THE ROOF COMES FIRST · WHITEPAPER

DC arcs at the roof-PV interface

What determines roof exposure to a sustained DC arc and what current evidence shows about measures to limit it

> CORE PRINCIPLE
> **Exposure is determined by the source, the pathway and the receiving roof assembly.**

Olivier Langejan
Chief Commercial Officer, AllShield
AllShield | ol@allshield.com | allshield.com/en/olivier-langejan

Use and scope. This paper reviews published and available evidence on the exposure of the roof to sustained DC arcs. It does not present new testing and is not a substitute for project-specific electrical, fire, roofing, structural, insurance or legal advice. Test results, standards and approvals apply only within their stated scope. The responsible professionals and approving parties remain responsible for project-specific decisions.

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Author's perspective

This series is a synthesis of published research, fire tests, standards, approvals and insurer guidance on fire safety and rooftop PV, written from an explicit roof-first perspective: I look at the complete commercial roof system and the building beneath it rather than at individual product classifications. Within that perspective I summarise what the evidence shows, add my own technical analysis and, where relevant, propose design principles. Those proposals are marked as mine and kept separate from what has been demonstrated.

My background is in architecture and building engineering. Over the past three years I have discussed this subject with engineers, risk specialists, insurers and test institutes, and I have been involved in setting up and supervising fire-test programmes for AllShield's own roof systems. That experience shapes the questions I ask; the papers test those questions against external evidence. How the sources were selected, and what remains open, is described at the end of each paper.

These papers are prepared by Olivier Langejan as lead author with support from a small team. His own professional focus is building and roof design; specialist findings are drawn from the cited evidence, with AI assistance disclosed separately in Method and sources.
I am affiliated with AllShield, which develops BarrierSheet and other roof fire-protection solutions. That commercial relationship is relevant and is therefore stated explicitly. The analysis does not assume that an AllShield product provides the effects discussed. Where an AllShield product is discussed, it is treated as one product-specific example and its performance should be read only within the boundaries of the cited tests, approvals and roof assemblies.

This paper begins where DC arcs as a heat source ends. The companion paper characterises the electrical source and hands over a source vector. This paper asks what happens between that source and the roof: which pathway factors determine the exposure at the first roof surface and what evidence exists for measures intended to limit that exposure or deeper escalation. It also separates the exposure supported by the arc itself from the self-sustaining combustion that may follow it, because the two call for different measures and different evidence. It does not seek a universal safe distance and it does not prescribe a proprietary solution. The evidence labels DEMONSTRATED, PHYSICALLY SUPPORTED, CONTRADICTED and UNKNOWN are applied in the same way to every measure. Absence of evidence is treated neither as evidence of performance nor as evidence of failure.

Olivier Langejan
Chief Commercial Officer, AllShield

Executive summary

> CORE THESIS
> **The roof does not experience an arc in the abstract. It experiences the exposure that remains after source characteristics, geometry, separation, interposition and duration have shaped the pathway to the roof assembly.**

Why this paper

DC arcs as a heat source establishes the source-side problem: a sustained DC arc can remain electrically supported for a period that depends on the wider PV circuit and it should be characterised by intensity or thermal output, emission mode, source geometry and orientation, particle characteristics where relevant and duration. This paper takes that source vector as an input. It does not reopen arc physics. Its question is what portion of that source actually reaches the roof and what can be said about measures intended to reduce the resulting exposure or escalation.

That distinction matters because source intensity and roof exposure are not the same thing. A source close to the membrane, oriented towards it and accompanied by hot material can create a different local exposure from the same nominal electrical condition at another position. Conversely, a severe source does not impose the same exposure on every nearby surface. Distance, orientation, obstructions, interposed elements and the trajectory of ejected material all influence the pathway.

What current evidence shows

The reviewed evidence includes DC-arc-specific results for one connector-to-roof separation geometry and for one local connector-containment configuration. In the programme described in manufacturer technical note ARC002, unprotected connector tests at approximately 50 mm above EPDM and bituminous roof coverings, described in ARC002 as fire-retardant, resulted in membrane ignition and fire spread under a deliberately maintained 35 A arc. The same programme reported successful containment for five minutes when the tested connector enclosure was present. [1] These are meaningful but narrow results. The unprotected reference tests were designed to compare containment performance, not to establish a distance-response curve and the five-minute exposure was deliberately maintained rather than measured as a natural upper bound for connector-arc duration.

The evidence reviewed does not establish a universal fire-safe connector-to-roof distance. Installation guidance and mounting-system hardware keep connectors clear of the roof for water management, mechanical protection, abrasion control and cable management. [3][4] Those are valid objectives but they do not establish fire performance. A connector being kept off the roof is therefore not evidence that it is being kept at a fire-safe distance from the roof.

Two exposure mechanisms, two design objectives

An incident that starts with a DC arc can expose the roof through two mechanisms that may follow or overlap: arc-supported exposure, which depends on the electrical energy feeding the fault, and self-sustaining combustion of connector material, the membrane or other combustible material. Fast detection and interruption can shorten the first considerably but do not necessarily end the second, and a shorter electrical fault does not automatically mean a proportionally smaller thermal load on the roof. The mechanisms correspond to two design objectives: preventing an arc from igniting the roof, to which detection, interruption, separation and local containment mainly contribute, and preventing a local ignition from developing into a larger fire in the roof construction, to which a protective sublayer can mainly

contribute. Neither makes the other unnecessary. This is also why fire tests without an electrical arc can be relevant to the second mechanism without being evidence for the first.

Pathway and receptor measures

This paper uses a source-pathway-receptor framework. Prevention, detection and interruption act on the source and are addressed in the companion paper. Separation and interposition act in the pathway. The roof assembly is the receptor. Within that receptor the primary receiving surface, normally the membrane, has to be distinguished from a protective sublayer within the build-up.

The distinction applies to any protective sublayer, including AllShield's BarrierSheet. A protective sublayer beneath a membrane cannot be credited with preventing initial membrane ignition merely because it is present below the membrane. Its evidence status depends on the exposure considered. For a direct sustained local DC arc it is UNKNOWN: no sustained DC-arc test of BarrierSheet, or of another protective sublayer identified in this review, has been found. For a burning membrane above the layer, the ZAG and Kiwa programmes provide relevant support within their tested configurations. Heat transfer to the materials below depends on the build-up, the exposure and the measured temperatures. Absence of direct flame penetration and thermal protection of the underlying materials are separate performance criteria. External-fire testing and an assembly-specific FM Approval apply to their tested assemblies and documented basis. [8][9][10][11]

Main conclusion

Separation, local connector containment, other interposition and protective sublayers are not interchangeable measures. Each acts at a different place or by a different mechanism and each should be credited only for what its evidence demonstrates. The reviewed evidence gives DC-arc-specific information for one separation geometry and one connector-containment configuration, but it does not identify a universal single interface measure that can be treated as sufficient across sustained DC-arc exposures. The measures also differ in coverage: source-side controls have an electrical scope, local pathway measures have a spatially bounded scope and continuous receptor measures can provide area-wide coverage across the part of the roof in which they are installed, but only for deeper escalation and without demonstrated sustained-DC-arc performance. Where residual DC-arc exposure is considered relevant, a layered interface strategy is therefore more defensible than reliance on any single unvalidated measure. A highly effective source-side control does not by itself answer what limits escalation once self-sustaining combustion has begun, and a receptor measure does not reduce the need for source-side control.

1. The interface problem

From source to exposure

DC arcs as a heat source stops at the point where the electrical fault has been characterised as a potential external thermal source. That boundary is deliberate. An electrical source can be described by current, voltage, duration and other source variables without yet knowing what thermal load will reach a particular material. The roof question begins only after the source has been defined.

This paper therefore starts with a sustained source already present. The first question is not whether the arc can exist. It is what exposure that source imposes on the roof beneath or beside it. The answer depends on the source vector but also on the physical route between source and roof. A connector 20 mm above a membrane, a junction box on the rear of a module and a damaged cable suspended beside a rail may all produce an arc, yet they do not create identical pathways to the same receiving surface.

Three different quantities

Three concepts have to remain separate. The source is the thermal output created by the arc and associated component failure. Exposure is the part of that source that actually reaches the roof. Response is what the roof assembly does when it receives that exposure. Collapsing those three into one statement is the quickest route to overclaiming.

A source can be severe while the exposure at a particular surface is reduced by separation, orientation or interposition. A membrane can receive a significant exposure and ignite while deeper layers remain separated from direct flame. Conversely, a modest local source can become consequential if it is positioned in sustained contact with a vulnerable surface. The physical problem is therefore not only how energetic the arc is. It is how source, pathway and receptor interact.

Scope boundary

The paper is intentionally narrow. Arc initiation, electrical stability, natural duration and source-side detection and interruption are treated in DC arcs as a heat source. Once membrane involvement develops into wider flame spread, insulation involvement, cavity fire or developed roof-PV fire behaviour, the analysis belongs in Beyond flame spread. Consequence, defence in depth and risk treatment are treated in From risk models to design requirements. The present paper occupies the interface between those subjects. The handover to Beyond flame spread is defined by mechanism rather than by a moment in time: this paper covers arc-supported exposure and the onset of self-sustaining combustion at the interface, not its further development.

> **SCOPE**
>
> **This paper asks what reaches the roof and what interface measures can credibly modify that exposure. It does not re-explain arc physics and it does not re-write the developed-fire literature.**

The paper does not argue that a sustained connector arc is a common event and does not calculate its frequency. Its subject is conditional: if a sustained source exists at the roof-PV interface, what determines the exposure that follows? A designer may conclude that upstream electrical controls make a particular source highly unlikely and still choose to understand the remaining interface consequence. This paper provides the exposure logic for that discussion; it does not prescribe one risk appetite.

2. From source vector to roof exposure

The companion paper hands over five source-vector components. The purpose of this chapter is to translate each component into a pathway question without adding precision that the source evidence does not provide.

Intensity or thermal output

Intensity describes the magnitude of the source but it is not the same as heat flux at the roof. Electrical current can help define the fault condition, yet current alone does not specify how much energy reaches a separate surface. Arc voltage, radiative fraction, convective flow, direct impingement and particle emission can all change the transfer. Where a study reports only electrical conditions, this paper does not invent a roof heat flux.

Distance and position can change the fraction of source output that reaches the roof. For radiation, increasing separation changes the geometric relationship between source and surface. For direct flame or plasma contact, small changes in source position can decide whether contact occurs at all. For convective heating, orientation and the local cavity geometry can alter where heated gases move. [7] The source magnitude therefore enters the pathway analysis as an input, not as a complete exposure value.

Emission mode

The source can emit energy through more than one mechanism. Direct flame or plasma, radiation, convection and hot or molten material may occur together. Each mode interacts differently with the pathway. A solid obstruction can intercept particles and direct impingement while having a different effect on radiative exchange. A larger distance may reduce some modes substantially while still allowing hot material to fall onto the surface below.

The distinction matters when a protection claim is based on one observed mechanism. A measure that catches particles should not automatically be credited with controlling radiation. A shield that blocks direct line-of-sight exposure should not automatically be treated as a thermal barrier for an undefined duration. The pathway has to be matched to the emission mode actually being claimed.

Source geometry and orientation

Geometry includes component height, horizontal displacement, connector or junction-box orientation, cable routing, sagging and nearby mounting components. It also includes the orientation of the arc and the failing component itself. These variables influence whether direct impingement is possible, how far particles have to travel and whether a rail, tray or module edge acts as an obstruction or secondary heated surface.

The geometry is not necessarily static. A connector housing can soften, conductors can move, a cable can sag and the arc path can change as material is lost. Controlled tests may deliberately hold or adjust the geometry to maintain a defined exposure. That is legitimate experimental control, but the controlled geometry remains part of the evidence boundary.

Fault location also changes which pathway is relevant. A rear-mounted junction box is normally separated from the roof by the module cavity and its source may be partly screened by the module or mounting structure. A field connector can hang much closer to the membrane. Damaged cable may lie on a support, cross a rail or sag into contact with the roof. The electrical source category alone therefore does not define the spatial exposure problem; the location and installation geometry have to travel with it.

Particle characteristics where relevant

Where a failing component ejects or drops hot material, the particle pathway depends on more than gravity. Initial ejection direction and velocity matter. Wind can alter the trajectory. Modules and connectors are often inclined. A particle can strike an intermediate component before reaching the roof or can leave the immediate area entirely. Particle temperature, mass, size, composition and persistence determine whether arrival at the roof remains thermally significant.

The available connector evidence is stronger qualitatively than quantitatively. The secondary account of the ARC002 programme reports hot material falling from the failing connector during unprotected tests. [2] The reviewed sources do not provide a representative particle-size or temperature distribution for real deteriorating connectors. That uncertainty should remain visible. Later involvement of a PV module can also create falling burning material, but that is a different source from the initiating arc and falls outside the scope of this paper. [5]

Duration

Duration determines for how long the pathway is supplied. A short intense source and a lower source that persists longer cannot be assumed to produce equivalent exposure. The companion paper therefore carries duration as a separate source-vector component. This paper carries the same variable through the pathway to the receiving surface and returns to it in Chapter 7. The duration of the electrical fault and the duration of the thermal exposure at the roof are not necessarily the same; Chapter 7 separates the two.

> **Source intensity and roof exposure are related but not interchangeable.**

SOURCE	PATHWAY	RECEPTOR
DC arc source vector	**How the source reaches the roof**	**Roof assembly**
Intensity or thermal output	Separation	Primary receiving surface
Emission mode	Position and orientation	(normally the membrane)
Source geometry and orientation	Interposition	
Particle characteristics where relevant	Particle trajectory	Protective sublayer
Duration	Exposure duration	(within the roof build-up)

Figure 1. Source, pathway and receptor at the roof-PV interface. The framework is descriptive. It identifies where a measure acts; it does not rank source, pathway and receptor measures by default.

3. Mechanical separation is not fire-safe separation

Why connectors are kept off the roof

Installation guidance and mounting systems keep connectors and cables clear of the roof surface. Current connector instructions state that connectors should not lie directly on the roof covering, should not be positioned where water can collect and should not remain in standing water. [3] Flat-roof mounting systems also provide clips, supports or cable-management positions that keep connectors and wiring away from the membrane. [4]

These measures are sensible for reasons that have little to do with fire distance. They reduce unnecessary contact with water and contamination, avoid abrasion, help preserve connector geometry and improve cable management and inspection. A support position can therefore be a valuable reliability measure even if no fire test has ever been performed at that clearance.

Two claims that should not be confused

Mechanical separation is a position or clearance selected for installation, maintenance or mechanical reasons. Fire-safe separation is a much stronger claim. It implies that the chosen position has been shown to keep the receiving surface within an acceptable performance criterion for a defined source, duration and geometry.

> **A connector being kept off the roof is not evidence that it is being kept at a fire-safe distance from the roof.**

The difference is not semantic. If a mounting instruction says that a connector should be supported clear of the membrane, that instruction demonstrates an installation requirement. It does not establish the thermal exposure at the membrane under a sustained arc. To turn a clearance into a fire-performance claim requires an exposure-specific evidence chain.

What a fire-safe claim would have to define

At minimum, a fire-safe separation claim would need to identify the source condition, source duration, vertical and horizontal geometry, orientation, receiving surface and failure criterion. If particle emission is relevant, the particle source and trajectory also matter. If the receiving surface is a complete roof build-up rather than a membrane specimen, the construction has to be defined sufficiently to know what the result applies to.

This is why a single distance cannot be lifted from installation practice and relabelled as a fire threshold. It is also why one failed distance does not automatically define the next distance as safe. Separation is a continuous pathway variable, while fire-safe performance is an evidence claim tied to a test or validated model.

A useful way to express the distinction is as a performance envelope rather than a number. A distance can only be called fire-safe for the range of source intensities, durations, orientations, receiving surfaces and failure criteria for which acceptable performance has been established. If any of those variables changes materially, the evidence has to justify transfer beyond the tested envelope. This is the same discipline used elsewhere in the series for classifications and tested assemblies.

That also prevents an inverse error. Failure at one geometry is evidence about that geometry, not proof that separation as a design mechanism is ineffective. The approximately 50 mm reference case is valuable precisely because it is a measured point on an otherwise poorly characterised relationship. It should motivate caution about unvalidated clearances without being converted into a universal statement against separation.

4. A source-pathway-receptor framework for the roof-PV interface

Source

The source is the electrical fault and the thermal output it produces. Prevention, detection and interruption act here. Good installation reduces the probability that a source forms. Detection identifies an electrical signature after arcing begins. Interruption changes the circuit and can truncate the duration of a relevant series arc. These source-side functions are treated in DC arcs as a heat source.

Pathway

The pathway is the route by which heat, flame, plasma or particles travel from the source to the roof. Two broad intervention types are relevant. Separation changes distance, position or geometry. Interposition places an element physically between source and receiving surface. A connector enclosure is therefore a pathway measure: it can allow the electrical source to remain present while restricting transfer out of the protected volume.

Receptor

For this paper the receptor is the roof assembly. Within it, two locations should be distinguished. The primary receiving surface is the first surface of the roof assembly that receives the exposure, normally the waterproofing membrane. A protective sublayer sits within the roof build-up beneath that surface and may influence whether involvement progresses into deeper layers.

This spatial distinction prevents a common overclaim. A protective sublayer beneath the membrane cannot be credited with preventing initial membrane ignition unless evidence specifically demonstrates that effect. Its potential function is different: limiting heat transfer, penetration or deeper escalation after the primary receiving surface has already become involved.

Edge cases

For the purposes of this framework, classification follows physical position. A loose, non-bonded plate, pad or gravel layer placed on top of the membrane directly beneath a connector is treated as interposition because it sits in the pathway before the roof assembly's primary receiving surface. A coating bonded to the membrane changes the primary receiving surface itself. A board installed beneath the membrane is a protective sublayer within the receptor. This is an analytical convention for locating measures, not a general building definition; ballast can be part of the roof system in other respects. In a recover build-up, the existing roof covering beneath a new protective sublayer remains part of the underlying layers. A sublayer above it does not make that covering or the insulation below non-combustible.

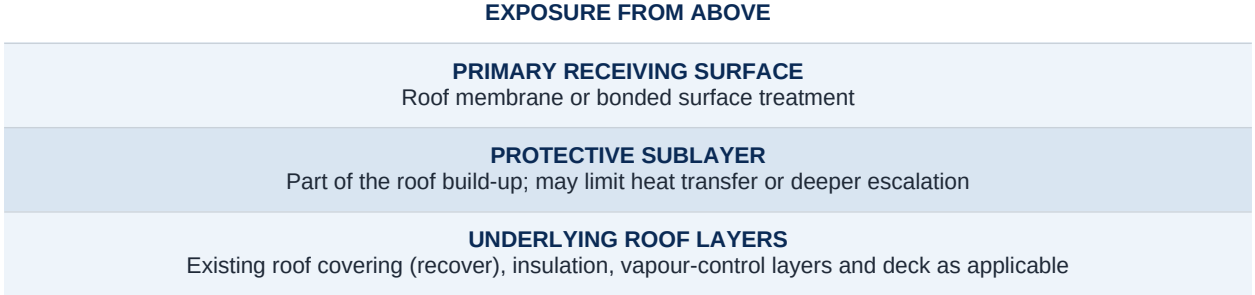


Figure 2. Functional positions within the receptor. A loose plate or pad on top of the membrane is treated as interposition. A coating bonded to the membrane modifies the primary receiving surface.

Descriptive, not hierarchical

The source-pathway-receptor framework is used here to identify where a measure acts. It is not a ranking that automatically makes a source-side measure superior to a receptor-side measure. Different measures have different dependencies. Active detection depends on sensing, configuration and successful interruption. A passive roof sublayer depends on correct installation, continuity, durability and its tested thermal behaviour. Their effectiveness has to be judged against the relevant exposure and the evidence for the function being claimed.

This is consistent with defence in depth. The purpose of a layered strategy is not to compensate for poor electrical design by adding roof protection. It is to recognise that source reduction, pathway control and receptor resilience solve different parts of the incident chain and can have different failure modes.

The distinction between active and passive measures is relevant but does not create a universal ranking. Detection and interruption can act early and can remove the electrical energy that sustains a series arc, but their benefit depends on the fault being detected, the protection remaining enabled and the circuit being interrupted as intended. A passive interposed element or roof sublayer does not depend on sensing the electrical signature, but its benefit depends on being physically present, correctly installed and able to retain its function during the exposure. Comparing these measures therefore requires reliability and scope as well as nominal position in the model.

5. Separation

What increasing distance can change

Increasing separation can reduce direct coupling between a source and the roof. It may eliminate direct contact, reduce the solid angle seen by a receiving surface and change the likelihood of direct flame or plasma impingement. It can also increase the time and distance over which convective flow or particles travel. Those mechanisms make separation physically plausible as a risk-reduction measure.

The effect is not described by vertical height alone. Horizontal offset matters. Source and receiving-surface orientation matter. A connector hanging 50 mm above a membrane but displaced laterally from the vulnerable surface is a different geometry from a connector directly over it. A mounting rail may obstruct one pathway while a sloping cable directs molten material towards another area. Separation should therefore be treated as geometry, not as one scalar number detached from configuration.

The approximately 50 mm reference case

The ARC002 connector-containment programme included unprotected reference tests as well as tests with the enclosure. In the flat-roof arrangement the modified connector was positioned approximately 50 mm above EPDM or bituminous roof coverings and carried a 35 A arc that was deliberately maintained for the five-minute test interval. The technical note describes the 50 mm position as following industry best practice for keeping connectors out of contact with the membrane. According to the primary technical note, the unprotected reference tests led to ignition of the roof membrane and fire spread in the tested south-facing and east-west arrangements. [1]

This is direct DC-arc-specific evidence for one separation geometry. It is also unfavourable evidence: approximately 50 mm did not prevent membrane ignition under the defined test condition. That finding is important because it demonstrates the difference between physical clearance and demonstrated fire-safe separation.

The test should not be asked to answer a question it was not designed to answer. The unprotected configurations were reference cases in a containment programme. The programme compared outcomes with and without the enclosure; it was not a systematic distance-response study. It therefore provides one tested distance, one defined electrical condition and two roof-covering types. It does not establish how exposure changes at 75, 100, 150 or 200 mm and it does not define a universal threshold.

What the secondary account adds

A secondary article describing the same experiments reports that ignition of the membrane occurred after approximately three to five minutes and describes the combined role of the arc and falling hot material. [2] Those observations help interpret the pathway but their evidential status is different from the primary test note. The three-to-five-minute ignition time and the hot-debris description should therefore be attributed to the secondary source rather than silently merged into the primary record.

What the case does and does not demonstrate

The case demonstrates that a connector can be physically clear of the membrane and still impose sufficient exposure for ignition under one deliberately maintained 35 A arc condition. It also demonstrates that separation performance cannot be inferred from the fact that a connector is supported rather than lying directly on the roof.

It does not demonstrate that 50 mm is generally unsafe under every connector fault, nor that another distance is generally safe. The natural duration of a deteriorating connector may be shorter or longer than the maintained test interval and the source vector can differ in current, geometry, particle emission and

orientation. The correct conclusion is methodological: no universal fire-safe connector-to-roof distance was identified in the reviewed evidence. Nor does it show what the same geometry produces under an arc that source-side interruption ends within seconds. In that case the arc-supported exposure would be a small fraction of the maintained test interval and the outcome would depend mainly on whether self-sustaining combustion had begun (Chapter 7).

Three unresolved variables are particularly important if separation is to become a validated design tool. The first is source severity: the relationship between electrical conditions and the thermal output actually directed towards the roof. The second is duration: a geometry that avoids ignition for a short event may not do so for a longer one. The third is particle behaviour: increasing height can reduce direct coupling while giving hot material a longer trajectory rather than eliminating its arrival at the roof. A distance study that ignores any of these variables would still leave a substantial evidence gap.

Wind and array geometry add a further practical complication. A test performed in still laboratory conditions at one module inclination cannot automatically define a field distance for an exposed roof. This does not mean that wind always worsens exposure; it can move flame or particles away as well as towards a surface. It means that the direction and magnitude of airflow are part of the geometry when they are material to the pathway.

6. Interposition

What interposition means

Interposition places an element physically between the source and the primary receiving surface. It therefore acts on the pathway rather than on the electrical source. A useful interposed element may intercept hot or molten material, prevent direct impingement, alter line-of-sight radiation, distribute a local thermal load or change the geometry through which heated gases travel.

Examples include shields, catch surfaces, plates, deflectors, elements integrated into mounting or cable-management systems and local connector-containment devices. The category is functional rather than product-based. The question is what the interposed element is intended to interrupt and whether that function has been demonstrated under the exposure being claimed.

Local connector containment

The most direct DC-arc-specific interposition evidence identified in the reviewed set comes from the ARC002 connector-containment programme. The programme deliberately maintained a 35 A connector arc for five minutes and compared tests with and without a local enclosure. The primary technical note reports that the enclosure prevented ignition of the surrounding roofing in the tested flat-roof scenarios while unprotected reference tests led to membrane ignition and fire spread. [1]

That is meaningful evidence and should be described positively. It demonstrates containment performance for the tested connector, enclosure, electrical condition, geometry, roof covering and five-minute maintained exposure. It is more direct evidence for sustained DC-arc pathway control than has been identified for a protective sublayer within the roof build-up.

The boundary of the containment claim

The same test also illustrates why evidence has to remain attached to its conditions. Five minutes was deliberately maintained. It was not measured as the maximum natural duration of a deteriorating connector. The technical note explains an engineering rationale for expecting connector destruction and self-extinction within that period, but the test itself did not measure the uncontrolled natural lifetime of the fault. [1]

The enclosure also addresses a defined physical location. It surrounds a connector. It does not physically contain an arc inside the module, at a junction box or at a damaged cable that lies outside the protected volume. This is not a criticism of the enclosure. It is the normal consequence of a local pathway measure having a local scope.

Other interposed elements

For other shields, plates or catch surfaces, the mechanism can be physically plausible even where the evidence is limited. A non-combustible plate below a connector may intercept particles. A deflector may prevent direct flame impingement. A rail or cable tray may unintentionally perform a similar function. But the presence of an obstruction is not by itself evidence of fire-safe performance. Its material, dimensions, spacing, temperature rise, continuity and the exposure modes it does or does not block all matter.

Where no sustained DC-arc test has been identified, the status for that specific exposure remains UNKNOWN. That does not mean the measure is ineffective. It means that performance has not been demonstrated under the exposure being claimed.

Interposition can also fail in several distinct ways and the failure criterion should match the claimed function. A catch surface may successfully intercept particles but heat sufficiently to ignite the membrane

by conduction or radiation. A shield may prevent direct impingement but deform and open a line of sight after prolonged exposure. An enclosure may contain the connector fault yet have no relevance to another source outside its protected volume. A test that records only visible flame outside the device can therefore support a different claim from one that measures temperatures at the receiving surface.

Separation and containment can also interact. An enclosure has its own internal geometry around the connector and its external position relative to the roof. A successful local containment result does not prove that external clearance is irrelevant, just as a larger clearance does not reproduce the physical containment function of an enclosure. If both measures are present, the system benefits from two different pathway mechanisms. Their combined performance should be inferred only where the evidence supports the interaction.

7. Exposure duration and receptor response

Exposure duration is not test duration

The duration that reaches the roof is inherited from the source but can be changed by source-side interruption or by the behaviour of a pathway measure. A five-minute maintained test demonstrates five minutes of exposure under the stated conditions. It does not automatically establish a five-minute design duration for the roof-PV interface. The companion paper reaches the same conclusion from the source side: the reviewed literature does not provide a universal maximum natural duration for deteriorating rooftop connector arcs. Where source-side interruption operates as intended, the arc-supported exposure can be a small fraction of a maintained test interval. Without that distinction a maintained five-minute test would carry more weight than it can bear for an installation in which interruption works.

This distinction matters for every measure, not only for connector containment. A separation distance tested for five minutes has only been assessed for that period. A shield exposed for five minutes has not demonstrated indefinite performance. A roof sublayer tested under a developed roof-PV fire has demonstrated that later fire exposure in the tested configuration, not a universal arc-duration capability. The duration critique has to be applied symmetrically.

Two exposure mechanisms

An arc-initiated incident can expose the roof through two mechanisms. Arc-supported exposure is the direct flame or plasma, radiation, convection and hot material produced while electrical energy feeds the fault. Self-sustaining combustion is burning of connector material, cable insulation, the membrane or other combustible material that continues without that energy. The mechanisms are defined by what sustains the heat release, not by time or by the moment of interruption. They may follow one another or overlap: an arc can persist while the membrane or connector housing is already burning on its own.

Interruption ends the first mechanism but not necessarily the second. Once self-sustaining combustion has started, the further exposure is governed by the combustible materials present, ventilation and the geometry of the cavity beneath the modules. [7] A secondary fire is therefore not necessarily a lighter exposure than the arc that started it, nor necessarily a heavier one. A shorter electrical fault does not automatically mean a proportionally smaller thermal load on the roof assembly. This is physical reasoning about the incident chain, not an empirically established general outcome.

The distinction explains why fire tests without an electrical arc can be relevant to an incident that begins with one. They address the second mechanism. They provide no evidence for the first. It also maps onto two design objectives: preventing an arc from igniting the roof and preventing a local ignition from developing into a larger fire in the roof construction. Detection, interruption, separation and local containment contribute mainly to the first; a protective sublayer can contribute mainly to the second. A highly effective arc-fault circuit interrupter (AFCI) does not remove the second question and a protective sublayer does not remove the first.

The primary receiving surface

The primary receiving surface is the first surface of the roof assembly that receives the exposure. On a conventional flat roof this will normally be the waterproofing membrane or a bonded surface treatment. The relevant response can range from no visible involvement through thermal damage to ignition, sustained local flaming or continued burning after the electrical source has ended.

The ARC002 reference tests are direct evidence of one such response: under the defined maintained arc and approximately 50 mm geometry, the roof membrane ignited and fire spread in the unprotected configurations. [1] That result should not be generalised into a universal ignition behaviour for

membranes, because the source, geometry and roof covering were specific; ARC002 tested EPDM and bituminous coverings, not PVC or other membranes.

Protective sublayers within the roof assembly

A protective sublayer occupies a different functional position. It is below the primary receiving surface and therefore cannot be assumed to prevent the membrane from receiving the arc exposure. If the membrane ignites, the sublayer may still influence whether heat and flame progress into combustible material below.

> **A protective sublayer beneath the membrane cannot be assumed to prevent initial membrane ignition. Its potential function is to limit heat transfer or further escalation into deeper layers after the receiving surface has become involved.**

This distinction is visible in the developed-fire evidence for protective layers more generally. In roof-PV experiments with protective layers above combustible insulation, fire could develop at membrane level above the layer while involvement of the insulation below was delayed or remained more limited. [6] Several such programmes with different protective materials are reviewed in Beyond flame spread. Their relevant function lies downstream of surface involvement. They support a consequence-limiting mechanism after the membrane has become involved, not a claim that an initial DC-arc exposure has been controlled.

Two performance criteria follow from this position and should be kept separate. The first is absence of direct flame penetration: whether flames pass through the protective layer into the layers below. The second is thermal protection of the underlying materials: how much heat reaches the construction below and what that means for the insulation present. A layer can meet the first criterion without meeting the second. With thermoplastic insulation such as EPS, temperature rise below the layer can cause softening, shrinkage or thermal decomposition without any flame penetration. Meeting the first criterion also does not show that fire cannot reach deeper layers by another route, such as a discontinuity in the layer (Chapter 8). If the design objective is to prevent ignition of the membrane, membrane ignition is a failure regardless of what happens below; for a sublayer it is not in itself a failure.

What the sublayer receives also needs to be stated precisely. Where the membrane is intact, it is normally the first surface to receive an arc above it. A sublayer beneath it is then exposed mainly to the involved membrane, but it can at the same time receive heat by conduction, local temperature peaks and, where the membrane is breached, more direct exposure. Its exposure therefore has three parts with a different evidence status: a direct sustained local DC arc, for which no test of a protective sublayer has been identified; a burning membrane above the layer, which developed-fire programmes address within their tested configurations; and heat transfer to the materials below, which depends on the build-up, the exposure and the measured temperatures. A membrane fire ignited by an arc starts locally and may differ in size and duration from the fires in those programmes, so their support applies to the mechanism, not automatically to every arc-initiated incident.

For insurers and risk engineers this distinction is more than terminology. It changes the consequence being controlled. Surface damage and replacement of the waterproofing can still be a material loss even where deeper insulation remains uninvolved. Conversely, prevention of deep propagation can materially change the scale of an event without making the initial surface event harmless. The evidence should therefore state which consequence layer it addresses.

8. A layered interface strategy

The source-pathway-receptor framework makes one design point visible: different measures act at different points and therefore do not automatically substitute for one another. Prevention, detection and interruption reduce the probability or duration of the source. Separation changes pathway geometry. Connector containment or another interposed element can interrupt transfer from a local source. The primary receiving surface and any protective sublayer determine what happens if exposure still reaches the roof assembly.

The purpose of layering is not to accumulate products. It is to avoid a design in which the entire outcome depends on one assumption that has not been demonstrated across the relevant incident range. An AFCI does not prove that every electrical ignition mechanism has been removed. A supported connector does not prove a fire-safe distance. A connector enclosure does not cover a junction-box fault outside the enclosure. A protective sublayer does not stop the membrane above it from being exposed.

Those boundaries can complement one another. Successful source-side interruption can shorten the arc-supported exposure that a pathway measure has to control, but it does not end self-sustaining combustion that has already begun. Local containment can prevent a connector fault from reaching the roof while interruption operates. Separation can reduce coupling for faults that occur outside a local enclosure. A receptor-side sublayer can limit deeper escalation if exposure nevertheless causes surface involvement. The engineering value lies in the overlap of independently bounded functions. The combined performance of such layers should not be assumed unless their interaction has itself been demonstrated or otherwise justified.

The measures also differ in coverage. Source-side protection acts only on faults within its electrical scope. A connector enclosure acts only at the connector it surrounds. A separation distance acts only where that geometry is actually maintained. DC arcs as a heat source shows that credible arc locations include the module, the junction box, connectors, cables and switching equipment. Coverage therefore has different meanings at different points in the model. Source-side controls can cover multiple physical fault locations within their electrical scope. Local pathway measures such as connector containment or a defined separation depend on the source being located within the geometry they protect. An area-wide receptor measure, where it is continuous across the relevant roof area, provides spatial coverage that is less dependent on the exact location of the source once exposure reaches the roof. A protective sublayer installed continuously across that area, or a roof build-up without combustible insulation beneath the membrane, can therefore address deeper escalation at locations not covered by a local pathway measure. That broader spatial coverage does not make either strategy universally sufficient. It does not prevent membrane ignition and does not establish sustained-DC-arc performance. Which area-wide route suits a given roof depends on its construction and structural reserve, as discussed in Beyond flame spread and From risk models to design requirements. Coverage is therefore a reason to consider an area-wide receptor measure alongside local measures, not evidence that it is sufficient on its own.

Area-wide coverage exists only where the protective function is continuous. Joints, laps, upstands, roof edges, penetrations and damage can each interrupt it, but not to the same degree. A properly lapped or sealed joint need not create a route to the layers below. A cable penetration that passes through the protective layer and opens directly onto combustible insulation can bypass the layer entirely. Penetrations are therefore the most important continuity detail at the roof-PV interface: DC cabling that is kept clear of the roof surface still has to pass through or around the roof build-up somewhere. Their number, position and detailing belong in the design drawings. No reviewed test addressed such details under DC-arc exposure; detailing more generally is discussed in Beyond flame spread.

This is why the argument is not that every installation requires every measure. The appropriate combination depends on the source conditions, physical layout, roof construction, available evidence and consequence being controlled. The paper's narrower conclusion is that no individual interface measure should be treated as sufficient outside the exposure for which its performance has actually been demonstrated.

9. Evidence status of interface measures

One standard for every measure

The central test is symmetry. A measure is not credited more generously because it is familiar, passive, active, manufacturer-developed or commercially useful. The same questions apply throughout: what was the source, where did the measure act, for how long was it exposed, which mechanism was tested and what failure criterion was used?

Measure	Place in model	What has been demonstrated	Status for sustained DC-arc exposure
Detection and interruption	Source	Performance within defined detection and interruption conditions.	Scope-dependent; treated in DC arcs as a heat source.
Separation	Pathway	DC-arc-specific evidence for one approximately 50 mm reference geometry. In the ARC002 unprotected tests, the EPDM or bituminous membrane ignited and fire spread under a deliberately maintained 35 A arc. [1]	DEMONSTRATED for that geometry and outcome. No universal fire-safe distance identified.
Local connector containment	Pathway (interposition)	ARC002 reports containment of a deliberately maintained 35 A connector arc for five minutes in the tested flat-roof configurations. [1]	DEMONSTRATED for that condition. UNKNOWN for other source characteristics and non-connector arc locations.
Other shields and interposed elements	Pathway (interposition)	Exposure-specific results where available; no general sustained-DC-arc evidence identified in the reviewed set.	UNKNOWN where the claimed sustained DC-arc exposure has not been tested.
Protective sublayer	Receptor	Performance under the external-fire and roof-PV fire exposures actually tested [8][9][10]; assembly-specific FM Approval under its documented approval basis [11].	UNKNOWN for direct sustained DC-arc exposure; later exposures in the evidence box below.

The table makes two asymmetries explicit. First, the separation result at approximately 50 mm is direct DC-arc evidence even though the outcome was unfavourable. It came from unprotected reference tests within a containment programme rather than from a systematic distance study and should therefore be used only for the tested geometry. Second, local connector containment currently has more direct sustained-DC-arc evidence than any protective sublayer identified in this review.

Evidence box: BarrierSheet

> **BARRIERSHEET – EVIDENCE STATUS BY EXPOSURE**
>
> **Direct sustained local DC arc:** UNKNOWN. No reviewed BarrierSheet test used a sustained DC arc as the ignition source.
>
> **Burning membrane above the layer: DEMONSTRATED within the tested configurations. ZAG**

> **concluded that the sheet prevented direct flame penetration into deeper structural layers while the membrane burned above it; localised burn-through of the sheet was recorded in two runs. The earlier Kiwa programme, using a 1.2 mm version, found that damage extended less far in the insulation beneath the sheet than in the layers above it; that is a within-assembly comparison without an unprotected reference. [8][9]**
>
> **Heat transfer to underlying materials:** dependent on build-up, exposure and measured temperatures. Substantial heating still occurred below the sheet in the ZAG tests; its significance has to be assessed for the insulation present. [9]
>
> **Approvals and classifications:** Efectis external-fire testing of a specific assembly and an assembly-specific FM Approval under the basis documented in PR472014, each within its own scope. [10][11]

The position of the product in the roof matters to the claim. BarrierSheet sits beneath the membrane in the application discussed here. It should therefore not be presented as preventing the membrane from receiving the initial arc exposure or as preventing initial membrane ignition. Its possible function lies in the second mechanism of Chapter 7: limiting access from an involved surface to deeper combustible layers. Absence of direct flame penetration in the tested configurations is evidence for the first of the two performance criteria; the second, thermal protection of the materials below, has to be assessed for the build-up in question. The FM Approval should not be read as an additional exposure test beyond its documented basis.

Evidence hierarchy is about relevance, not sponsor

Manufacturer-commissioned independent testing can provide valid evidence, but sponsorship and test purpose remain part of the context. The ARC002 primary document was produced for a containment product and its unprotected cases were reference tests. The AllShield programmes were commissioned to assess roof or roof-PV fire performance, not sustained DC-arc exposure. In each case the result should be credited within the question the programme was designed to answer.

10. What adequate evidence would require

A defined source

A meaningful interface claim starts with a defined source. Electrical current and voltage should be recorded together with the source vector as far as it is known: intensity or thermal output, emission mode, source geometry and orientation, relevant particle characteristics and duration. If important components are not measured, that limitation should be explicit.

A defined geometry

Geometry should record vertical and horizontal separation, source orientation, movement or adjustment during the test, receiving-surface position and any shielding or mounting components between source and roof. For particle pathways, the test description should also make clear whether material is free to fall, is ejected laterally or can be affected by airflow.

A defined exposure duration

Duration should be specified before the result is interpreted. A maintained five-minute exposure is not the same as a naturally self-extinguishing five-minute fault. A test stopped by the laboratory is not a measurement of natural extinction. Where the objective is to establish a design duration, the evidence also has to explain why that duration represents the incident being bounded. The duration of the electrical fault should be reported separately from the duration of any self-sustaining combustion it starts.

A defined receiving system

The receiving system should identify the primary receiving surface and any sublayer relevant to the claimed function. If the claim concerns the roof assembly rather than only the membrane, the build-up, joints, fixings and underlying materials have to be described sufficiently to know what was actually tested. A loose plate above a membrane, a coating bonded to the membrane and a board below it are not the same intervention and should not be grouped under one undefined term such as barrier.

A failure criterion selected in advance

Existing external-fire roof test methods and classification systems use defined exposure scenarios and associated performance criteria. [12][13][14] A local sustained DC arc has a different source geometry and exposure history. A DC-arc interface assessment therefore needs its own explicit failure criteria rather than assuming that a result from another fire method automatically answers the new question.

Possible criteria include ignition of the primary receiving surface, self-sustaining flaming, continued smouldering after the source ends, penetration through an interposed element or sublayer, critical thermal exposure of underlying combustible material and continued fire development after electrical interruption. The appropriate criterion depends on the function being claimed. This paper does not select one universal criterion.

The important methodological point is that success should not be defined after the test result is known. If a measure is claimed to prevent membrane ignition, membrane ignition is a failure even if deeper layers remain protected. If a protective sublayer is claimed only to prevent direct flame access to insulation, membrane ignition is not itself proof of sublayer failure. The criterion must follow the stated function.

What comparable evidence would need to report

Comparable evidence would report source conditions, geometry, duration and receiving system together with failure criteria defined in advance. Only then can a convenient installation clearance be distinguished

from a validated fire-safe separation, and can it be shown which interposition or receptor measures keep their function as the source vector changes. This is an agenda for the field generally, not an AllShield test programme.

Reporting negative and borderline results is equally important. If a membrane ignites without deeper penetration, or a shield prevents particles but allows a high surface temperature, those outcomes help define the function and limit of the measure. A binary pass/fail label without the underlying mechanism would be less useful for interface design than a transparent record of what happened at each layer.

11. Design implications

Do not rely on a single interface measure

No single interface measure identified in the reviewed evidence has been demonstrated as universally sufficient across sustained DC-arc exposures. A design should therefore avoid treating one unvalidated assumption as the only barrier between an electrical fault and roof escalation.

Do not confuse installation clearance with fire-safe separation

A connector clip or support can be good installation practice without establishing fire performance. A clearance should be described as fire-safe only when evidence connects the geometry to a defined source, duration, receiving system and failure criterion.

Treat duration as a design variable

Separation, interposition and receptor performance all depend on time. A test result without a defined exposure duration is incomplete and a defined test duration should not be silently converted into a universal natural hazard duration. The duration of the electrical fault should also be kept separate from the duration of any combustion it starts.

Consider source, pathway and receptor together

The source vector determines what can be emitted. The pathway determines what reaches the roof. The receptor determines what happens next. Design review should follow that chain rather than treating the electrical component and roof build-up as unrelated systems.

Keep ignition prevention and escalation control apart

Design review should state for each measure whether it serves to prevent an arc from igniting the roof or to prevent a local ignition from becoming a larger fire in the roof construction. Effective source-side control does not answer the second question and a protective sublayer does not answer the first. Each should be credited only within the exposure for which its performance has been demonstrated.

Questions for project review

A project team can translate the evidence into eight practical questions. What credible source locations remain after the electrical design is defined? Which of those sources can directly expose the roof? What separation or interposition is actually present at those locations? What is the primary receiving surface and what lies beneath it, including any existing roof covering? If exposure reaches the roof at a location that no local measure covers, what limits escalation into combustible layers beneath the membrane? Where does DC cabling pass through or around the roof build-up and how is continuity of any protective layer maintained there? Which documentation shows the existing and the new build-up for each roof area and which tested or approved assembly does it correspond to? Finally, which claimed protection functions are supported by evidence that matches the source, duration and geometry being considered? These questions do not require the project team to solve arc physics again. They require the interfaces between disciplines to be made explicit.

Electrical designers, PV mounting suppliers, roof designers and fire engineers often own different parts of the same pathway. Source-pathway-receptor provides a common language for asking where each responsibility begins and ends.

12. Conclusions

1. A sustained DC arc can act as an external thermal source, but the source alone does not determine the exposure imposed on the roof.
2. Roof exposure depends on the pathway between source and primary receiving surface, including position, geometry, separation, orientation, particle trajectory and duration.
3. Mechanical separation is not equivalent to validated fire-safe separation. A clearance chosen for installation, mechanical or maintenance reasons does not by itself establish fire performance.
4. Separation, interposition and protective sublayers each have a physically plausible mechanism for limiting exposure or escalation. The reviewed evidence includes DC-arc-specific results for one approximately 50 mm separation geometry and one local connector-containment configuration, but it does not establish a universally sufficient interface measure. No protective sublayer identified in the review has sustained DC-arc-specific evidence.
5. Protective sublayers beneath the membrane occupy a different functional position from measures that prevent exposure of the membrane itself. Their potential contribution lies in limiting heat transfer or deeper escalation after the primary receiving surface has become involved. Area-wide receptor strategies, whether based on a continuous protective sublayer or on a roof build-up that avoids combustible insulation beneath the membrane, can provide spatial coverage that is less dependent on the exact source location within the covered roof area. That broader coverage does not establish sustained-DC-arc performance and does not prevent initial membrane involvement. Absence of direct flame penetration and thermal protection of the materials below are separate performance criteria, and area-wide coverage depends on continuity at penetrations and other details.
6. An arc-initiated incident can expose the roof through arc-supported exposure and through self-sustaining combustion, which may follow or overlap. Fast interruption shortens the first but does not necessarily end the second; a shorter electrical fault does not automatically mean a proportionally smaller thermal load on the roof. Fire tests without an electrical arc can therefore be relevant to the second mechanism without being evidence for the first.
7. Where residual DC-arc exposure is considered relevant, a layered interface strategy is more defensible than reliance on any single unvalidated measure.

References

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[3] Stäubli Electrical Connectors AG. MC4-Evo 2 connector – MA273 (en) assembly instructions. MA273, Index l, December 2025. Used for connector installation practice only, not as fire-performance evidence.

[4] Van der Valk Solar Systems B.V. ValkCableCare. Catalogue 2026, version 1.1; and SL Rack GmbH. Flat Roof Systems 2026. Version 02/2026, V11. Used to show manufacturer-provided cable and connector support positions in flat-roof PV mounting systems; not as evidence of fire-safe separation.

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[8] Kiwa BDA Testing. Test report 24L0241/1: External fire exposure to roofs in combination with photovoltaic arrays according to the principles of CLC/TR 50670. 2 September 2024. Principal: AllShield Holding B.V.

[9] ZAG. Report 448/25-560-1-EN: About performance comparison of lightweight non-combustible sheet in rooftop PV-related fires. 1 August 2025. Orderer: AllShield Holding B.V.

[10] Efectis Nederland. 2025-Efectis-R000982: Exposure to external fire to roofing membrane + BarrierSheet on PIR according to CEN/TS 1187:2012, Test 1: Method with burning brands. July 2025. Sponsor: AllShield Coatings B.V.

[11] FM Approvals. Approval Report PR472014: AllShield BarrierSheet. Approved 11 December 2025. FM 4470/4478; RoofNav assembly 568563-0-0.

[12] CENELEC. CLC/TR 50670:2016 - External fire exposure to roofs in combination with photovoltaic (PV) arrays - Test method(s).

[13] CEN. CEN/TS 1187:2012 - Test methods for external fire exposure to roofs; and EN 13501-5:2016 - Fire classification of construction products and building elements - Part 5: Classification using data from external fire exposure to roofs tests.

[14] ASTM International. ASTM E108 - Standard Test Methods for Fire Tests of Roof Coverings.

Research transparency

Professional relationship

My relationship with AllShield is stated in the Author's perspective. In this paper it concerns one product-specific evidence box, in which BarrierSheet is held to the same evidence standard as separation and connector containment and its performance under direct sustained DC-arc exposure is classified as UNKNOWN.

Appendix A: evidence map

Source	Evidence type	What it supports	Important boundary
[1] ARC002	Manufacturer technical note; independent laboratory programme commissioned by manufacturer	Unprotected approximately 50 mm reference geometry; maintained 35 A arc; five-minute connector containment	Reference tests were part of a containment programme, not a distance-response study. Maintained duration is not a measured natural maximum.
[2] Tan / Burning Matters	Interested secondary source	Approx. 3-5 minute ignition observation and qualitative hot-debris account	Secondary; lower evidential weight than the primary test note.
[3]-[4] Installation guidance	Manufacturer installation documents	Connectors and cables kept clear of roof for water, mechanical and cable-management reasons	Installation practice only; no fire-safe distance established.
[5] Fraunhofer / TÜV	Research synthesis, experiments and guidance	Source modes; module material can become later particle source	Historical German context; module-fire data are not a connector-arc pathway test.
[6]-[7] Roof-PV fire research	Controlled fire experiments	System context and boundary with developed roof fire	Detailed roof-fire response belongs in Beyond flame spread.
[8] Kiwa	Third-party laboratory testing commissioned by manufacturer	BarrierSheet in roof-PV gas-burner exposure	Historical 1.2 mm configuration; not a sustained DC-arc test.
[9] ZAG	Third-party laboratory testing commissioned by manufacturer	Protective sublayer during developed roof-PV fires; membrane can burn above layer	Specific specimens and durations; heating below the sheet to be assessed for the insulation present; not a sustained DC-arc test.
[10] Efectis	Third-party laboratory testing commissioned by manufacturer	External-fire roof-system evidence	Specific double-BarrierSheet build-up; not a sustained DC-arc test.
[11] FM Approvals	Third-party approval requested by manufacturer	Defined approved roof-PV assembly	Assembly-specific; not a material-wide or DC-arc claim.
[12]-[14] Roof fire methods	Standards and technical report	Examples of exposure-specific test methods and criteria	Do not reproduce sustained DC-arc source geometry.

Appendix B: interface variables and control locations

Variable or measure	Place in model	Role
Arc intensity / thermal output	Source	Defines the magnitude available to the pathway; does not by itself define roof heat flux.
Emission mode	Source	Determines whether radiation, convection, direct impingement or particles must be considered.
Connector height and offset	Pathway	Changes coupling between source and primary receiving surface.
Orientation and obstruction	Pathway	Can enable or block direct exposure and alter particle trajectories.
Connector enclosure / local containment	Pathway - interposition	Restricts transfer from a connector source while the electrical source may remain active.
Roof membrane	Receptor - primary receiving surface	Receives the initial roof exposure and may remain uninvolved, be damaged or ignite.
Protective board beneath membrane	Receptor - protective sublayer	May limit heat transfer or deeper escalation after surface involvement.
Exposure duration	Source and pathway history	Must remain attached to every performance claim; electrical and combustion duration reported separately.
Arc-supported exposure	Source and pathway	Lasts while electrical energy feeds the fault; shortened by successful interruption.
Self-sustaining combustion	Pathway and receptor	Governed by combustible materials, ventilation and geometry; not necessarily ended by interruption.
Criterion: no direct flame penetration	Receptor - protective sublayer	Whether flames pass through the layer into the layers below.
Criterion: thermal protection	Receptor - underlying layers	Heat reaching the materials below; relevant for thermoplastic insulation even without penetration.
Continuity details	Receptor	Penetrations, joints, upstands and edges can interrupt a protective layer; penetrations can bypass it.

Method and sources

This is a targeted inventory and synthesis of identified knowledge, updated through the checks documented for 1 November 2026. It does not claim exhaustive coverage of the latest literature. Source findings, author analysis and practical design proposals remain distinct. The author endorses the conclusions within these evidence boundaries.

Authorship and contributions

Olivier Langejan is the lead author, supported by a small team. His professional focus is building and roof design. The papers synthesise the cited research, standards and test evidence; specialist fire-science and electrical findings are attributed to those sources rather than presented as expertise personally established across every discipline. The author endorses the synthesis and its stated limits. AI assistance is described separately below.

Scope and selection

This paper synthesises the source, pathway and receiving roof in a sustained DC-arc exposure. Arc-specific experiments are distinguished from developed roof-PV fire tests. Separation, connector containment and receiving roof layers are included for their location in that pathway. Whole-building loss and developed-fire behaviour are outside the principal question.

Sources and dates

The evidence base is the research, standards, approval documents, technical guidance and incident material identified in the references. This is a targeted narrative synthesis, not a systematic review. English-language sources and relevant Dutch or German material are included where cited. The original search dates and a complete search log are not available in the retained publication record, so no reconstructed search period or exhaustive publication cut-off is asserted. Sources retain their individual publication dates. The present editorial and targeted source checks were completed on 1 November 2026.

Publication range

Publication dates and editions are identified for the individual references. This targeted synthesis does not claim exhaustive chronological coverage or a reconstructed complete search period.

Verification

This revision checked the requested wording against the source papers and carried out targeted primary-source checks for the additions and source corrections identified in its revision history. It is not a new claim-by-claim audit of the entire paper. References identify primary documents where available; secondary accounts and access limitations are identified where material. Author interpretations and design proposals do not acquire test or approval status.

Known gaps

Representative particle distributions, universal safe distances and direct sustained-arc performance of the cited roof separation sheet are not established.

AI-assisted research and writing

Artificial intelligence was used to help identify and locate technical literature, compare findings across sources, analyse evidence boundaries, organise the argument and assist with drafting and editing. AI-generated summaries were not treated as technical evidence. The selection of sources, interpretation of the evidence, conclusions and final wording remain the responsibility of the author.

Updates

New research, test results, incidents and regulation may lead to new versions. Editorial corrections and technical additions are identified separately in the revision history. Missing sources and evidence that challenges a conclusion are welcome.

REVISION HISTORY

Version	Date	Changes
1.0	21 October 2026	First published version. Status labels aligned with the two-axis evidence model of What does a fire test actually prove?. Attributed the ZAG conclusion to ZAG and added the localised burn-through; clarified that the Kiwa result is a within-assembly comparison.
1.01	1 November 2026	Editorial corrections: reframed as a roof-first knowledge synthesis; shortened the author perspective, added method and source limitations, labelled author interpretations and corrected the requested wording and transparency statements. Technical additions and source checks: No new fire-performance claims or tests.
1.02	1 November 2026	Method and sources and series overview: clarified synthesis status and description of the risk-model companion. Sustained DC-arc performance of BarrierSheet remains UNKNOWN; no new test claim introduced.
1.03	1 November 2026	Ch. 9: ZAG conclusion uses deeper structural layers (448/25-560-1-EN p. 46). Appendix A: third-party commissioning terminology aligned. Authorship and expertise scope added.

THE SERIES

The roof comes first is a synthesis of knowledge on fire safety and rooftop PV from a roof-first perspective, by Olivier Langejan. Each paper stands on its own; together they follow one line of thought.

At the time of this version, the series consisted of:

Paper	For	In one line
Rooftop PV on existing commercial buildings	Asset owners, developers, project teams	A decision framework for resolving roof constraints before the PV investment is committed.
Rooftop PV on new commercial buildings	Developers, architects, project teams	Designing the roof and PV as one system from the start.
The economics of the rooftop PV decision	Asset owners, CFOs, risk managers	Probability, consequence and lifecycle cost from the asset owner's perspective, including Business Interruption.
From risk models to design requirements	Risk engineers, insurers, designers	An application of five established risk frameworks to consequence-limiting design for roofs with PV.
Beyond flame spread	Risk engineers, insurers, fire engineers	How far a rooftop PV fire can travel into the roof before it becomes a building loss, and what a separation layer changes.
What does a fire test actually prove?	Insurers, risk engineers, specifiers	What a fire test result does and does not demonstrate about a real roof with PV.
DC arcs as a heat source	Insurers, risk engineers, PV designers	How DC arc faults start, persist and end in rooftop PV.
DC arcs at the roof-PV interface (this paper)	Insurers, risk engineers, PV and roof designers	What determines roof exposure to a sustained DC arc and what current evidence shows about measures to limit it.
How much does PV clearance actually solve?	Insurers, risk engineers, PV designers, asset owners	What module-to-roof clearance does and does not demonstrate about the roof beneath it.
What if the PV panel could not burn?	Asset owners, risk engineers, insurers, PV designers	What a lower-combustibility PV module does and does not change for the roof beneath it.
What does an inspection actually prove?	Insurers, risk engineers, asset owners, inspectors	What inspection can establish, what it cannot and what still protects the roof when a fault is missed.

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