PU Europe
Factsheet

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Glossary

- BAPV (Building Attached Photovoltaics): In BAPV, the PV modules are attached to the buildings using additional mounting structure (sometimes also named as "building applied")
- BIPV (Building Integrated Photovoltaics): Photovoltaic products that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or façades
- FM: Factory Mutual Insurance Company
- MW: Mineral Wool according to EN13162
- PIR: According to EN13165 "Factory made rigid polyurethane foam (PU) products"
- PV array: A linked collection of PV panels
- PV panel: Separate photovoltaic panel which may be constructed from a number of PV modules
- TC: Thermocouple

Fire performance of thermal insulation products in end-use conditions

Comparative fire tests to investigate the contribution of PIR & MW thermal insulation products to the fire performance of flat roofs under PV systems

Executive summary

Fire safety is an important consideration for the design and construction of buildings.

Increasingly PhotoVoltaic (PV) systems are installed on buildings in order to help meet energy saving and GHG (greenhouse gas) emission reduction targets as well as to reduce fuel bills for occupants. In a number of countries installation of PV systems on new build houses and especially large industrial premises has become mandatory. It is therefore important that regulators and insurance companies have sound research results to enable them to make informed risk-based decisions.

PIR is the thermal insulation product of choice especially for flat roofs. In addition to its excellent thermal performance, the mechanical stability of PIR insulation boards allows installation and maintenance of PV systems above the roof insulation and waterproofing system.

Architects, building owners, regulators and insurance companies need to know that in case of a fire where PV systems are involved, the safety objectives for flat roof systems are met.

<u>Fire safety of PV systems and connected installations</u>
Whilst regulations and standards have been developed to prevent PV installations and related electrical cabling and equipment becoming an ignition source, damage by weather conditions and/or possible faulty installation means there is still a remaining risk that a fire could start. PV systems are not considered as construction products, therefore no reaction to fire or CE marking requirement for building applied PV systems is currently available under the CPR. Whilst the fire performance of PV systems themselves is an important parameter to be considered further, this aspect is not covered in this paper.

<u>Additional considerations for roofs in combination with PV systems</u>
In Europe, spread of fire on and into roof insulation and waterproofing systems exposed to an external fire source can be assessed and regulated by using one of the 4 test methods given in CEN TS 1187 [1] and the related classification standard

In this configuration it was shown that it is not necessary to require non-combustible insulation in terms of fire spread and internal damage.

EN13501-5 [2]. For roofs with PV systems mounted above the roof system, insurance companies and some regulators are questioning whether the historically accepted safety level is still sufficient for the combination of such systems, taking into account that the PV systems may be a possible ignition source and may add to the fire load on the roof. In addition, there are concerns that they may intensify fires due to re-radiation.

As a simplistic mitigation measure, it has been proposed by a number of insurance companies, to require replacement of combustible insulation on roofs by non-combustible products if PV systems are mounted above. In order to determine whether this proposal is justified, PU Europe commissioned two comparative tests. Two FM [3] approved roofing systems were chosen, one insulated with PIR and one with MW. PV panels in a configuration commonly used in Northern and Western Europe were mounted above the roof and a gas burner was used as an external ignition source.

For both tests, the spread rates of the flame front on the roof were similar under the PV modules. Also for the fire spread on the roof systems outside the perimeter of the PV modules, it was impossible to see any direct influence from the different thermal insulation layers.

The PIR insulation was only charred to just over 25 % of its thickness and the roof cooled down continuously after the PV panels had stopped burning.

Conclusions from these tests:

- Roofs below burning PV systems can be exposed to a high level of heat and radiation;
- Notwithstanding the high fire exposure resulting from the gas burner combined with the burning of the PV modules, the performance of the roof assembly with PIR insulation compared well with that of the MW insulated roof. Fire spread on the roof extending beyond and around the burning PV systems was similar for both tested roofs;
- In this configuration it was shown that it is not necessary to require non-combustible insulation in terms of fire spread and internal damage.

The results herein are specific to the flat roof and PV configurations that were tested.

Introduction

PU Europe commissioned "KIWA BDA Testing" to perform comparative tests of two FM approved roofing systems in combination with BAPV.

Construction products marketed and applied in the European Economic Area (EEA) have to be tested and classified regarding their reaction to fire and/or fire resistance in order to be placed on the market with CE marking. For roofing systems, specific requirements are in place to classify fire performance in the event of external fire exposure. With the introduction of PV systems on roofs, additional requirements may need to be considered.

PV systems which are part of the building envelope, like BIPV, can be tested and classified as construction products according to the CPR (Construction Products Regulation **(EU) No 305/2011**). For PV systems integrated in roofs – so called in-roof systems - this means that they are subject to the national regulations for roofs based on the reaction to fire requirements (based on EN13501-1) and regarding external fire exposure of roofs (EN13501-5) as for all other roofing products.

PV systems which are mounted on/above finished roofs, like BAPV, are not considered as construction products in Europe according to the CPR. They are subject instead to the low voltage directive (**2014/35/EU**). Nevertheless, building authorities in some countries have introduced requirements regarding reaction to fire for PV modules mounted on top of roofs (for example in Germany a minimum class E according to EN13501-1) and are working on installation and maintenance certification schemes (e.g. in the Netherlands). Some countries in the European Union are investigating requirements and additional certification schemes.

Recently, the European standardisation committee CEN/TC 127 "Fire safety in buildings" initiated work to investigate the need for developing a standard or technical specification, which covers the combined effects for fire safety of roofs and PV modules. In addition, insurance companies have started considering additional requirements for insuring buildings with BAPV systems, with some of their experts increasingly considering allowing only non-combustible insulation on roofs below such systems.

PU Europe commissioned "KIWA BDA Testing" to perform comparative tests of two FM approved roofing systems in combination with BAPV at the Troned Twente Safety Campus in the Netherlands.

The tests were performed in 2021 to assess the impact of the tested insulation materials on the fire performance of a whole roof assembly, in response to a fire involving a BAPV system, both in terms of fire propagation and fire penetration.

The tests were not intended to rate specific insulation products (brands) but were performed solely:

- to explore whether a general requirement to use non-combustible insulation products in roof assemblies below PV systems, in order to limit fire propagation and penetration in the event of a fire, can be justified;
- to provide general information on how the fire performance of two different insulation products influences the fire performance of a flat roof assembly below BAPV.

Other factors which have an impact on the performance of a roof with BAPV, when exposed to an external fire, such as the response of the PV supporting structure, its installation details and the fire performance of the PV panels themselves were not considered in this test program.

Experimental setup

Two roof assemblies of 6 m x 6 m, identical except for the insulation layer were tested.

Figure 1: PV array on the flat roof after ignition of the gas burner

Fire scenario and test setup
The tests simulated an external fire starting below a PV array on top of a flat roof.

The ignition source used was a gas burner as proposed in CENELEC CLC/TR 50670:2016 **[4]** which was applied for 15 minutes. This burner has been shown to deliver a fire exposure to the roof leading to results comparable to that of the wood crib used in CEN/TS 1187 t1, representing a burning brand **[5]**.

Thermocouples were installed directly on the steel roof deck and in the middle of the insulation product layers. Videos were taken for both tests.

Test environment
The two tests were performed outdoors on the same day. The wind direction changed between tests one and two and it could clearly be observed that the wind direction has a strong influence on the direction of flame spread on the roof.

An additional difference between the two tests was the ambient conditions. The first test with MW insulation was performed in the morning when the air humidity was high and the temperature still cool. The maximum temperatures in the middle of the insulation layer were 13 °C for MW and 33.9 °C for PIR at the start of their tests.

Figure 2: Arrangement of PV system on the roof

Roof and PV systems
Two roof assemblies of 6 m x 6 m, identical except for the insulation layer were tested.

For the tests, FM approved roof assemblies were chosen which included PIR and MW respectively, two commonly used product types for insulating flat roofs.

The assemblies comprised a waterproofing membrane (PVC), an insulation layer, a vapour barrier (PE foil) and a supporting steel roof deck. The thicknesses of the two insulants were such that the roof assemblies were thermally equivalent (PIR insulation: one layer, 142 mm; MW insulation: 2 layers of 130 mm – total thickness 260 mm).

The PV system was comprised of PV panels with foil back sheets rated fire class C according to IEC 61730-2 [6]. Four of those panels (total size 3.2 m x 1.84 m, angle to roof 13°) were mounted in a back-to-back configuration, which mimics the east-west configuration which is increasingly used in Northern and Western Europe. In order to have a more critical scenario for possible fire spread, there were no vertical shields at the open ends of the PV array.

Recorded data and observations

The damage to the waterproofing layer and the top surface of the insulation layer was similar for both tests.

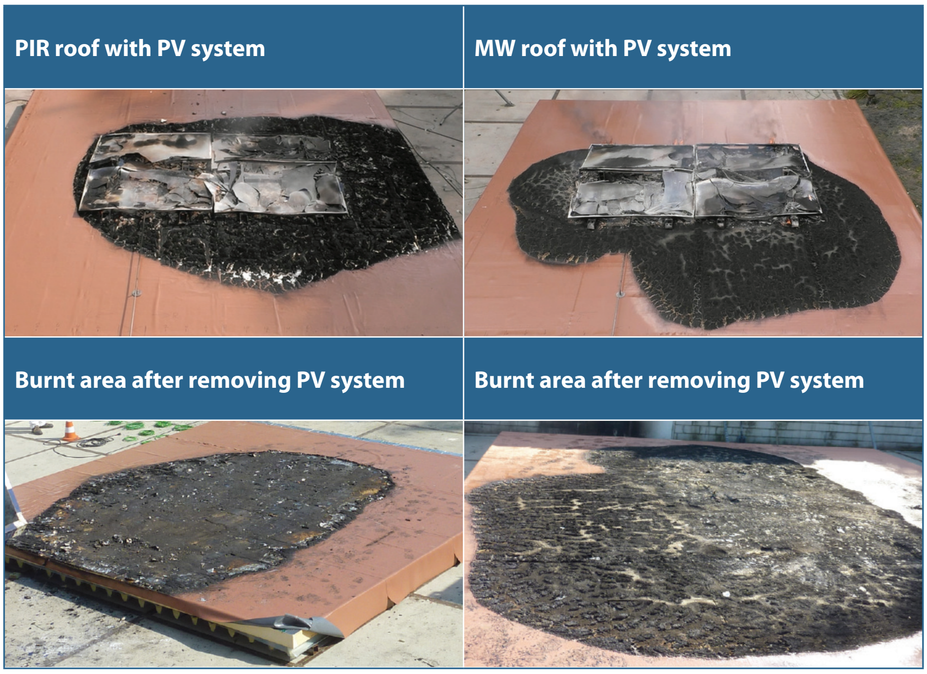


Figure 3: Specimens on the day after the test

Fire spread on the roofs
Both tests showed an intense ignition phase of the PV panels resulting in self-sustained flame spread on part of the surface of the roof outside the perimeter of the PV system.

With the chosen PV panel configuration, the heat exposure of the roof assembly was increased by the partial entrapment of flames under the apex of the PV system and by re-radiation from the PV system, as well as from the fire load of the burning PV panels themselves.

The main direction of fire spread beyond the PV system was different in the two tests, driven by the wind direction.

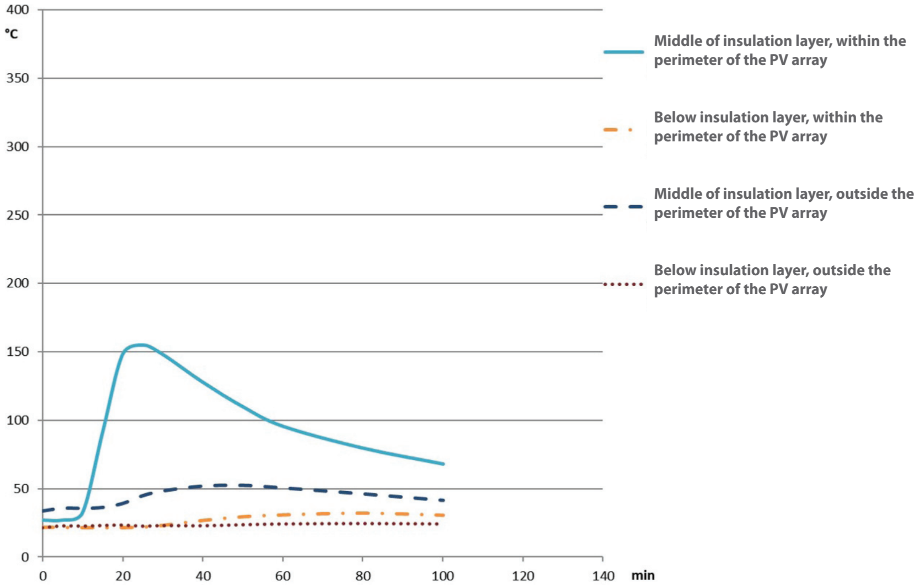
The PV system and the roof insulation and waterproofing system stopped burning after about 32 min (PIR) and 28 min (MW). The flames self-extinguished, without the need for external action, and did not extend to the complete roof area in both tests.

The ***figure 3*** shows that the damaged area of the roofs in both tests was limited and very similar [7].

Temperatures in the middle and below the insulation layers (see also "Test Environment" section for the start temperatures and note [8])
For the roof assembly with PIR, within the perimeter of the PV system, the temperatures in the middle of the insulation layer reached 155 °C after 23 minutes and started to decrease after this time. On the steel deck, below the insulation layer, within the perimeter of the PV system, only a slight increase (by 10 °C) could be observed up to 80 min after the start of the test. The complete roof including the steel deck started cooling down about 80 min after the start of the test.

For the MW insulated roof, within the perimeter of the PV system, the temperature in the middle of the insulation layer reached 35 °C 30 minutes after the start of the test. Though visible flaming had ceased about 30 min after the start of the test, the temperature reached 290 °C after 80 minutes and was increasing further. The maximum temperature recorded was 440 °C after 4 hours within the perimeter of the PV system. Overnight measurements on the steel deck showed a peak temperature of 190 °C.

Roof with PIR insulation



Roof with MW insulation

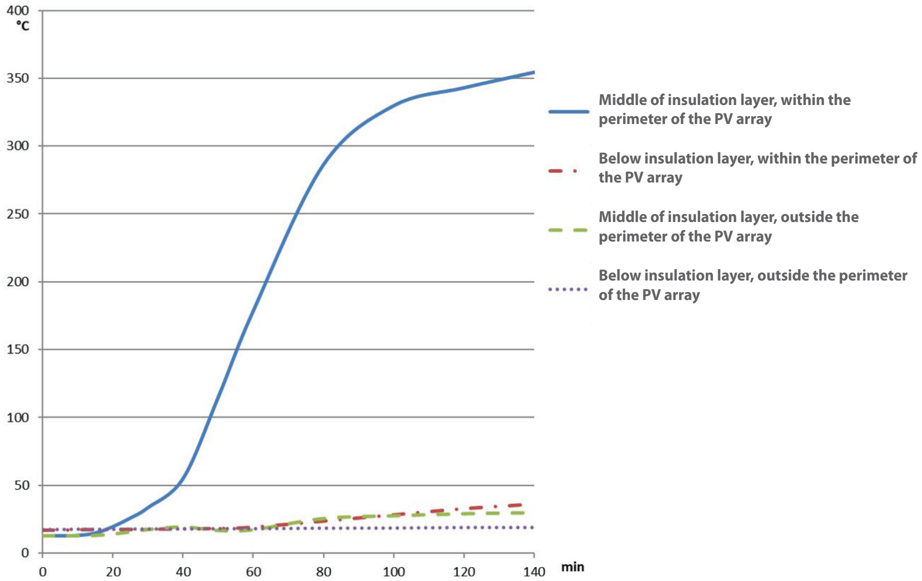


Figure 4: Maximum temperatures in ºC measured after the start of the tests

Burn through / Fire spread downwards
The damage to the waterproofing layer and the top surface of the insulation layer was similar for both tests. The damage further down into the insulation was quite different. For the PIR roof, the PIR layer was only charred downwards from the surface to about 25 % of the total thickness. The lower part of the insulation and the vapour barrier underneath remained undamaged. For the MW roof, the damage had reached the steel roof deck and had caused melting of the vapour barrier.

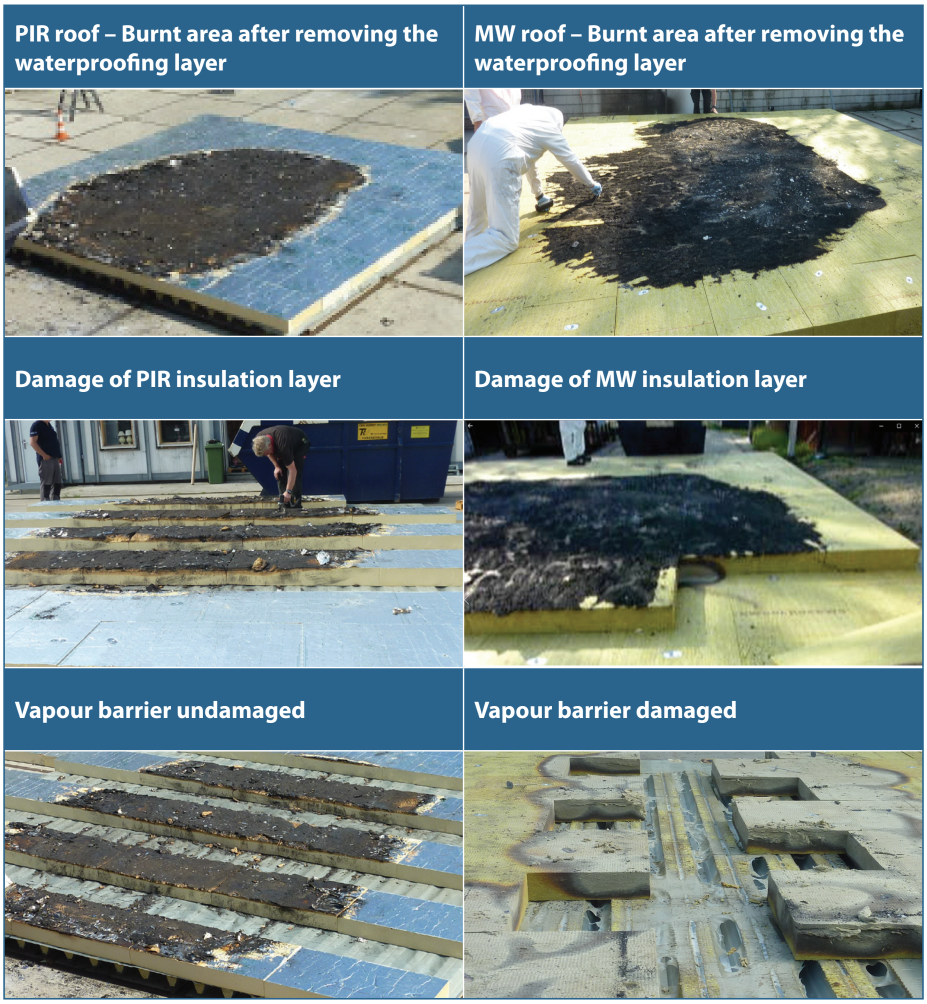


Figure 5: Pictures of the insulation layers and vapour barriers after the test

Summary and conclusions

The difference in spread of flame between the two build-ups was small.

Two roof covering assemblies with roof mounted PV systems (BAPV) on a steel roof deck were subjected to an external fire test. The general concept of the test method (4 PV-modules in two rows of two on a 6 m x 6 m flat roof construction, ignited with a burner according to CLC/TR 50670: 2016) is assumed to be a reasonable representation of the fire scenario being considered.

It was demonstrated that the performance of the tested FM approved roof with PIR insulation and a combustible waterproofing membrane compared well with a similar roof with MW insulation. At the end of the test for both build-ups it was not necessary to extinguish the flames – the fire died out without intervention. The fire did not spread across the complete surface of the roof but the PV systems completely burnt out. The difference in spread of flame between the two build-ups was small. When the roofs were dismantled the day after the tests, the vapour barrier on the steel deck was undamaged for PIR, while it was partly molten for MW.

In order to make sure that the risks for roof assemblies below PV systems are fully understood, additional tests might be needed in order to demonstrate that neither burn through of the roofs nor relevant fire propagation beyond the PV arrays can be expected. The use of a meaningful test method to address this knowledge gap is a more robust approach than simply replace PIR with non-combustible insulation.

Disclaimer

References and notes

- [1] CEN TS 1187:2012 Test methods for external fire exposure to roofs
- [2] EN 13501-5:2016 Classification using data from external fire exposure to roofs tests
- [3] FM 4470 Single-ply, polymer-modified bitumen sheet, built-up roof (BUR) and liquid applied roof assemblies for use in Class 1 and non-combustible roof deck construction
- [4] CLC/TR 50670:2016 External fire exposure to roofs in combination with photovoltaic (PV) arrays – Test method(s)
- [5] Bachelor Thesis, Constantin Niederwieser, Entwicklung einer Prüfmethode zur Beurteilung des Brandverhaltens von dachadditiven und dachintegrierten Photovoltaikanlagen, Hochschule Bonn-Rhein-Sieg, 2013
- [6] IEC 61730-2:2016 Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing
- [7] The exact areas have not been calculated, since due to the different wind directions between the two tests, the fire started under the PV system reached the closest edge of the PIR roof assembly system
- [8] For the PIR roof, the data acquisition was stopped when it became clear that all TCs were cooling down. For the MW roof, all TCs were monitored for a longer time, as there was a continuous increase of temperatures for a longer time