construction works are limited;

(3) The spread of fire to neighbouring construction work is limited;

(4) Occupants can leave the construction work or be rescued by other means;

(5) The safety of rescue teams is taken into consideration.

BIPV - working with these targets

1. Avoiding interference with the ventilation system of the combustion products, obstruction of skylights and impediment of natural smoke and heat exhaust ventilators;

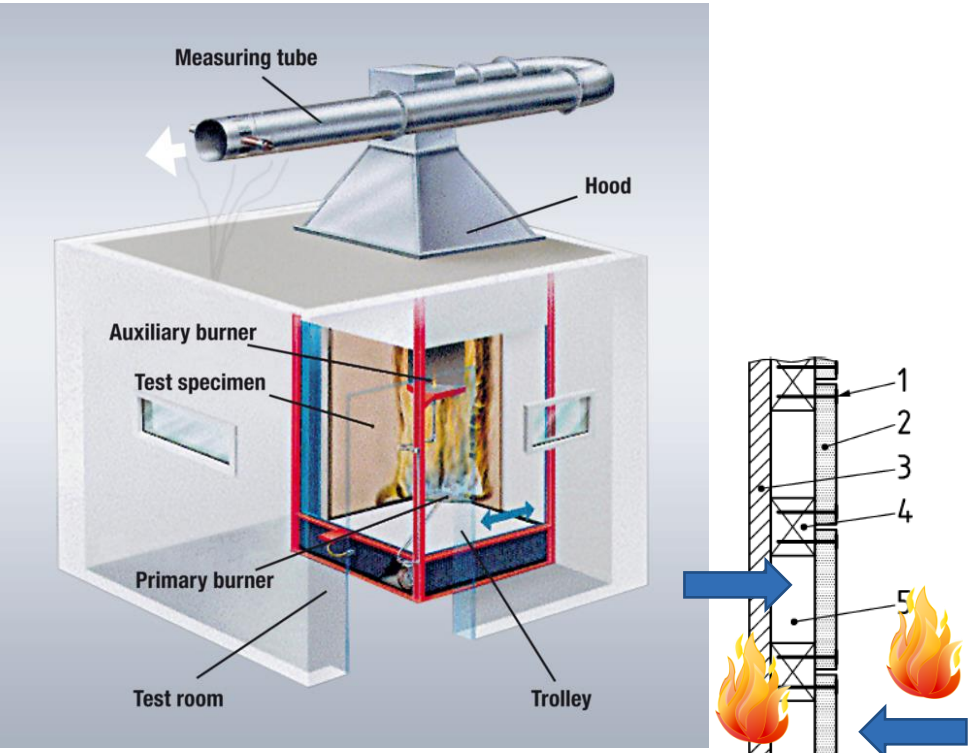
2. Avoiding the spread of an outbreak fire from the photovoltaic generator to the building and /or between its compartments in which it's incorporated;

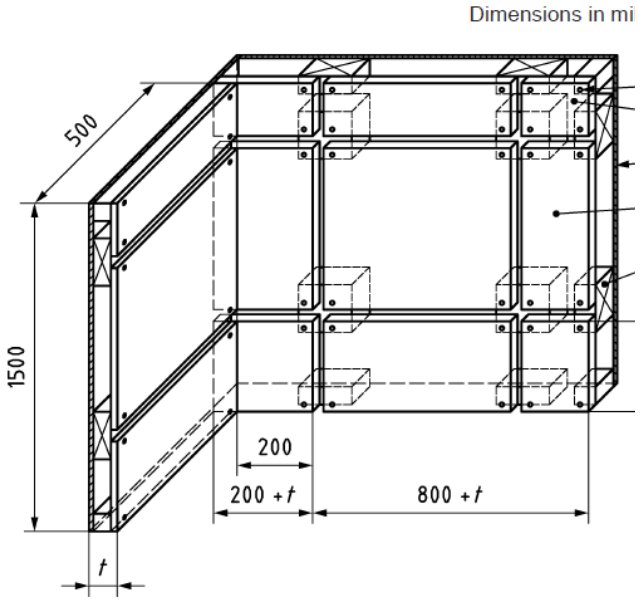
3. Evaluating the influence on the fire spread due to PV cables, switchboards and modules on the roof and or the façade of the host building/construction work;

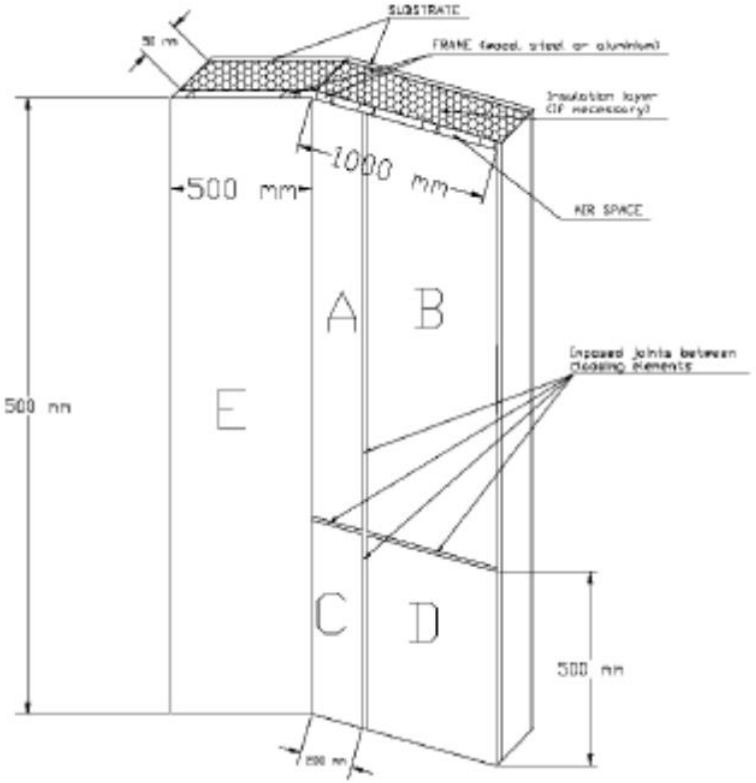
4. Safety of maintenance personnel;

5. Safety of the rescue team

BIPV vertical or ceiling - SBI and EN 13501-1







Key

1	fixing
2	suspended ceiling membrane
3	substrate
4	spacer
5	air gap
t	thickness of the test specimen (incl. substrate)

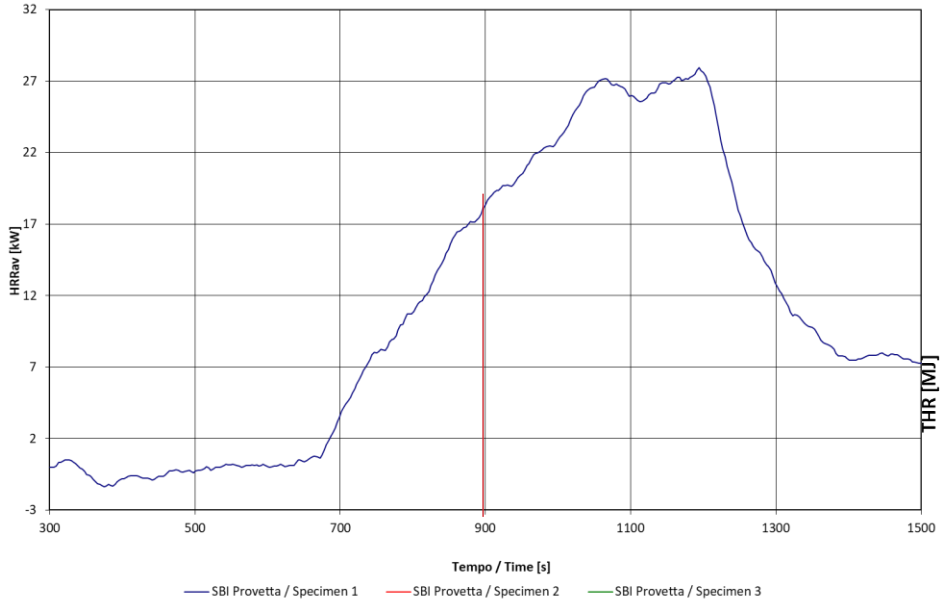
Figure A.1 – Example of SBI test installation

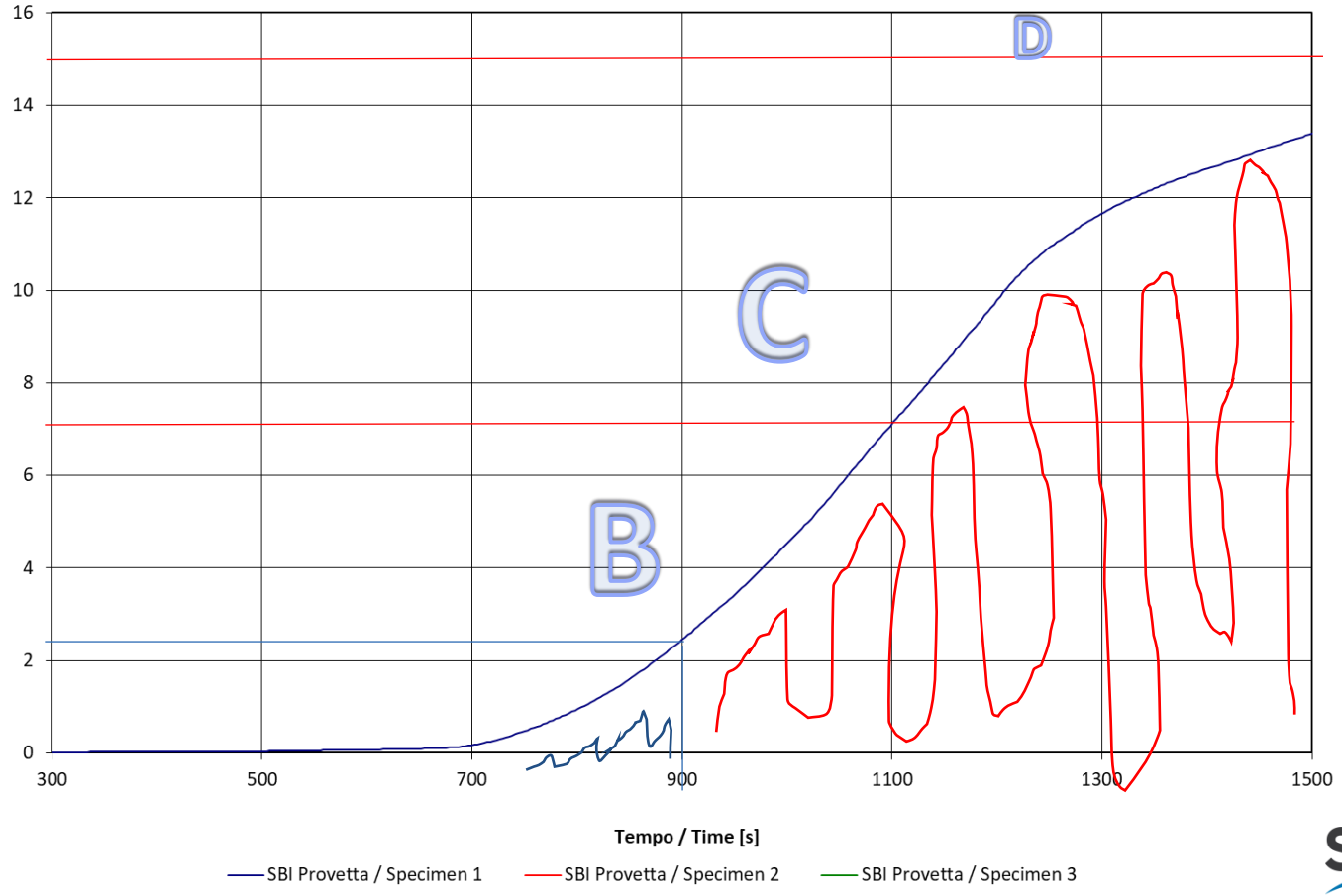
BIPV vertical or ceiling - SBI and EN 13501-1

BIPV vertical or ceiling - SBI and EN 13501-1

Results will depend on the PV's behaviour with the flame, from a mechanical point of view!

THR_{600s} but, it start to burn after 10 minutes…

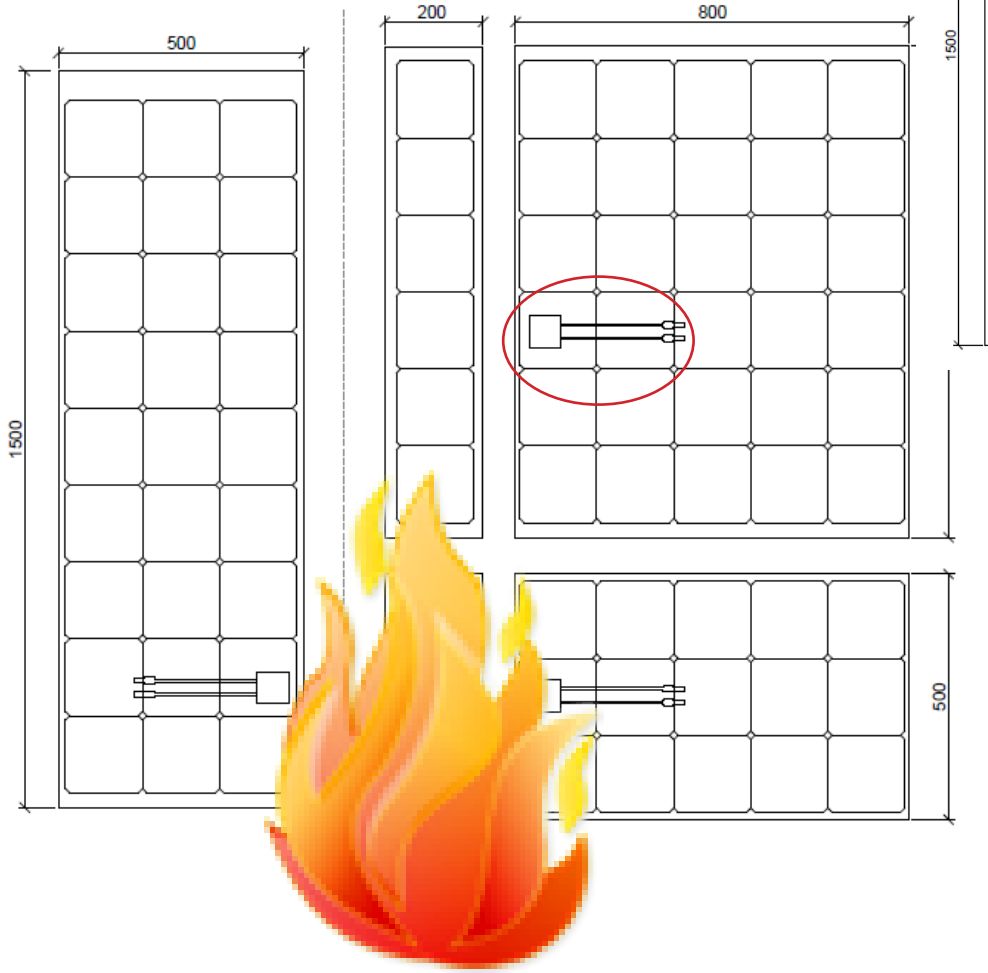


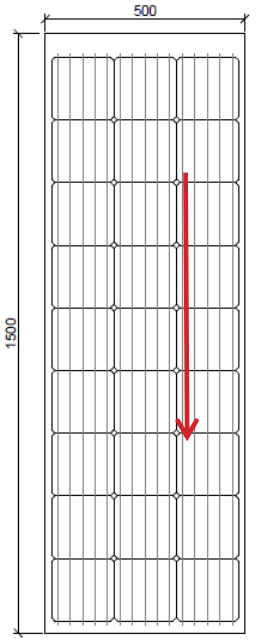


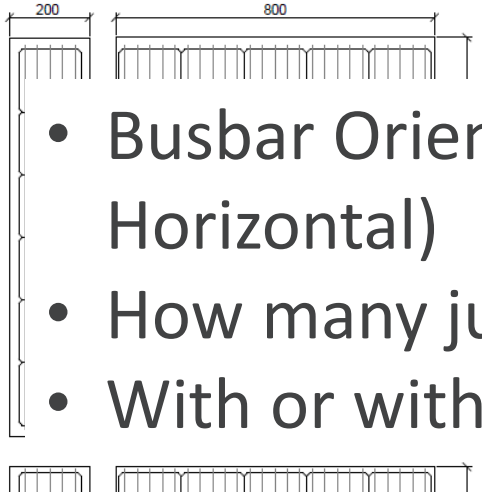
BIPV - SBI how many variabilities?
We need more experience and Harmonization

- Type of cells (Poly, mono, half cut, shingled, etc)
- Number of busbars (from 4 to 12)
- Type and thickness of the glass (Tempered, Toughened ,Heat-Strengthened, Annealed)
- Fixing and mountings

Variation of PV?







- Busbar Orientation (vertical or Horizontal)
- How many junction box in the SBI
- With or without cables?

Thanks to Fabio Parolini SUPSI

BIPV - why a FACADE testing

use SBI to find the worst case to be tested in large scale

- Different fire scenarios; 100 kW can break the glass sooner than 30 kW (INTERNAL SCENARIO) with the result of a huge fire (even if class B was reached)

- The fixing system can be a weak point with the risk of the falling of great slabs of glass

- The falling of flaming debris will be enhanced since the glass will break and part of the burned encapsulant will remain on the glass fragment *(information needed also to protect the egress)*

BIPV - why a FACADE testing

use SBI to find the worst case to be tested in large scale

- Harmonization of the European test method requires more than 10 years…
- *But having in mind our targets, we need to find the best method or just use the one required in your country*

DIN 4102-20

https://www.ed.tum.de/ed/startseite/

NFPA 285

https://europeanfiresafetyalliance.org/wp-content/uploads/2021/12/4-YKo-A-state-of-the-art-review-of-fire-safety-of-photovoltaic.pdf

SP FIRE 105

https://risefr.com/services/research-and-assessments/fric-fire-research-and-innovation-centre

BAPV outside EN 13501-1
focus on the combination (PV+ROOF)

- CEN TC 127 WG5 (fire safety in buildings – Roofs EN 13501**-5**) has been working on the topic since **2015**

- Each country is developing its own test method, but the common idea is that a real combination of PV and roof needs to be verified

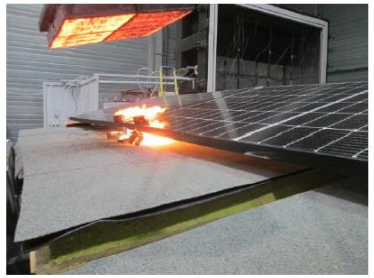
- Researchers have underlined that PVs on a Roof definitely change the original fire performances of the roof coverings (J. Kristensen, G. Jomaas, R.Stølen)

BAPV outside EN 13501-1 focus on the combination (PV+ROOF)

- France (CSTB - Efectis)

TESTS - EXAMPLES

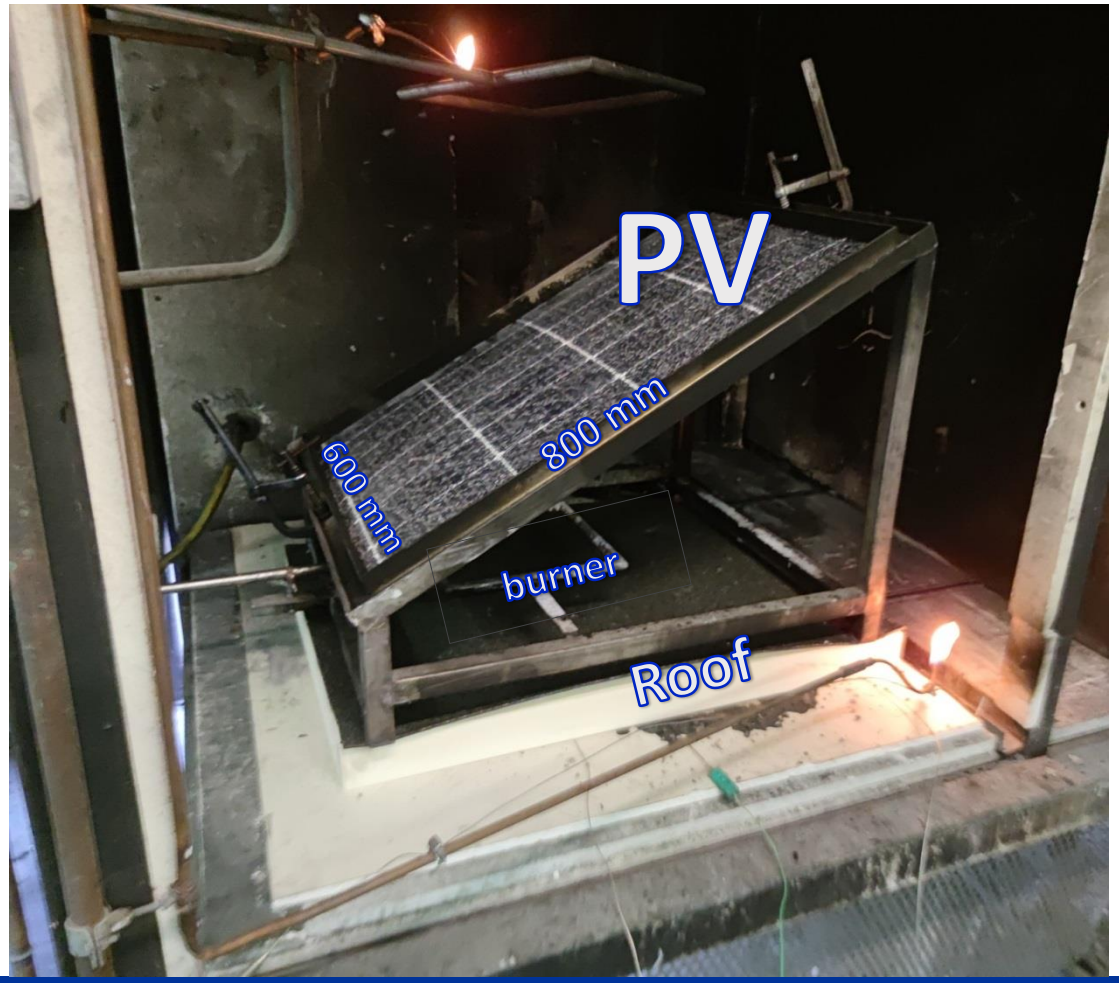
- ❑ B_{roof} T3 (EN TS 1187): firebrands + radiation + wind
- ❑ Test according to French protocole



Efectis EUROPEAN FIRE SAFETY WEEK 2021 Fire Resistance in Plastics

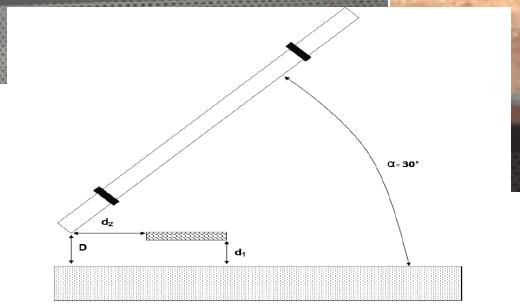
- FM4478 from FM Approval
- New Dutch test method
- Italian CEI TS 82-89

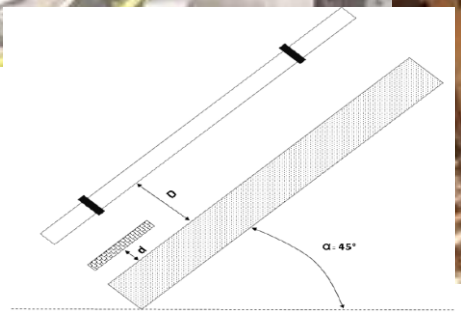
BAPV Italian CEI TS 82-89
focus on the combination (PV+ROOF)



- The Technical Specification provides a way to test a PV coupled with a roof covering (last 50 mm of roof)
- It provides also a fire rating from B_{FV} to E_{FV}
- The Classification is based on the THR, the HRR is measured
- It is possible to extend to other roof coverings with lower THR from ISO 5660-1
- There are essentially 2 mountings that permit to extend to other mountings

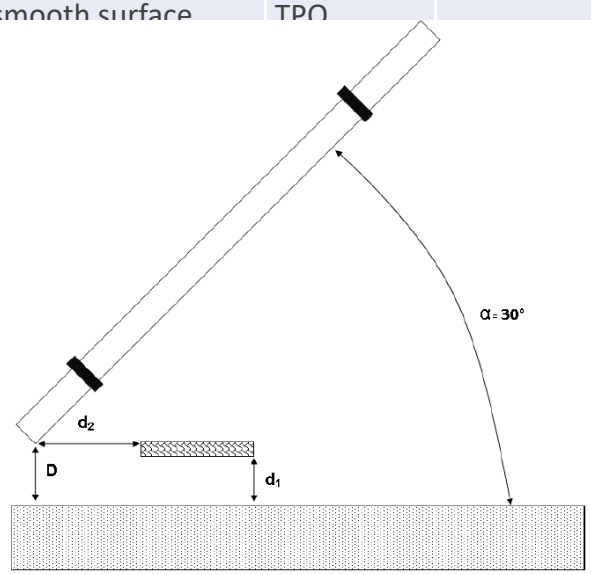
BAPV Italian CEI TS 82-89



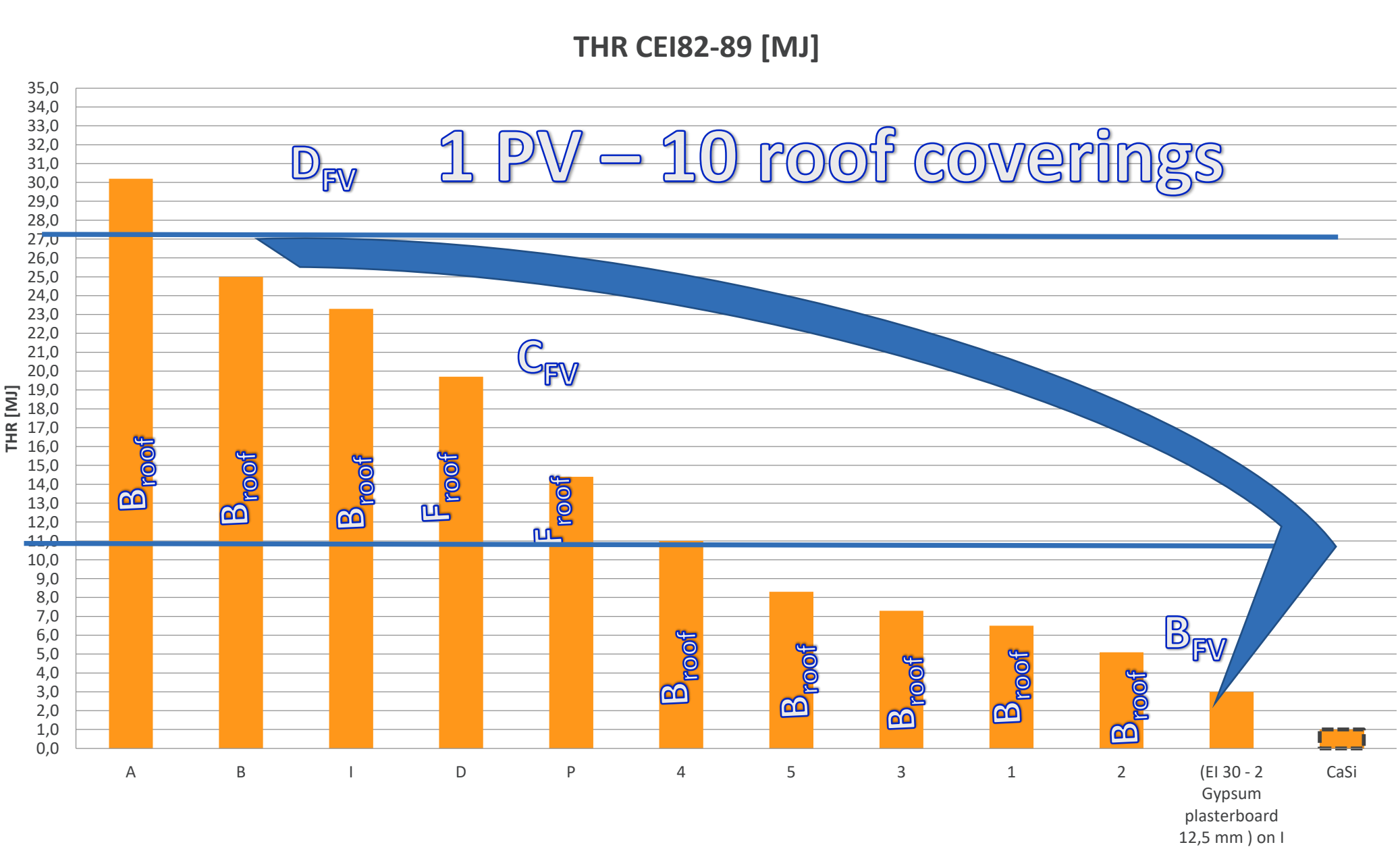


Tests with variation of the roof membrane

Specimen	Surface Type	Polymer	Thickness (mm)	Surface density (kg/m2)	Indicative Class EN 13501-5
A	mineral surfaced	SBS	4,5	5,9	Broof (T2
B	mineral surfaced	APP	5,0	6,0	Broof (T2
I	mineral surfaced	SBS	4,5	6,0	Broof (T2
D	mineral surfaced	APP	3,6	4,5	Froof (T2
P	mineral surfaced	SBS	3,0	3,5	Froof (T2
4	smooth surface	TPO	1,8	1,9	Broof (T2
5	smooth surface	TPO	1,8	2,2	Broof (T2
3	smooth surface	PVC	1,8	2,4	Broof (T2
1	smooth surface	TPO	1,8		
2	smooth surface	TPO	1,6		



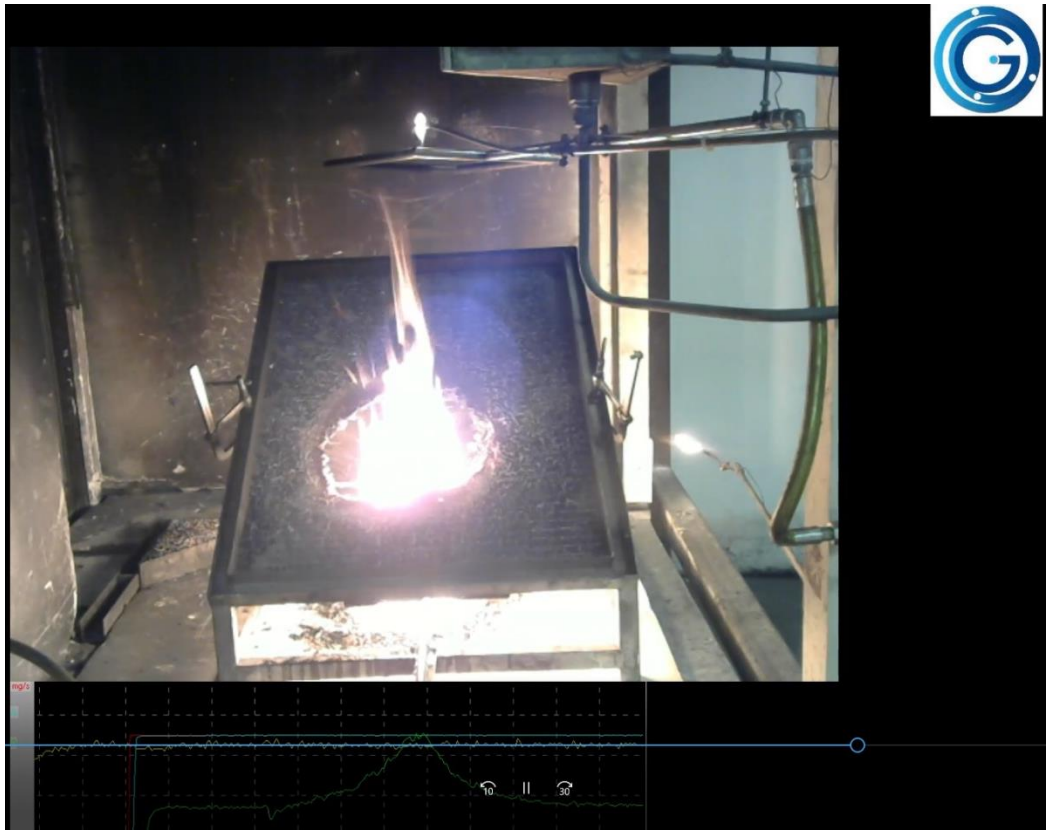
PV	UNI 9174 (velocity)	UNI 9174 (damaged zone)	Specimen	test
class 2 (I)	32-36 mm/min	300 mm	A	1
class 2(I)	32-36 mm/min	300 mm	B	2
class 2 (II)	33-44 mm/min	300 mm	I	3
class 2 (II)	33-44 mm/min	300 mm	D	4
class 2 (II)	33-44 mm/min	300 mm	P	5
class 2(I)	32-36 mm/min	300 mm	4	6
class 2 (II)	33-44 mm/min	300 mm	5	7
class 2(I)	32-36 mm/min	300 mm	3	8
class 2 (II)	33-44 mm/min	300 mm	1	9
class 2(I)	32-36 mm/min	300 mm	2	10
class 2 (II)	33-44 mm/min	300 mm	(EI 30 - 2 Gypsum plasterboards 12,5 mm) on I	11
class 1 (Al)	0	100 mm	CaSi	12



25 MJ

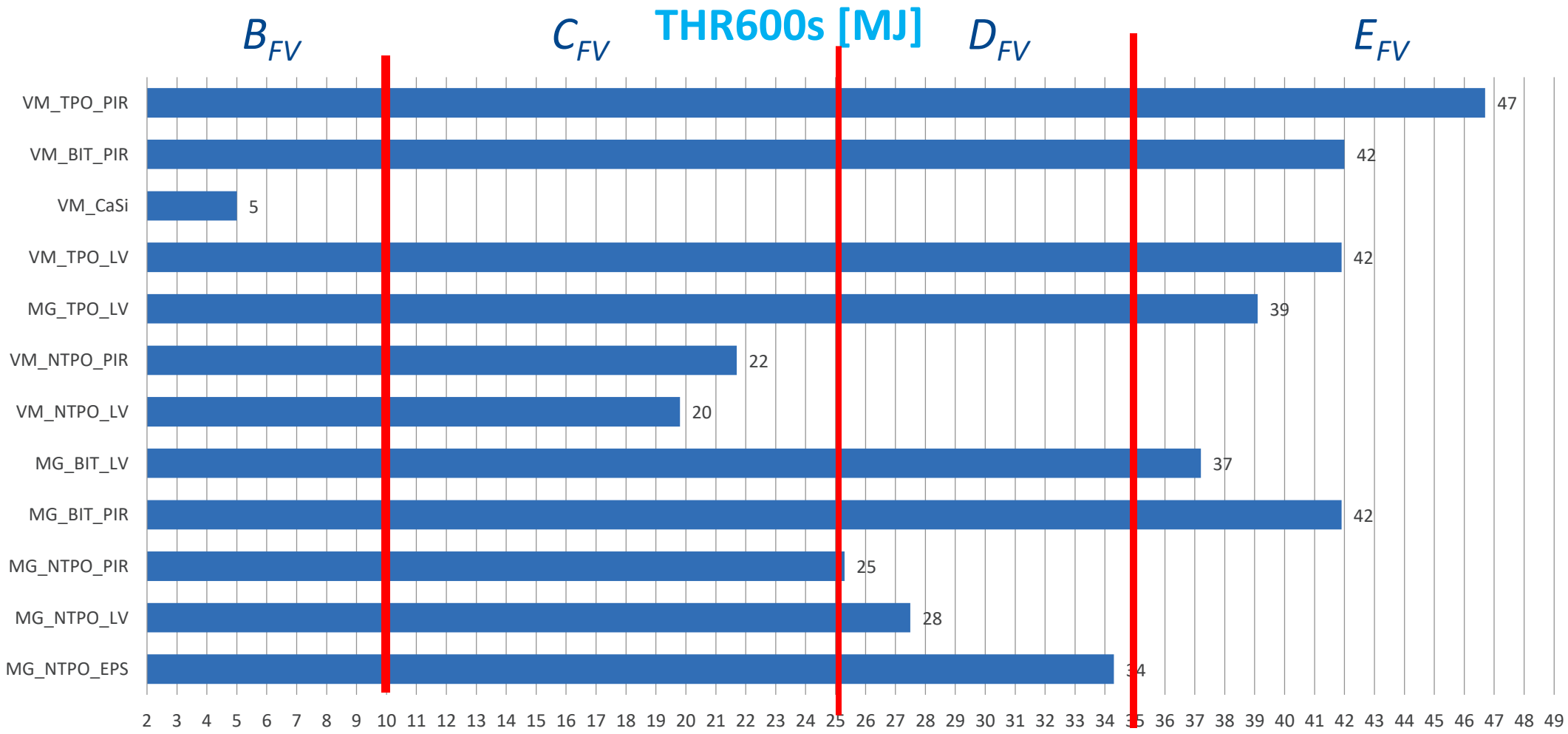
[Link to the video (B vs 2)]

5 MJ



[Link to the video (I vs I+EI30) e Alu su incombustibile]

RSE spa research program



BAPV Italian CEI TS 82-89

ONLY FR-PV
(roof - A1)

1 MJ

8 MJ

PV without FR? > 25 MJ (C_{FV})

1 MJ

PV (FR) + Roof

50 MJ

My two cents

Testing labs and Certification bodies

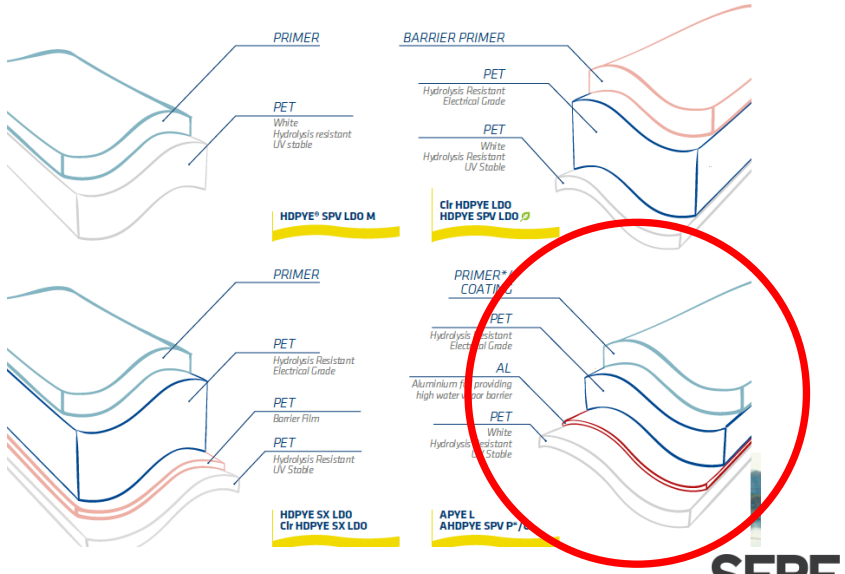
- Harmonization: Create guidelines, TR, EGOLF Reccomandations on how to mount in the SBI and for Facades test methods (BIPV)
- Testing only the PV, without cables and junction box, since they need to be tested according to other methods
- Collect and share information to create a DIAP avoiding too many tests and work for standardization (CEN/CENELEC long process)
- Reduce the number and the size of samples (Envirnomental costs during and after the tests) *Commercial Testing is not a research…*

Tips for Fire engineers

- BAPV or BIPV fire is not a Reaction fo fire matter, you need to treat this risk with an holistic approach with the aim to find solutions to mitigate the overall risk for occupants, buildings, environment and fire brigades

- Push the market finding the best solutions to have safer products, but we will have anyway COMBUSTIBLE products!

  Therefore we need to reduce the Probability of a severe hazard



*Coveme

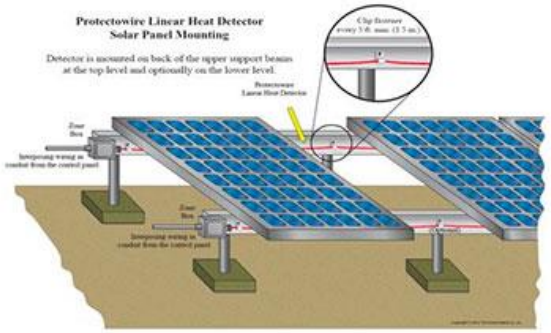
Tips for Fire engineers

The ONLY way to de-energise or "switch off" solar panels at the source of production (the solar panel) is to block the light – light is the source of power

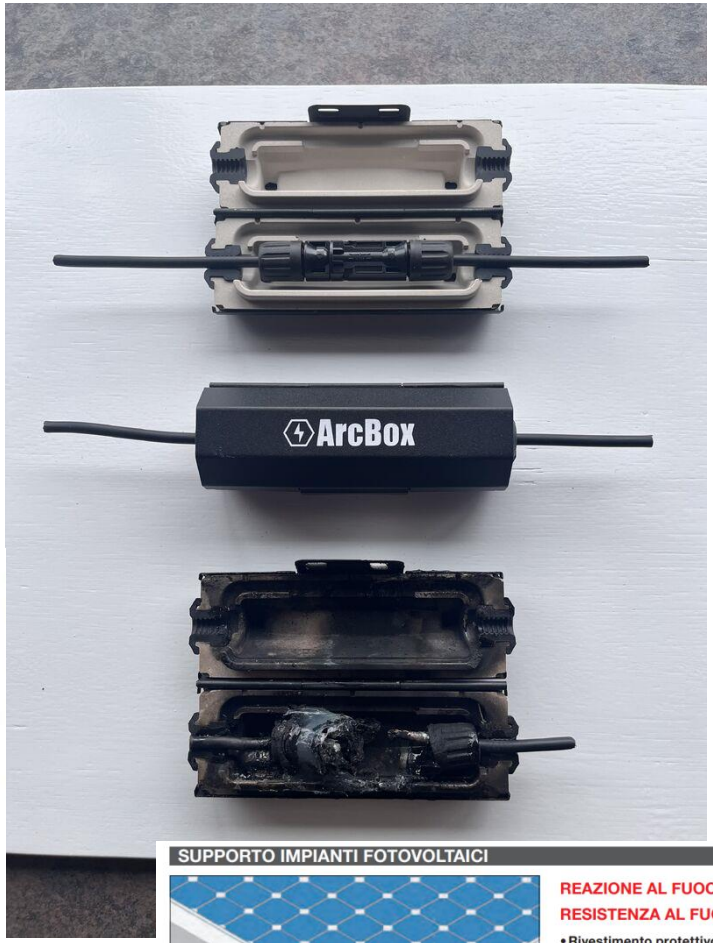
https://www.pv-stop.com

* https://www.bouwtotaal.nl/2023/06/brandwerende-minerale-coating-onder-pv-panelen/

heat sensitive cable
(fibre optics or other materials)



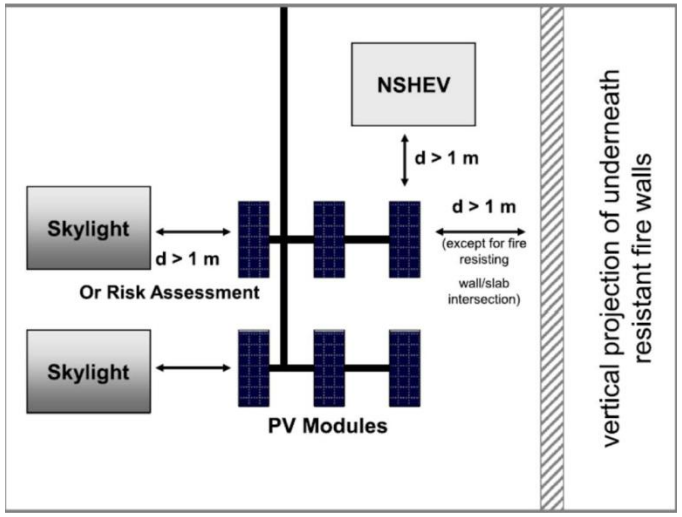
https://www.thermostick.com/en/prodotto/termosensibili-digitali/#



https://www.globalbuilding.it/protezione-passiva-allincendio

Tips for Fire engineers

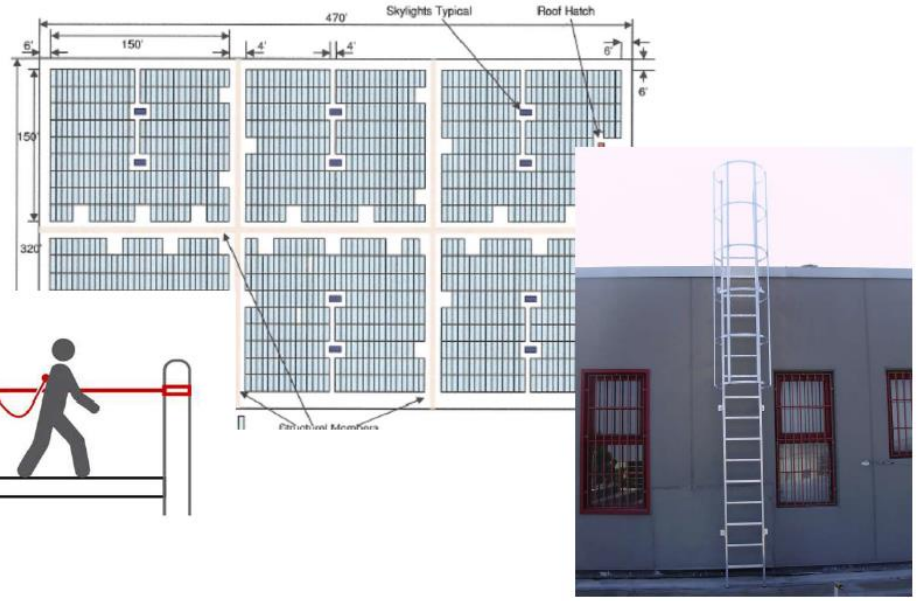
- Fire barriers (BAPV and BIPV)
- Gravel ballast (BAPV)
- Increased standoff height



Safety of maintenance personnel

It is necessary to allow safe access to all parts of the system:

- Walkways
- Safety stairs
- Lifelines
- ...



Thanks to Piergiacomo Cancelliere CNVVF

Tips for Fire engineers

- Ensure easy access for the fire brigade.
- Educate/train building owners and occupiers
- Regular maintenance and inspections

Maintenance of the PV systems

As a good reference for developing a proper maintenance program the following international standard could be applied:

NORMA ITALIANA CEI

Norma Italiana — *Data Pubblicazione*

CEI EN IEC 62446-2 — **2020-11**

La seguente Norma è identica a: EN IEC 62446-2:2020-05.

Titolo

Sistemi fotovoltaici (FV) - Prescrizioni per le prove, la documentazione e la manutenzione
Parte 2: Sistemi collegati alla rete elettrica - Manutenzione di sistemi fotovoltaici

Title

Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance
Part 2: Grid connected systems - Maintenance of PV systems

Maintenance of the PV systems

IEC TS 62446-3: Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 3: Photovoltaic modules and plants - Outdoor infrared thermography

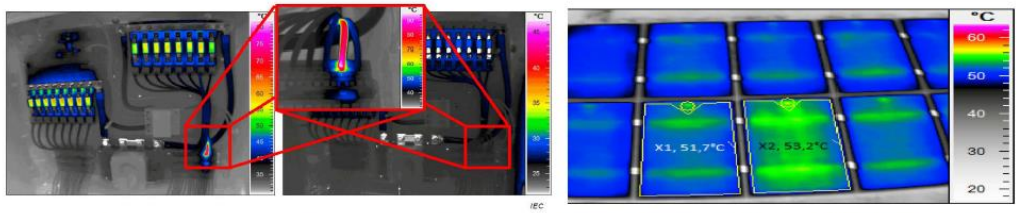


Figure 4 – Example infrared thermograms of a PV string combiner box with cables, contacts, fuses and switches before (left) and after (right) maintenance on a faulty contact

Key

right: color scheme of temperature, center: IR image, left: image information like file name, date, time, used equipment with setting, ambient conditions like T_{refl}, T_{atm}, irradiance, wind speed and project information such as module efficiency

Figure 6 – Example of image reporting

Thanks to Piergiacomo Cancelliere (CNVVF)

https://www.literoflightusa.org/solar-panel-problems/

Conclusion

- BAPV/BIPV will increase the Fire risk of the building. We need to evaluate the severity of the hazard, working to reduce the probability of its occurrence. It's difficult to find "prescriptive rules" and "deemed to satisfy solutions" in the national codes

- As Fire engineer, you can push the market towards safer productions

- We need harmonization, of course, but we have the tools to evaluate the risk and mitigate it

Thank you

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Annex to the main presentation

Useful references

- 4-YKo-A-state-of-the-art-review-of-fire-safety-of-photovoltaic- https://europeanfiresafetyalliance.org/
- RC62 - Recommendations for fire safety with PV panel installations https://www.thefpa.co.uk/resource-download/363
- assessing-fire-risks-photovoltaic-systems-and-developing-safety-concepts-risk https://www.energy.gov/sites/prod/files/2018/10/f56/PV%20Fire%20Safety%20Fire%20Guideline_Translation_V04%2020180614_FINAL.pdf
- RFDevelopmentFireMitigationSolutions https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/RFDevelopmentFireMitigationSolutions.ashx
- Overview of the Current State of Flexible Solar Panels and Photovoltaic Materials. Rashid Dallaev et al. Materials 2023, 16, 5839. https://doi.org/10.3390/ma16175839
- Fire safety of BIPV: International mapping of accredited and R&D facilities in the context of codes and standards. Report IEA-PVPS T15-15:2023
- Fire Safety of Building Integrated Photovoltaic Systems: Regulatory Gaps for Solar Façades Yoon Koet al https://www.sfpe.org/publications/fpemagazine/fpeextra/fpeextra2022
- Analysis of requirements, specifications and regulation of BIPV. Report IEA-PVPS T15-08: 2019

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Useful references

- PV electrical plants fire risk assessment and mitigation according to the Italian national fire services guidelines December 2014 Fire and Materials 40(3) DOI: 10.1002/fam P. Cncelliere;
- PV modules on buildings – Outlines of PV roof samples fire rating assessment May 2020 Fire Safety Journal 120(4):103139 DOI: 10.1016/j.firesaf.2020.103139 – P. Cancelliere G. Manzini G. Traina M. Cavriani
- Maintenance of PV systems: how to reduce fire risk and enhance the overall reliability June 2017 Conference: IFireSS 2017 – 2nd International Fire Safety SymposiumAt: Naples, Italy C. Liciotti P. Cancelliere
- Fire Behaviour and Performance of Photovoltaic Module Backsheets June 2015 Fire Technology 52(2) DOI: 10.1007/s10694-014-0449-7 C. Liciotti P. Cancelliere
- Fire risk related to the use of PV systems in building facades EDP Sciences January 2016MATEC Web of Conferences 46(11):05001 DOI: 10.1051/matecconf/20164605001 –L. Mazziotti P. Cancelliere et al.
- PERFORMANCE ASSESSMENT OF BIPV FAÇADES EQUIPPED WITH ACTIVE RAPID SHUTDOWN, September 2020 Conference: 37th EU PVSEC, 07 - 11 September 2020, European PV Solar Energy Conference and Exhibition – P. Cancelliere et al.
- Experimental study of flame spread underneath photovoltaic (PV) modules. J. Kristensen https://doi.org/10.1016/j.firesaf.2020.103027
- Kristensen JS, Faudzi FBM, Jomaas G (2021) Experimental study of flame spread underneath photovoltaic (PV) modules. Fire Safe J 120:103027

BIPV integrated in the roof EN 13501-5

If a PV is integrated in the roof, it shall be tested as any other roof covering.

In the EU the classification is carried out according to EN 13501-5 and testing against CEN/TS 1187

There are 4 test methods, T2 in the picture

BIPV cannot reach class A1 or A2, EN 13501-1

The encapsulant thickness shall be less than 1,0 mm and the weight less than 1,0 kg/m2 and the PCS < 4,0 MJ/m2.

Normally the weight is a bit less than 1 kg/m2, but with a PCS >> 4 MJ/m2

Table 1 — Classes of reaction to fire performance for construction products excluding floorings and linear pipe thermal insulation products

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 [a] and	$\Delta T \leq 30$ °C; and $\Delta m \leq 50$ %; and $t_f = 0$ (i.e. no sustained flaming)	-
	EN ISO 1716	*PCS* ≤ 2,0 MJ/kg [a] and *PCS* ≤ 2,0 MJ/kg [b c] and *PCS* ≤ 1,4 MJ/m^2 [d] and *PCS* ≤ 2,0 MJ/kg [e]	-
A2	EN ISO 1182 [a] or	$\Delta T \leq 50$ °C; and $\Delta m \leq 50$ %; and $t_f \leq 20$ s	-
	EN ISO 1716 and	*PCS* ≤ 3,0 MJ/kg [a] and *PCS* ≤ 4,0 MJ/m^2 [b] and *PCS* ≤ 4,0 MJ/m^2 [d] and *PCS* ≤ 3,0 MJ/kg [e]	-
	EN 13823	*FIGRA* ≤ 120 W/s and *LFS* < edge of specimen and $THR_{600s} \leq 7,5$ MJ	Smoke production [f] and Flaming droplets/particles [g]

[a] For homogeneous products and substantial components of non-homogeneous products.
[b] For any external non-substantial component of non-homogeneous products.
[c] Alternatively, any external non-substantial component having a *PCS* ≤ 2,0 MJ/m^2, provided that the product satisfies the following criteria of EN 13823: *FIGRA* ≤ 20 W/s, and *LFS* < edge of specimen, and $THR_{600s} \leq 4,0$ MJ, and s1, and d0.
[d] For any internal non-substantial component of non-homogeneous products.
[e] For the product as a whole.