THE ROOF COMES FIRST · WHITEPAPER

What does a fire test actually prove?

Reading fire classifications, approvals and test reports for roofs with PV

CENTRAL QUESTION

When does a valid fire-test result become an invalid design assumption?

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

Prepared for insurers, risk engineers and specifiers.

Version 1.43 | 1 November 2026

Contents

Author's perspective....3
Executive summary....4
1 The question behind the fire classification....5
2 Standards already draw the boundaries....8
3 Who decides what is sufficient?....12
4 From material to roof field: levels of evidence....15
5 Reading a test backwards....18
6 What a test cannot see....21
7 When the roof or the rules change....24
8 Evidence routes across jurisdictions....27
9 A five-step method for reading fire evidence....31
10 The method in practice: four cases....35
11 The same method applied to BarrierSheet....39
12 What the method does not claim....44
Appendix A. One-page method....47
Appendix B. Fire-test and evidence-route map....48
References....50
Method and sources....52
REVISION HISTORY....54
THE SERIES....55

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. The starting point is the physical or economic problem. 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.

In this paper I apply that roof-first approach to the evidence itself: what a fire classification, approval or test report actually demonstrates about a real roof with PV. This paper was written as part of my role as Chief Commercial Officer at AllShield. It includes a clearly identified product case study. Chapter 11 applies the method to AllShield's own evidence for BarrierSheet, with the same discipline that is applied to external evidence in the chapters before it, including the conclusions that are commercially inconvenient.

Several relationships are relevant to the evidence cited here. Grunde Jomaas, who is affiliated with FRISSBE at ZAG, co-authored the Kristensen and Jomaas study on which Chapters 6 and 10 partly rely. AllShield commissioned the ZAG roof-PV fire programme and the Efectis classifications discussed in Chapter 11. AllShield BarrierSheet is FM Approved in a defined roof-PV assembly, while this paper discusses FM Data Sheet 1-15 as an institutional evidence framework. The documents behind these statements are listed after the references.

None of the conclusions depends on an AllShield product being selected. The method in this paper can conclude that existing evidence is sufficient, that a different design route is more appropriate, or that no further measure is needed.

Olivier Langejan
Chief Commercial Officer, AllShield

Executive summary

A fire test does not ask whether a roof is “safe”. It exposes a defined specimen to a defined fire scenario and applies defined criteria. The result is valid for the question the test was designed to answer. Problems begin when that result is later used to answer a different question.

Rooftop PV makes that gap unusually visible. The roof below may be correctly classified, the modules may be certified and the mounting system may be listed, while the combined roof-PV system raises a question that none of those results was designed to answer. CEN/TR 18326:2026 records that no harmonised European method yet exists for that combined question. FM Data Sheet 1-15 states that the roof-PV system acts as one during a fire and cannot be tested component by component. Experimental research shows that a change of a few centimetres in cavity height, or the frame of a module, can change the governing fire mechanism.

This paper does not argue that fire tests are weak or that every project needs more testing. It develops a practical method for reading fire evidence in five steps: define the decision, verify the evidence, reconstruct the test question, compare the evidence with the intended roof-PV system, and conclude.

The conclusion is stated on two separate axes. The first describes the claim: **directly demonstrated, physically supported, contradicted or unknown**. The second describes how the evidence reaches the real roof: **as tested, formally covered or engineering extrapolated**. Only then is the decision outcome stated: **sufficient, requires additional justification or insufficient**. Project-specific acceptance by an insurer is a decision outcome, not a change in the formal status of the evidence.

Four cases show that the method produces different answers when the evidence and the decision differ. A US Class A result can be fully valid while the route behind it did not examine behaviour towards combustible insulation. A classified roof remains valid evidence of its own test, while experimental work contradicts the assumption that the same classification limits flame spread beneath PV. And a gravel roof can be sufficient for the Dutch regulatory requirement while lying outside the PV question and contrary to FM's recommendation for a different hazard. The fourth case bounds the interpretation of a vegetated-roof test.

The same method is then applied to AllShield's own evidence for BarrierSheet. Its A1 classification, its B_{ROOF}(t1) classification for a defined double-layer build-up, its FM Approval in a listed new-build assembly and the ZAG roof-PV programme each support a specific, bounded claim. None of them demonstrates long-duration behaviour beyond 30 to 40 minutes, a single-layer B_{ROOF}(t1) build-up, a PV fire test within the FM approval or behaviour at the scale of a full commercial roof field.

Where evidence leaves a relevant mechanism uncertain, there are two legitimate responses: obtain more evidence, or make the design less dependent on that mechanism. FM and the OFR review for the UK Building Safety Regulator both point towards reducing or separating combustible material beneath PV. That is one robust strategy among several, each with its own boundaries. The method does not lead inevitably to any product.

The objective is not maximum evidence. It is sufficient evidence for a defensible decision.

1 The question behind the fire classification

A fire test does not ask whether a product, roof or building is “safe” in some universal sense. It exposes a defined specimen to a defined fire scenario, observes defined phenomena and applies defined acceptance criteria. If those criteria are satisfied, the result is valid for the question the test was designed to answer. The difficulty begins when that result is later used to answer a different question.

A roof can therefore pass a valid fire test and still leave an important design question unanswered. That does not mean the test is weak, outdated or wrong. It means that the test answered a narrower question than the one now being asked.

A classification or approval compresses a large amount of technical information into a short result. That is useful. Designers, regulators, insurers and manufacturers cannot reopen every laboratory report every time a product is specified. But the shorthand can also hide the question that produced it. The result normally depends on what was tested, how it was assembled, how the fire was applied, what was measured, how long the test continued, what counted as failure and how far the result is formally allowed to travel beyond the specimen tested.

A label therefore tells us that a defined requirement has been met. It does not automatically tell us that every fire mechanism relevant to the real building has been investigated.

The distinction is not unique to roofing. A material can, for example, be classified A1 for reaction to fire while having no determined performance for fire resistance. Both statements can be correct because they answer different questions.

This becomes especially important on commercial roofs because several forms of fire evidence can coexist within the same project. A material may have a reaction-to-fire classification, a roof build-up an external-fire classification, a mounting system a listing and a complete roof-PV configuration an insurer approval. Each may be valid while answering a different technical question.

The mistake is not using those classifications. The mistake is allowing the classification name to replace the underlying engineering question.

When the system changes, the question may change

Rooftop PV makes this problem more visible because it changes the conditions above the roof. The waterproofing, insulation and deck may remain unchanged while module geometry, cavity height, mounting arrangement, wind interaction, combustible module components and the position of an ignition source alter the way heat and flame interact with the roof.

> **The test result did not change. The boundary conditions did.**

A valid classification for a roof without PV does not become invalid because PV is installed above it. But neither does the original classification automatically answer every question about the combined roof-PV system. The engineering task is to establish where the original evidence still applies, where its application is formally extended and where an additional assumption has entered the design.

The same principle applies to the level of evidence. Roof fire tests are often already assembly tests, so the issue is not simply that individual materials were tested instead of the roof. The more precise question is whether the tested roof assembly represents the intended construction and, where PV materially changes the fire exposure, whether the evidence also represents the relevant roof-PV interaction.

Later chapters return to those evidence levels in more detail. For now, the important point is that evidence from one level should not silently be used to support a claim at another.

Valid for one decision, not every decision

This paper is not an argument for more testing in every project. Evidence must instead be judged against the decision it is being used to support.

A regulator may ask whether a roof satisfies a prescribed external-fire requirement. If the applicable classification covers the intended construction, that evidence may be fully sufficient for that decision. An insurer or asset owner may ask a different question, such as whether a fire beneath a PV array could involve combustible insulation or develop into a major property loss.

The first classification is not made wrong by the second question. It simply may not answer it.

The same evidence can therefore be sufficient for one decision and require additional justification for another. The relevant question is not whether a certificate is “good enough” in the abstract, but whether it answers the acceptance criterion set for the decision being made.

What would failure have looked like?

The most revealing question is often not what the final classification was, but what the specimen would have had to do in order to fail.

Would failure have meant flame reaching a defined distance? A burning particle penetrating the roof? A through-opening forming? A temperature limit being exceeded? Loss of mechanical integrity? Sustained flaming after removal of the ignition source? Or was the phenomenon now being discussed not part of the failure criteria at all?

If a test did not measure a phenomenon and did not include it in its failure criteria, the result cannot be used as direct evidence that the phenomenon did not occur. The reverse is equally important: the fact that a test was blind to something does not demonstrate that it did occur. **Not measured is not the same as absent, but it is also not evidence of presence.**

The chapters that follow develop a practical way of making those boundaries visible, brought together in the five-step method of Chapter 9.

A valid classification applied within its field of application may be exactly the evidence required. A recognised extended application may formally cover a configuration that was not separately tested. An insurer approval may legitimately rely on earlier test evidence and engineering assessment rather than repeating every possible experiment.

Those are not weaknesses in the evidence system. They are part of how engineering evidence is used.

The question is therefore not whether classifications can be trusted, but:

When does a valid fire-test result become an invalid design assumption?

2 Standards already draw the boundaries

The limits of fire-test evidence are not a new problem created by rooftop PV. Standards and fire-safety engineering frameworks already distinguish between the objective of an assessment, the test performed, the field within which its result can be applied and the formal mechanisms by which that field may be extended.

Rooftop PV makes those distinctions unusually visible because two established systems meet at the same interface: the roof construction and the electrical installation above it.

CEN/TR 18326:2026 addresses that interface explicitly. It is a Technical Report, not a classification standard, and it does not invalidate existing roof classifications. Its importance lies elsewhere. The introduction notes that above-roof PV modules are usually not considered construction products and that harmonised European standards have therefore not been developed for assessing their fire performance, either alone or in combination with the roof system beneath them.

Clause 4.1 states that harmonised methodologies for assessing the external-fire performance of roof systems in combination with above-roof PV modules do not exist. Approval therefore relies on different non-harmonised assessments and test methods, in most cases supported by guidance or legislation. In parallel, insurance test methods, guidelines and recommendations are also used. *(CEN, 2026)*.

That is a more precise description of the evidence gap than saying that ordinary roof testing is inadequate. Established methods exist for roofs. Established requirements also exist for PV products and electrical systems. What is not harmonised is the assessment of the combined BAPV-roof system for these external-fire scenarios.

CEN/TR 18326 does not provide a harmonised extended-application route for adding above-roof PV to an existing roof classification. It notes that the creation of EXAP rules will require careful consideration because of the complexity and number of variables involved.

Objectives come first

The broader logic is already established in fire-safety engineering.

ISO 23932-1 provides general principles for performance-based fire-safety engineering. It recognises several possible fire-safety objectives, including life safety, property protection, continuity of operations, environmental protection and preservation of heritage. *(ISO, 2018)*.

That matters because the same fire evidence can be judged against different objectives. A regulator may be concerned with compliance with a prescribed building requirement. An insurer may focus on the size and development of a property loss. An owner of a critical facility may place additional weight on continuity of operations.

ISO 23932-1 also recognises that designs complying with prescriptive fire-safety requirements can be used as a basis for comparison with engineered designs. Prescriptive compliance is therefore a legitimate reference point, not something performance-based reasoning has to replace.

Whether that evidence is sufficient for a particular decision is a separate question. Chapter 3 addresses how that judgement is made and who sets the relevant acceptance criterion.

Formal extension has defined boundaries

European fire-classification practice also recognises that it is neither practical nor necessary to test every possible construction separately.

EN 15725 provides the framework for extended application of fire-test results and for the preparation of EXAP standards and reports. It is not itself the detailed roof-specific rule. For external fire exposure of roofs, CEN/TS 16459 provides the relevant extended-application provisions for roof-test results.

This distinction matters because extended application is a formal evidence route. A construction does not have to have been physically tested in exactly the form in which it is later used if an applicable field of application or EXAP rule formally covers the variation.

That can be seen in practice in the Efectis B_{ROOF}(t1) classification discussed later in this paper. The classification applies CEN/TS 16459:2019 to determine which parameters of the tested roof construction may vary and which remain as tested.

EN 15725 also draws a boundary around what belongs inside that formal process. An expert judgement that is not covered by an EXAP standard and relies only on individual experience is not part of the formal EXAP route. *(CEN, 2023)*.

That distinction is central to the terminology used in this paper. A configuration may be **as tested**, it may be **formally covered** through an accepted field of application, EXAP, listing or approval, or its use may depend on **engineering extrapolation** outside those formal boundaries.

None of those terms should be substituted for another.

At the roof-PV interface, CEN/TR 18326 shows why this becomes more difficult. The established roof-classification system does not currently provide a harmonised EXAP route that automatically extends a conventional roof classification to the addition of an above-roof PV system.

Test data have limits of application

The same principle appears elsewhere in fire engineering.

ISO/TR 17252 concerns reaction-to-fire data used in fire modelling and fire-safety engineering. It addresses a different family of evidence and is not a foundation for the roof-PV argument in this paper, but the parallel is useful. Measured fire behaviour has to be interpreted in relation to the test conditions and the application for which those data are being used.

The point is not that laboratory evidence is somehow less real than full-scale behaviour. Controlled tests gain their value precisely by defining the specimen, exposure, observations and criteria.

Those boundaries are a strength of the test.

New methods appear when the question changes

The absence of a harmonised European roof-PV method has led to additional research and pre-normative approaches.

In January 2025 ZAG published the first edition of its *Fire test method for flat roofs with photovoltaic (PV) modules*. The document is a test procedure, not a European standard or classification system, and its initial validity period is three years. The procedure investigates fire propagation and resulting damage within a flat-roof PV configuration, including the roof layers, PV modules and mounting system. It does not define a classification or pass/fail threshold. *(ZAG, 2025a)*.

Importantly, the procedure does not treat ignition as the performance question. Its purpose is to assess the development and consequences of an established fire. The ignition source may therefore be increased if necessary to obtain propagation. The method also defines a *mitigation layer* within the roof build-up. That makes the method relevant to the questions in this paper without turning it into an authority beyond its status.

The distinction between method and evidence remains important. A later test programme may use the procedure as a reference framework, but its commissioning, configuration, deviations and reporting still have to be examined separately. That becomes relevant when the method is applied to BarrierSheet in Chapter 11.

The Netherlands provides another example of the same development. NEN 6063 remains the Dutch method for experimentally determining whether a roof is fire hazardous under its defined external-fire exposure, but NEN explicitly states that the method is not suitable for determining the fire behaviour of PV modules or vegetated roofs. *(NEN, 2019)*.

A DGMR investigation into fire spread between separate PV fields on flat roofs was published by NEN in February 2024. The investigators reported that they could not identify scientific research establishing the size and intensity of such PV-field fires. In the absence of such data, they analysed fire cases for which online imagery was available. *(NEN, 2024)*.

That work does not create a classification or fixed separation rule by itself. It illustrates another important point: when the existing evidence base does not answer a question, the next step may be to investigate the mechanism rather than to assume that an established test already covers it.

Boundaries are what make evidence usable

The emerging roof-PV discussion therefore does not show that established fire tests have failed. It shows why their boundaries matter.

Objectives determine what has to be demonstrated. Test standards define a controlled question. Classification and EXAP rules define how far the result may formally travel. New research methods appear where another mechanism or configuration needs to be investigated.

> **Standards work because they define the question, the specimen, the exposure, the criteria and the permitted field of application.**

The next chapter starts with the decision those boundaries are being used to support.

3 Who decides what is sufficient?

Evidence cannot be sufficient in the abstract. It can only be sufficient for a defined decision. Many disputes about fire evidence begin because that decision has not been made explicit. One party points to a valid classification. Another argues that an important scenario has not been tested. Both may be correct because they are applying different acceptance criteria to the same evidence.

The first step is therefore not to ask whether the evidence is strong enough. It is to ask what decision is being made, who has authority to set the acceptance criterion and what consequence that criterion is intended to control. A regulator, insurer and building owner may all look at the same roof and ask different questions. The regulator may ask whether the construction satisfies a statutory requirement. The insurer may ask whether the same construction meets its property-protection criteria. The owner may ask whether a fire could interrupt operations at a site where even a technically compliant loss would be unacceptable. None of those questions replaces the others.

This paper does not determine which fire scenario should govern the design. That decision belongs to the risk assessment. *From risk models to design requirements* addresses how objectives, consequences and risk models become design requirements; the method here begins once the evidence for such a requirement has to be assessed.

The acceptance criterion belongs to the decision

A fire test provides observations and a result against defined test criteria. It does not by itself decide what level of evidence a particular project requires. For a regulatory decision, the acceptance criterion is established by legislation, referenced standards and the applicable classification route. For an insured property, additional criteria may be set through insurer standards, approvals or project-specific engineering review. An owner may impose further requirements because of asset value, business continuity or internal risk policy.

The engineer's task is therefore not to invent a higher threshold simply because more testing is possible. Nor is it to assume that regulatory compliance automatically satisfies every other decision. The correct sequence runs in the opposite direction: first identify the decision and its acceptance criterion, then ask whether the available evidence answers it within the boundaries of that evidence.

> **Evidence is sufficient when it answers the acceptance criteria set by the party responsible for the decision, within the applicable boundaries of that evidence.**

The word *sufficient* matters. The method in this paper must be capable of reaching a positive conclusion. If a roof construction falls within an applicable classification and that classification answers the statutory requirement being assessed, further investigation may add information but is not automatically required for that decision. A methodology that always concludes that another test would be useful is not a decision method. It is an uncertainty generator.

At the same time, the same evidence can legitimately be insufficient for another purpose. A classification designed to address external flame spread may not answer a property-protection question about delayed involvement of combustible insulation. That does not weaken the classification. It

identifies a different decision. Chapter 10 works through a case in which the existing evidence is sufficient for the decision being made.

This becomes particularly important in roof-PV projects because regulatory compliance, insurance acceptance and owner risk can coexist. A roof construction may satisfy the applicable external-fire classification required by regulation while an insurer applies an additional roof-PV property-protection criterion and an owner of a critical facility imposes a further resilience requirement. The construction has not changed between those three conversations. The decision has.

This is why the question *"Is this roof fire safe?"* is too broad to be useful as an evidence question. The answer depends on what outcome is being controlled and which party has responsibility for accepting it.

Compliance and resilience should therefore not be collapsed into one scale. A design can be compliant without meeting a particular insurer's requirement and it can meet an insurer requirement without satisfying every additional resilience objective an owner could set. Conversely, an owner's conservative design preference does not redefine the legal compliance threshold.

Consequence and robustness

The party setting the criterion is not always the party carrying the entire consequence if the decision proves wrong. A regulator is concerned with public requirements. An insurer may carry a substantial part of the financial loss. The owner may retain deductibles, uninsured losses, interruption costs, reputational consequences and the operational effects of losing the building. That makes consequence relevant even when the same test evidence is being used.

A higher-consequence asset may justify an additional or more demanding acceptance criterion set by the owner or insurer. That is not the same as saying that the original classification becomes less valid as the consequence rises. The test result stays the same. What changes is the decision threshold. This distinction prevents a common category error: using consequence to reinterpret the test result itself.

> **The test says what it says. The decision determines whether that is enough.**

There is also a second design choice. Some decisions are not only about proving that a particular fire mechanism is acceptable. They are about reducing how much the design depends on that mechanism in the first place. Where a regulator may accept evidence against a defined classification criterion, an owner or insurer may choose a more robust design objective: reduce the amount of combustible material that can become involved, or separate it so that the consequences of an uncertain fire scenario are limited.

Where uncertainty remains, one response is therefore to obtain more evidence. Another is to alter the design so that the uncertain mechanism becomes less consequential. That does not invalidate the original evidence. It changes the design decision being made.

A different question requires a different conclusion

Once the decision is explicit, disagreements about evidence become easier to diagnose. If two parties use the same acceptance criterion and disagree about whether the evidence covers the intended

construction, the dispute is about the evidence. If they accept the same evidence but apply different thresholds, the dispute is about the decision. If one party asks about regulatory flame spread and another about property-loss development under PV, they are not yet answering the same question at all.

Those distinctions matter because they determine what additional information could actually resolve the disagreement. Sometimes the answer is another test. Sometimes it is an EXAP, listing or approval that shows the intended configuration is already formally covered. Sometimes it is project-specific engineering. Sometimes the better response is to change the design so that the disputed mechanism has less influence on the outcome. And sometimes no additional evidence is necessary because the existing evidence already answers the defined criterion.

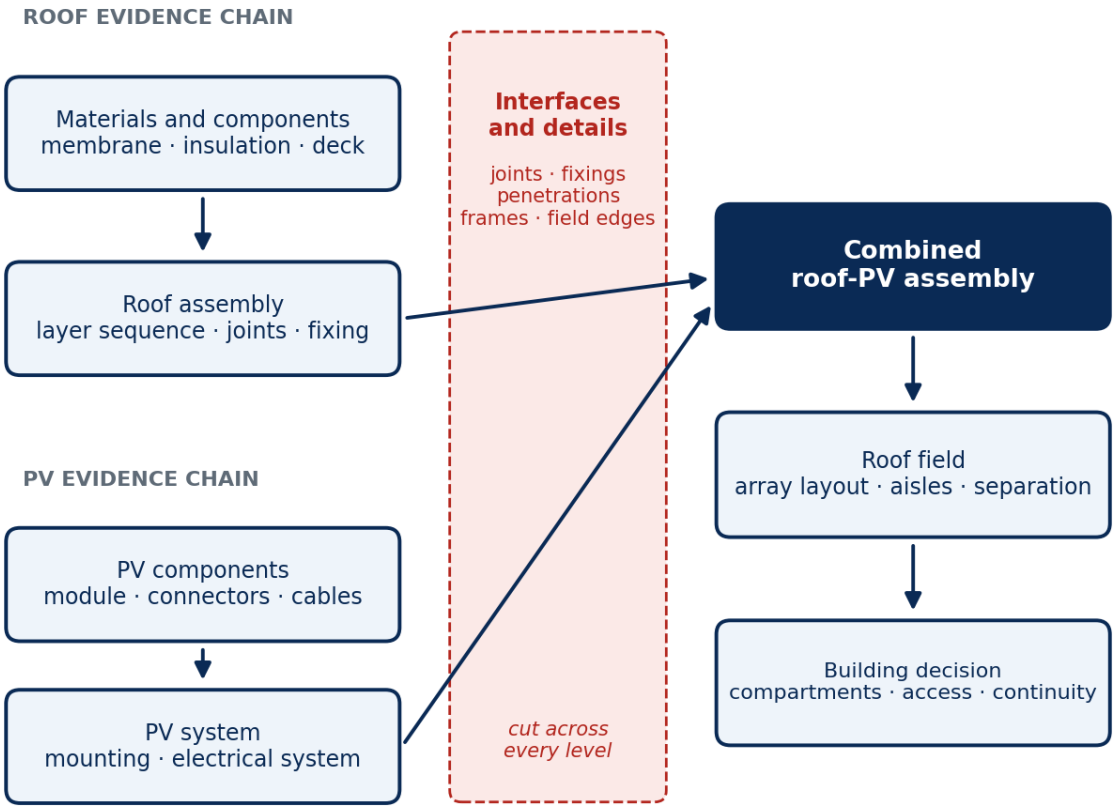
The method developed later in this paper therefore begins with three questions before any laboratory report is opened: **What decision is being made? Who sets the acceptance criterion? What consequence is that criterion intended to control?**

Only after those questions have been answered does it make sense to ask what evidence is required.

4 From material to roof field: levels of evidence

Fire evidence exists at different levels because fire questions exist at different levels. A material classification can answer a material question. A roof test can answer a roof-assembly question. A PV-module test can answer a module question. None of those results becomes invalid merely because a larger system is later assembled from the tested parts. The difficulty begins when evidence generated at one level is used to support a claim about an interaction that only exists at another.

For rooftop PV, this is better understood as two parallel evidence chains than as a simple ladder. On the roof side, evidence may begin with individual materials and components such as the membrane, insulation, cover board, vapour-control layer and deck. Those components are then combined into a roof assembly in which layer sequence, joints, fixing method, substrate and thickness can become part of the tested or classified construction. On the PV side, evidence may concern the module, connectors, cables, electrical equipment and mounting system. Those products can have valid classifications, certifications or listings of their own.



Two evidence chains converge at the roof-PV interface. Interfaces and detailing cut across every level.

The two chains meet at the roof-PV interface. At that point the relevant questions can change. CEN/TR 18326:2026 identifies parameters including module inclination, distance from the roof, spacing between modules and orientation as factors that can influence the fire behaviour of the combined system. *(CEN, 2026)*.

FM reaches the same principle from a loss-prevention perspective. Its April 2026 Data Sheet 1-15 states that the roof assembly and PV panels interact as a roof-PV system for exterior fire spread and that the system acts as one during a fire event. FM also states that the components cannot be **tested individually or by using small-scale testing** for this purpose. *(FM, 2026)*.

This is not just a theoretical system boundary. Experimental research reviewed by OFR for the Building Safety Regulator shows how strongly geometry can affect the mechanism. In one laboratory series using PMMA beneath an upper plate, the transition from slow flame spread to rapid acceleration occurred over changes in gap height as small as 2 to 3 cm. The critical height also changed with specimen width. Those values are specific to that experimental arrangement and should not be converted into universal design thresholds, but they show why geometry and scale are part of the evidence question rather than installation details that can automatically be ignored. *(OFR, 2026)*.

Product evidence remains useful for product properties. Roof-assembly evidence remains useful for the roof configuration within its field of application. But a question about fire development in the semi-enclosed space created by PV and a roof is a question about their interaction.

From assembly to roof field

A tested roof-PV specimen is still not the same thing as an entire commercial roof. Real installations can contain hundreds or thousands of modules, repeated cavities, different mounting orientations, electrical strings, rooflights, smoke vents, penetrations, drainage points, changes in geometry, fire compartments and areas without PV.

Scale is not a one-way severity factor. The OFR review describes large-scale experiments by Kristensen and Jomaas in which fire propagated beneath all six modules in the test array but did not propagate beyond the PV-covered area, irrespective of the wind conditions tested. A larger field can introduce repetition and longer propagation paths, but edges, aisles, separation distances and discontinuities can also interrupt a mechanism. *(Kristensen & Jomaas, 2018; OFR, 2026)*.

At roof-field level, evidence is often less experimental and more dependent on layout rules, engineering judgement and incident information. FM DS 1-15, for example, supplements assembly requirements with field-level provisions. The April 2026 edition limits arrays to 150 × 150 ft, approximately 46 × 46 m, and requires at least 4 ft, approximately 1.2 m, to the next array. *(FM, 2026)*.

The DGMR work discussed in Chapter 2 illustrates the same evidence boundary from another direction. Where scientific test data on fire spread between complete PV fields were not available, documented fire cases were examined instead.

At building level, further factors enter the decision, including compartmentation, fire-service access and intervention, the potential for fire to enter the building and the consequences of losing part or all of the roof for business continuity.

Evidence at roof-field and building level therefore does not replace assembly evidence. It adds questions that only exist at those larger scales.

Interfaces cut across every level

The levels above can suggest that evidence exists in clean boxes. Real roofs do not. Many critical details occur at interfaces: joints between sheets, fixings through a protective layer, cable penetrations, rooflight upstands, changes in substrate, drainage points, module-field edges or transitions between roof zones.

Small details can alter the governing mechanism. In experiments summarised by OFR, the critical gap height beneath real PV modules differed from tests using a steel plate. The explanation was not additional fuel from the module backsheet, but the aluminium module frame, which impeded the upward escape of hot gases and allowed a hotter layer to develop beneath the module. The frame was a detail of the interface, but it changed the flow conditions of the fire. *(OFR, 2026)*.

This is why the evidence structure used in this paper consists of two systems that converge: roof materials and components into a roof assembly, and PV components into a mounting and electrical system. They meet in the combined roof-PV assembly and can then be considered at roof-field and building-decision level. Interfaces and detailing cut across all of them.

A reaction-to-fire classification supports a claim about reaction to fire. A roof classification supports a roof construction within its applicable field. A roof-PV test supports observations about the combined configuration tested. A roof-field assessment can consider how those mechanisms repeat, stop or interact with the actual layout. A building-level decision adds the consequence that the evidence is ultimately intended to control.

The transition between those levels must remain visible. The next chapter therefore works in the opposite direction, from the result back to the question that generated it.

5 Reading a test backwards

The easiest document to read is often the certificate. The more useful document is usually the report behind it.

A certificate starts with the answer: A1, B_{ROOF}(t1), Class A, FM Approved or another concise outcome. Reading a test backwards means temporarily setting that outcome aside and reconstructing the question that produced it. Only then is it possible to decide whether the same answer can be used for the roof now being designed.

This is not an argument that every designer must reproduce the laboratory's work. It is a discipline for the moments when the classification is being asked to carry a claim beyond its most obvious meaning.

Reconstruct the test question

A useful reconstruction follows the same sequence each time:

test object → exposure → construction → observation → failure criteria → result

The first question is what the test object actually was. Was it a material, a membrane on a standard substrate, a complete roof build-up, a PV module, a mounting system or a combined roof-PV specimen? Product names alone are not enough. Thickness, density, backing, joints, fixing method, substrate and layer sequence may all form part of the tested identity.

The exposure comes next. A burning brand, gas burner, radiant panel and electrical arc are not interchangeable heat sources. Their power, duration, position and interaction with airflow differ. In PV-related work the electrical state matters as well. An energised fault, a de-energised module and a wood crib below an array may all be relevant to fire safety, but they represent different questions and different stages of an incident.

The construction then determines how that exposure reaches the object of interest. Cavity height, panel inclination, module framing, joints, penetrations, insulation and deck can change flame flow, heat transfer and the availability of fuel. The relevant construction is therefore not merely the list of materials. It is the way they were combined in the specimen.

The next questions are what was observed and what counted as failure. A test may measure flame spread but not temperatures beneath a protective layer. It may record temperature but have no criterion for delayed ignition after the main flames have ceased. It may inspect penetration through the roof but not quantify thermal degradation within the insulation. A result only answers the criteria actually built into the method and the observations actually reported.

Finally, duration and replication matter. How long was the specimen exposed? When did the test stop? Was there a defined cooling or post-fire observation period? Was the result obtained once or repeatedly? These questions do not automatically make a short or single test inadequate. They establish which part of the fire development has actually been observed.

Reading the sequence backwards converts the label into a technical sentence:

> **This object, in this construction, under this exposure, was observed in these ways, against these criteria, for this period, and produced this result.**

That sentence is usually more useful for design than the label on its own.

The report may also show how far the specimen remained from each criterion. That information can help to understand the mechanism. It does not provide a quantitative safety reserve. Repeated tests can show substantial scatter, the relationship between a measured response and the severity of exposure is rarely linear, and a result well inside one criterion says nothing about a mechanism that criterion does not address.

Define the evidence envelope

The term **evidence envelope** is used in this paper as a practical description, not as a formal standards term. It means the set of configurations and claims that the available evidence can support through direct testing or a recognised formal route.

The envelope begins with the tested specimen but may extend beyond it. A direct field of application, EXAP, classification rule, listing or approval can formally cover variations that were not individually placed on the test rig. Those configurations should not be called *as tested*, but neither are they merely speculative extrapolations. They are **formally covered**.

Establishing that envelope requires more than reading the test setup. The evidence itself has to be verified. Is the report current? Does it relate to the product generation being supplied? Were the samples selected by the laboratory, the sponsor or both? Who assembled the specimen and under whose supervision? Was the work performed under accreditation for the specific method, or was it research performed by a laboratory that is accredited for other activities? Who commissioned the work? Were deviations from the method recorded? Is there a separate classification report or listing that defines the permitted field of application?

These questions concern provenance, not an assumption that manufacturer-funded evidence is invalid. Much useful product evidence is necessarily commissioned by manufacturers. The purpose is simply to know what the evidence is and how it was generated.

The envelope is also not a quantitative measure of confidence. It should not be imagined as a boundary where one minor deviation produces a little more uncertainty, two deviations produce more again and five deviations make the evidence weak. Fire behaviour is too mechanism-dependent for that.

A configuration can differ from the tested specimen in several irrelevant details and remain physically representative. A single apparently small change can also alter the fire mechanism completely.

Find the governing mechanism

The key comparison is therefore not *how many things are different?* It is:

> **Does the difference change the governing mechanism relevant to the decision?**

A change in colour may be irrelevant to one roof-fire mechanism. Moving a module a few centimetres can be important if the resulting cavity changes flame deflection and heat feedback. Substituting one non-combustible fixing for another may not matter to fire spread. Opening a joint in a protective layer may matter greatly if it creates a direct path to combustible material beneath it.

The same reasoning applies to duration. If a protective layer remains intact during the period represented by the test but a different mechanism can develop after prolonged heating, the relevant issue is not simply that the real fire might last “longer”. The question is whether longer exposure allows the governing mechanism to change.

This is why test comparison cannot be reduced to a checklist of dimensions and product names. Those details matter because they may control heat transfer, ventilation, flame attachment, integrity, ignition or propagation. The engineering task is to identify which of them govern the claim being made.

That also provides a disciplined way of dealing with imperfect matches. If the intended construction is not as tested and not formally covered, the conclusion is not automatically that the evidence is useless. The evidence may still physically support the claim. But the route has changed from formal coverage to engineering extrapolation and that distinction must remain visible.

Reading a test backwards therefore produces three things that are needed before a conclusion can be drawn: **the question the test actually answered, the evidence envelope within which the answer can formally be used and the mechanism that determines whether the intended roof remains representative.**

The next chapter examines the other side of that exercise: what the test was not designed to see.

6 What a test cannot see

Every fire test is selective.

That is not a defect. A reproducible test has to define its specimen, exposure, observations and duration. It becomes useful precisely because it excludes much of the uncontrolled variation of a real fire and asks a narrower question under repeatable conditions.

The consequence is that every result also has blind spots. The important task is not to eliminate them, which is impossible, but to know whether a blind spot matters to the decision being made.

For the purposes of this paper, those blind spots can be grouped into three categories: **exposure blindness, construction blindness and observation blindness**. Replication sits alongside them because it determines how much is known about variability within the conditions that were observed.

> **Blind does not mean safe and it does not mean unsafe. It means that the test does not answer that question.**

Exposure blindness

A test only sees the fire exposure it creates. That exposure includes more than the nominal size of the ignition source. It includes the type of source, its power, location and duration, airflow and wind conditions and, in PV systems, the electrical state of the installation.

A burning brand on top of a roof, a burner beneath a PV module and an electrical arc close to a membrane are therefore not interchangeable exposures. They can transfer heat in different ways, produce different flame geometries and act at different stages of an incident. A roof that performs well under one exposure has not automatically been demonstrated to perform the same way under another.

This does not mean that a test should reproduce every conceivable ignition source. The relevant question is whether the exposure represents the mechanism for which the result is being used.

Electrical state deserves particular attention in PV. A test on an inert or disconnected module may be entirely appropriate if the question concerns flame propagation around the module. It does not directly answer a question about an energised DC fault. Conversely, an arc test can provide information about a local electrical heat source without answering how a developed fire will propagate beneath a large array.

Duration is partly an exposure issue as well. A short, intense source and a lower but sustained heat exposure can activate different mechanisms. A material may survive the peak of one scenario while degrading during a longer one. The important variable is therefore not simply maximum heat input but the time history of the exposure and whether it is capable of activating the mechanism relevant to the decision.

Construction blindness

A fire test only sees the construction that was placed in it, together with any variations formally permitted by the method or classification.

For roofs, that can include membrane type, insulation, deck, protection layers, vapour control, joints, fixing method and penetrations. For roof-PV systems it can also include cavity height, module inclination, module construction, frame geometry, mounting arrangement and the position of cables or connectors.

Chapter 4 showed why these details cannot always be treated independently. A relatively small change in cavity geometry can alter the flow of hot gases and heat feedback. A frame can retain hot gases beneath a module. A joint can create a path through an otherwise continuous protection layer. The significance of a construction difference therefore depends on whether it changes the governing mechanism.

Scale and ageing belong in the same category. A new specimen does not directly demonstrate the behaviour of a roof after years of thermal cycling, moisture exposure, repairs or additional penetrations unless the method or a formal application rule addresses those conditions. Nor does a small specimen necessarily reproduce the repeated geometry of a large PV field.

Again, that does not make the test invalid. A test is not expected to contain every possible future condition. The blind spot becomes important when the design claim depends on a construction feature that the test did not contain or formally cover.

Observation blindness

Even when the exposure and construction are representative, a test only sees what it observes.

The first boundary is the acceptance criterion. A test concerned with external flame spread may record whether flames reach a defined distance. Another may focus on through-penetration. A third may measure temperature. Passing one criterion does not demonstrate that every other response remained insignificant.

Reaction-to-fire classifications illustrate the distinction. An A1 classification answers a defined question about contribution to fire under the relevant EN 13501-1 test regime. It does not establish that the product is inert under every form of prolonged heating.

Mineral-wool products, for example, can legitimately achieve A1 while containing small quantities of organic binder. De Paula et al. reported smouldering associated with insulation joints in experimental research on low-slope roofing systems. Leppänen and Malaska investigated sustained heating around chimney penetrations, a different application that should not be transferred directly to roofs. Neither finding contradicts A1. They address a different mechanism. *(de Paula et al., 2026; Leppänen & Malaska, 2019).*

The same discipline applies to every A1 product, including protective boards. An A1 classification should not be extended into a claim about long-duration integrity, resistance to smouldering or performance within a roof-PV assembly unless separate evidence supports that claim.

Instrumentation creates another boundary. A temperature sensor measures temperature where it is positioned. A visual inspection sees surfaces that remain accessible. Damage inside insulation or beneath an opaque layer may not be quantified unless the specimen is opened and inspected. The

absence of a recorded event can therefore mean either that it did not occur or that the method did not observe it.

Duration is particularly important here. A test can end after the prescribed flame exposure while heat remains stored in the assembly. A layer can continue to degrade after visible flaming has ceased. If the method contains no defined post-fire observation period, it cannot directly answer whether a delayed mechanism develops later.

Experimental work by Kristensen and Jomaas demonstrates why this matters. In roof experiments using protective layers above EPS, the EPS beneath the PIR protection ignited after approximately one hour through thermal degradation and loss of mechanical integrity. The maximum temperature measured beneath the PIR was only about 175°C. The measured temperature at that location therefore gave no simple warning that the governing mechanism was about to change. In the corresponding mineral-wool configurations, the protection remained mechanically stable and the underlying EPS did not ignite. *(Kristensen & Jomaas, 2018; Kristensen, 2023; OFR, 2026)*.

> **An observation made before a mechanism becomes active cannot be used as evidence about what happens after it becomes active.**

Replication places another boundary around what has been observed. One successful test can directly demonstrate that the reported specimen produced that result, but it provides less information about variability than a repeated series. Kristensen's intermediate-scale experiments also showed that relatively small variations between otherwise similar tests could produce substantially different fire development, including differences associated with the burning membrane and resulting heat exposure. Scatter can therefore contain useful information about how sensitive a governing mechanism is to apparently small changes. *(Kristensen, 2023; OFR, 2026)*.

That does not make replication a separate pass/fail label. Standards prescribe the number of specimens required for their own classification purposes, and results obtained within those rules remain valid. The practical question here is narrower: how much does the available evidence reveal about the repeatability of the particular response on which the design claim depends?

A good evidence review therefore asks not only *what did the test show?* but also *what could this test have shown if something else had happened?* If the method had no exposure, construction, criterion, instrument, duration or replication capable of detecting the phenomenon now being discussed, the correct conclusion is not that the phenomenon was absent.

It is **unknown within that evidence**.

That is a narrower statement, but also a more useful one. It identifies what additional evidence, formal coverage or design change could resolve the question.

The next chapter deals with a different boundary. The test and its result can remain perfectly valid while either the roof itself or the evidence framework around it changes.

7 When the roof or the rules change

Fire evidence is usually read as if the object and the evidence remain fixed. In practice, neither necessarily does.

A roof can gradually move away from the construction for which evidence was originally obtained. At the same time, the roof can remain physically unchanged while the standards, approvals or loss-prevention rules around it develop. Both processes matter because the link between evidence and decision depends on the condition of the building **and** on the framework within which that evidence is being used.

In this paper, that process is described as **evidence drift**. It is not a standards term. It is a practical way of identifying when evidence that remains valid in itself needs to be read again before it is used for a new decision.

When the building moves away from the evidence

Between testing and decades of service, a construction passes through several stages: tested, specified, approved, built and maintained. Those stages are rarely identical.

A specified insulation may be substituted. A membrane may later be replaced. Rooflights, drains or cable penetrations can be added. Repair patches introduce new joints. PV arrays can be extended or modules replaced by a different generation. Cables and connectors can be rerouted. Moisture, thermal cycling and mechanical damage can change the condition of materials that were tested when new.

None of those changes automatically invalidates the original evidence. A new drain in one part of a roof does not make every fire classification on the building meaningless, and a replacement component does not necessarily alter the relevant fire mechanism.

The question remains the one developed in Chapter 5: does the current construction remain within the applicable evidence envelope and, where it differs, can that difference alter the governing mechanism relevant to the decision?

This becomes particularly important on existing roofs because a project rarely starts from a clean specification. The evidence has to be compared with what is actually present. A roof described in an old drawing may have been repaired repeatedly, partly re-covered or modified during earlier PV or mechanical installations. The practical evidence review therefore begins with the current construction rather than with the construction that was intended twenty years earlier. The wider design consequences for existing roofs are addressed in *Rooftop PV on existing commercial buildings*.

Product identity can drift as well. A familiar trade name may continue while thickness, formulation, facing or manufacturing method changes. A report on an earlier generation remains evidence for what was tested, but its applicability to the current product has to be established rather than assumed. Chapter 11 contains a practical example of this issue.

The evidence has not become false. The building or product has moved away from the configuration to which that evidence originally applied.

When the evidence framework changes around the building

The opposite can happen as well. A building can remain unchanged while the rules used to assess it move on.

Standards are revised. Fields of application develop. Approval standards change. Insurer guidance is updated as loss experience and research accumulate. A configuration for which no formal route existed at one point may later be addressed explicitly, while a design assumption that was once common may later require additional justification.

FM Data Sheet 1-15 provides a useful example. The document underwent interim revisions in 2025 and a full revision in April 2026. The current edition recommends that an existing roof more than ten years old be replaced or re-covered before PV is installed where the PV system may remain in service for another 25 to 30 years. The underlying roof may be exactly the same roof that was assessed several years earlier. What has changed is the current loss-prevention guidance against which a new PV decision is being made. *(FM, 2026)*.

The same edition also states the system principle quoted in Chapter 4 explicitly. That illustrates how the evidence framework itself can become more explicit even while the physical roof remains unchanged.

That does not mean every roof older than ten years suddenly became unsafe. Nor does a revision automatically invalidate a design that was previously accepted. The important trigger is a **new decision**: adding PV, replacing a roof, undertaking a major refurbishment or reassessing an asset against current insurer or owner criteria.

The same principle applies to formal fire evidence. A new classification standard does not erase the test that came before it. It can, however, change the formal route by which evidence is applied to a future project.

This distinction matters because otherwise evidence drift can be mistaken for retrospective failure. A building can have been properly designed against the rules applicable at the time and still require a different evidence route when it is modified later.

Evidence has to survive the next method too

Roof-PV fire assessment is still developing. CEN/TR 18326 documents the present absence of a harmonised European method for the combined external-fire performance of roofs with above-roof PV. The ZAG testing procedure described earlier is explicitly pre-normative and was initially issued for a limited three-year period. *(CEN, 2026; ZAG, 2025a)*.

A future harmonised method could therefore change the evidence landscape substantially.

That should not make the method in this paper obsolete. The method is deliberately not tied to one test standard. If a new harmonised roof-PV method appears, the same questions still apply: what decision does it answer, what configuration and exposure does it represent, what does it observe, what counts as failure and how far may the result formally be applied?

Existing evidence would not automatically become wrong. It would have to be read against the new question and the new formal route.

That is why evidence drift is best treated as a trigger to reopen the connection between evidence and decision, not as a reason to reject old evidence.

The practical check is straightforward. Has the product or construction changed enough that its provenance and identity need to be re-established? Has the applicable classification, approval, listing or guidance changed? Does the current construction still lie within the relevant evidence envelope? And, if something has changed, can that change alter the governing mechanism?

> **Evidence drift does not make old evidence false. It tells us when the link between evidence and the current decision needs to be checked again.**

The next chapter examines the formal routes through which that link is established across different jurisdictions.

8 Evidence routes across jurisdictions

Fire evidence is organised differently across jurisdictions. This chapter uses Europe, the United States and FM as three representative examples because they illustrate different ways in which test results become classifications, listings, approvals and project decisions. They are not intended as an exhaustive map of global requirements.

In other markets, national regulation may use local test methods, adopt or reference international standards, or combine regulatory requirements with insurer or project-specific criteria. The applicable jurisdiction ultimately determines which formal route is valid for the decision being made.

That distinction matters because familiar terms can suggest equivalence where none exists. A European B_{ROOF}(t1) classification is not the European version of a US Class A rating. An FM Approved assembly is not simply another building-code classification. An evaluation report is not a test standard. Each belongs to a different evidence and decision framework.

The correct question is therefore not which system is stricter in the abstract. It is what decision the applicable route was designed to support, what evidence it accepts and how far that evidence is formally allowed to travel.

Europe: test method, classification and national route

European external-fire classification of roofs separates the test method from the classification and from the national regulatory decision.

CEN/TS 1187 contains four distinct external-fire test methods, commonly identified as t1 to t4. They represent different fire-hazard scenarios. Commission Decision 2001/671/EC, as amended by Decision 2005/823/EC, explicitly states that there is no direct correlation between the test methods and therefore no generally acceptable hierarchy between them. (European Commission, 2001; 2005).

Member States may select the relevant test/class combinations and establish a national hierarchy between tests and classes; the available classes differ by method. Germany uses method 1 in its building-control evidence route, France specifies method 3 and England uses t4 classifications in Approved Document B for non-dwellings. These are national examples, not evidence that the four methods are equivalent or interchangeable. [N1–N3; European Commission, 2001/2005]
This is fundamentally different from a ladder in which t4 would simply be “better” than t1. The suffix identifies the test method behind the classification. To understand what the classification means, the test method, field of application and regulatory route have to be known as well.

Formal application can extend beyond the exact specimen tested. As discussed in Chapter 2, fields of application and EXAP rules can define which changes are formally covered. For external-fire roof evidence, CEN/TS 16459 provides extended-application provisions.

Europe also contains routes in which no fire test is required. Commission Decision 2000/553/EC identifies roof-covering products and configurations that may be regarded as satisfying the external-fire-performance requirement without testing, subject to the specified conditions and the applicable

national provisions. One example is a product completely covered in normal use by loose gravel at least 50 mm deep or at least 80 kg/m², with the specified aggregate size. *(European Commission, 2000)*.

That is a **deemed-to-satisfy route**. It is not evidence that the particular roof has passed CEN/TS 1187.

The national layer can provide another accepted route. In the Netherlands, Bbl Article 4.47 requires the top surface of a roof to be non-fire-hazardous as determined according to NEN 6063. Current Dutch assessment documentation applying that route recognises a gravel layer at least twice the nominal aggregate diameter, with a minimum thickness of 40 mm, as one way of meeting that requirement. *(Kiwa, BRL 1511)*.

The difference between the European 50 mm route and the Dutch 40 mm route is not a contradiction. They are different formal routes operating within different regulatory frameworks.

This illustrates a principle that applies well beyond Europe: the name of a fire classification is not enough. The formal route and the jurisdiction in which it is being used matter as well.

United States: roof classification and roof-PV system classification

The United States provides a different example of how evidence is organised.

ASTM E108 and UL 790 evaluate roof coverings under simulated external-fire exposure and use Classes A, B and C. Within this framework the classes form a severity hierarchy: Class A addresses severe exposure, Class B moderate exposure and Class C light exposure.

An important evidence boundary appears in the role of the deck. As described by the ICC Evaluation Service and by Intertek, roof coverings restricted to use over non-combustible decks require only the spread-of-flame test, whereas coverings not so restricted are also subjected to the intermittent-flame and burning-brand tests. *(ICC-ES, n.d.; Intertek, n.d.)*.

That distinction makes ASTM E108 a useful example for this paper. A Class A result can be entirely valid while the path by which that class was obtained depends on the intended substrate. The label alone does not reveal which failure modes were required for the particular application.

Module qualification is another evidence level. IEC 61730-1 and IEC 61730-2 address the safety qualification of the PV module itself, including construction and tests intended to identify hazards that could result in fire, electric shock or personal injury. The US UL 61730 series follows the same module-level structure. These standards also recognise that installation-specific and national or local requirements sit outside or in addition to module qualification.

A certified module therefore provides important module evidence, but does not by itself answer the fire-performance question of the roof beneath it or of the combined roof-PV system.

Rooftop PV introduces another formal evidence level. The International Building Code requires rooftop-mounted PV panel systems to be tested, listed and identified with a fire classification in accordance with UL 2703, with the required classification linked to the roof classification required for the building. UL describes that fire classification as applying to the rooftop-mounted PV **system**, including the specific module and mounting system. *(ICC, 2021; UL Solutions, n.d.)*.

That is significant. A roof may already have a valid roof-covering classification, but the regulatory framework recognises that adding rooftop PV creates another system-level fire question.

Evaluation reports can add another formal route. ICC-ES Evaluation Reports document how identified products or systems have been evaluated against particular code requirements or acceptance criteria and define the configurations within which that recognition applies. They are not the US equivalent of a European EXAP standard. They are part of a different formal framework.

The shared principle is narrower: **formal coverage only travels as far as the applicable listing, evaluation report or recognised configuration permits.**

FM: an international loss-prevention route

FM is treated separately because it is an international private property-loss prevention and approval system, not a US building-code classification route.

FM Property Loss Prevention Data Sheets and FM Approvals are organised around property protection rather than simply statutory building compliance. RoofNav records FM Approved roof assemblies and roof-PV systems, while Data Sheet 1-15 provides loss-prevention recommendations for roof-mounted PV installations.

As noted in Chapter 4, DS 1-15 treats the roof and the PV as one system for exterior fire spread. Where a new roof-PV installation is proposed, or a roof is replaced or re-covered together with PV, FM directs the user towards an FM Approved roof-PV system. *(FM, 2026)*.

For existing roof covers that remain in place, the routes are necessarily more varied. DS 1-15 provides several approaches, including use of applicable components from an FM Approved roof-PV system, formally approved retrofit routes and re-cover solutions meeting the stated FM criteria.

The important point is not the number of available routes. It is that an existing roof is not reduced to one generic assembly.

FM's project review requires information about the actual construction. Depending on the project, this can include the retained roof cover, insulation and deck, the presence of a non-combustible cover board, proposed re-cover layers and their securement.

This produces an important distinction: **an FM Approved assembly** and **project-specific FM engineering acceptance** are related, but they are not the same thing.

A complete RoofNav assembly provides a formally approved system configuration. Even where a complete approved assembly is used, installations at FM-insured locations are still submitted for plan review; the approved assembly removes the need to re-engineer the listed system, not the review of the project.

An existing building may instead require project-specific review of retained components and proposed changes. That reflects the greater variability of existing roofs compared with new construction, where the assembly can be selected before it is built.

FM 4470 and FM 4478 also occupy different positions within that system. FM 4470 applies to relevant roof assemblies and components, while FM 4478 addresses roof-mounted rigid PV systems. The route by which a particular product or assembly obtains approval can involve direct testing, accepted prior data and FM engineering judgement.

Chapter 11 applies the same evidence grammar to BarrierSheet and shows why the difference between **directly tested** and **formally covered** matters within FM Approval as much as it does elsewhere.

The method has to travel even when the classifications do not

Europe, the United States and FM illustrate different ways of organising fire evidence. Other jurisdictions may use different standards, classification names, approval bodies or combinations of national and international requirements.

The method in this paper does not depend on any one of them.

For any market, the same questions remain: what decision is being made, which authority or party sets the acceptance criterion, what was actually tested, which configurations are formally covered and where engineering extrapolation begins.

A result therefore has meaning within the route that produced it. **As tested**, **formally covered** and **engineering extrapolated** remain different statements regardless of jurisdiction.

> **The formal evidence route may be local. The discipline for reading it should not be.**

The next chapter turns those distinctions into a single five-step method for reading fire evidence consistently across jurisdictions.

9 A five-step method for reading fire evidence

The previous chapters have separated several questions that are often collapsed into one another. A fire-safety objective is not a test criterion. A material classification is not a roof classification. A directly tested configuration is not the same as one reached through formal application rules. A blind spot is not evidence of failure. And evidence that was appropriate when a roof was built may need to be reconsidered when the product, the construction, the applicable framework or the decision changes.

The purpose of the method is to bring those distinctions back together in a form that can be used on a real project.

It is deliberately short. A method that requires another specialist classification system before a fire report can be understood would only move the problem. The five steps are intended to lead from the decision to a conclusion that states clearly what the evidence demonstrates, how that evidence reaches the intended construction and whether it is sufficient for the decision being made.

The five steps

1. Define the decision

Start before the laboratory report. State what decision is actually being made, what fire-safety objective is relevant, who sets the acceptance criterion and what consequence that criterion is intended to control.

In practice, this step can be put as one question: what evidence does this decision need, and which evidence covers which part of it?

Regulatory compliance, insurer acceptance and owner resilience may require separate applications of the method even when they concern the same roof.

The relevant fire scenario should also be stated. A decision about external flame spread is different from one about an electrical ignition source, involvement of combustible insulation or continuation of operations after a roof fire.

If the acceptance criterion and the question it is intended to answer are not known, sufficiency cannot yet be judged.

2. Verify the evidence

Establish what document is actually being relied upon. Check authenticity, current revision, product identity and whether the evidence relates to the product generation being supplied.

Where relevant, establish who commissioned the work, who selected and prepared the samples, who configured the specimen and whether the laboratory supervised those activities. Accreditation should be checked for the **specific method**, not inferred from the general status of the laboratory. Research undertaken by an accredited laboratory is not automatically an accredited test.

Deviations from the method, restrictions in the classification or approval, separate field-of-application documents and relevant adverse or contrary results should also be identified.

Provenance is not a quality score. Manufacturer-commissioned evidence can be entirely valid. The purpose is to know exactly how the evidence was generated before deciding what it supports.

Evidence drift matters here as well. As Chapter 7 showed, the report may remain valid while the current product, product generation or applicable evidence framework has changed. The evidence therefore has to be current enough for the decision now being made.

3. Reconstruct the test question

Read the test backwards from the result. Identify the test object, exposure, construction, observations, failure criteria, duration and replication. Establish the electrical state where relevant and determine which stage of the fire the test represents.

The aim is to be able to rewrite the result as a technical sentence: *this object, in this construction, under this exposure, was observed in these ways, against these criteria, for this period, and produced this result*.

Then identify the blind spots. What exposure was absent? What construction feature was not represented? What phenomenon was not measured? What could have happened outside the observation period without being detected by the method?

The report may also show that a result sat comfortably inside a criterion. That can help explain the mechanism, but it should not be converted into a quantitative safety reserve. Test scatter, non-linear fire behaviour and unmeasured mechanisms prevent that interpretation.

4. Compare the evidence with the intended roof-PV system

First establish the evidence envelope: the tested configuration together with any variations reached through a recognised field of application, EXAP, listing, approval or other formal route applicable in the jurisdiction.

If the intended construction lies inside that formal envelope, identify whether it is **as tested** or **formally covered**.

If it lies outside, the next question is not how many differences can be found. It is whether a difference changes the governing mechanism relevant to the decision.

Several visible differences can be physically irrelevant. One small difference can be decisive. A few centimetres of cavity height, a joint through a protective layer or a frame that retains hot gases can matter more than several substitutions that leave the relevant heat-transfer and fire-spread mechanisms unchanged.

Where the intended application sits outside the formal route but the available evidence can still support a technical argument, the route is **engineering extrapolated**. That does not mean the conclusion is necessarily wrong. It means that formal coverage has ended and the engineering justification must now carry the connection.

Evidence drift also belongs here. A roof may have been altered since the evidence was produced even if the document itself is still current. The present construction, not merely the original specification, has to be compared with the evidence envelope and the governing mechanism.

5. Conclude and act

The conclusion should answer three separate questions: what the evidence says about the claim, how the evidence reaches the intended construction and whether that is sufficient for the decision.

It should also state what would change the conclusion. That may be a missing classification, a formal application rule, another test, confirmation of product identity, project-specific engineering or a design change that makes the uncertain mechanism less consequential.

If the available evidence already answers the acceptance criterion, the method should stop there. Further testing may be interesting, but it is not automatically necessary.

A consistent conclusion

The conclusion uses two evidence axes and one decision outcome.

For the **status of the claim**, this paper uses four terms.

- **Directly demonstrated:** the relevant phenomenon was actually established by the applicable evidence.
- **Physically supported:** the available evidence supports the mechanism or proposition, but does not directly demonstrate the complete claim being made.
- **Contradicted:** relevant evidence is incompatible with the claim.
- **Unknown:** the evidence does not establish the answer either way.

The other papers in the series use the same claim terms. In their tables, directly demonstrated is abbreviated as DEMONSTRATED.

The second axis describes the **route to the intended application**: **as tested**, **formally covered** or **engineering extrapolated**.

These axes must remain separate. A configuration may not have been physically tested but can still be formally covered through an EXAP, field of application, listing or approval. Conversely, strong physical evidence does not turn an application outside those formal boundaries into a formally covered one.

The distinction is particularly important for project-specific acceptance. A formal approval or listing can extend coverage to configurations that were not separately tested. Project-specific acceptance of an engineering extrapolation is different. If the party that sets the acceptance criterion reviews and accepts that extrapolation, the route does not become formally covered. It remains **engineering extrapolated**; the decision outcome for that party becomes **sufficient**.

Acceptance is an outcome of the decision process, not a retrospective change to the status of the underlying evidence.

Only after the two evidence axes have been established is the decision outcome stated.

- **Sufficient:** the evidence answers the applicable acceptance criterion within its relevant boundaries.

- **Requires additional justification:** the present evidence does not yet support the decision, but an identifiable additional route, evidence item, engineering justification, product confirmation or design change could close the gap.
- **Insufficient:** the available evidence contradicts the claim, falls fundamentally outside the relevant criterion or cannot support the decision without changing the claim or the design itself.

The fixed grammar is:

> THE EVIDENCE GRAMMAR
>
> **[Claim] is [directly demonstrated / physically supported / contradicted / unknown] in [as-tested / formally covered / engineering-extrapolated] configurations; for [decision] this is [sufficient / requires additional justification / insufficient].**

For example:

> *Classification $B_{ROOF}(t1)$ under CEN/TS 1187 Test 1 is directly demonstrated for the as-tested construction and formally covered for the variations permitted by CEN/TS 16459; for a decision whose acceptance criterion is that classification within its applicable field, this is sufficient.*

A different question could produce:

> *Prevention of delayed involvement of combustible insulation is unknown in the engineering-extrapolated configuration; for the stated property-protection decision, additional justification is required.*

The categories do not predetermine the decision. A formally covered configuration is not automatically sufficient for every objective, just as an engineering extrapolation is not automatically insufficient.

Nor does every unknown make a project unacceptable. A test can be blind to a phenomenon that is irrelevant to the decision being made. The purpose of the grammar is not to maximise the number of unknowns. It is to prevent an unknown on one question from being silently converted into proof on another.

This is also why the method deliberately has no numerical score. There is no universal point system in which direct testing scores higher than formal coverage, one deviation subtracts a point and an old report subtracts another. Fire evidence is too dependent on the mechanism, the formal route and the decision for such a scale to be meaningful.

The method instead forces the conclusion to remain traceable: from the decision, through the document and the test question, to the evidence envelope and the governing mechanism. A one-page version is given in Appendix A.

The next chapter applies that method to four cases. One shows how a valid label can conceal a narrower test question, one shows how adding PV changes the question being asked of roof evidence and one shows the equally important opposite outcome: the available evidence can be sufficient.

10 The method in practice: four cases

A method is only useful if it produces different answers when the evidence and the decision are different.

The four cases below deliberately do not all end in the same place. The first shows how a familiar classification can hide a narrower test route. The second shows how adding PV can change the system question without erasing the original test evidence. The third shows the opposite outcome: evidence can be fully sufficient for one decision while being irrelevant or unsuitable for another. The fourth separates observations on a vegetated roof from predicted compartment consequences and wider public communication.

Case 1: Class A on a non-combustible deck

Consider a roof covering classified Class A under ASTM E108 or UL 790.

The label appears straightforward. Class A is the highest of the three external-fire classes in that system and represents severe fire exposure. It would be easy to translate that into a broader statement that the roof has passed all relevant external-fire tests.

That conclusion can be too wide.

As described by the ICC Evaluation Service and Intertek, coverings restricted to use over non-combustible decks require only the spread-of-flame test for the relevant classification route, whereas coverings not so restricted are also subjected to the intermittent-flame and burning-brand tests.

An important consequence follows for a typical commercial construction comprising a non-combustible steel deck, insulation and a roof covering. The route for a covering limited to a non-combustible deck may not directly evaluate behaviour toward combustible insulation located between the covering and that deck.

Applying the five steps makes the boundary visible.

The decision might be whether the roof covering satisfies the required Class A classification for use over the intended non-combustible deck. The evidence is the applicable classification and test documentation. Reading the test backwards then asks which subtests were actually required for that application and what failure would have looked like.

If the applicable route only required spread-of-flame performance, the Class A result remains completely valid. It directly demonstrates compliance with the classification route that applies to that use.

What it does not do is directly demonstrate the roof's response to failure modes that were not required for that configuration, including behaviour towards combustible insulation where that mechanism falls outside the test route.

The conclusion is therefore not that Class A is incomplete. It is:

> *Class A performance is directly demonstrated within the applicable as-tested or formally covered configuration; for the stated code decision this may be sufficient. Behaviour towards combustible insulation through a failure mode not included in that route remains unknown within that evidence.*

The classification is not weakened by understanding its boundaries. Its meaning becomes more precise.

Case 2: A classified roof with PV added above it

Now consider a roof with a valid external-fire classification to which rooftop PV is added later.

At the level of the original test, the result remains evidence of the roof configuration and exposure for which it was obtained. Adding PV does not rewrite what happened in that test.

Some formal systems, however, explicitly prevent the classification from travelling to the modified system. FM makes that boundary unusually clear. Its April 2026 DS 1-15 states that, unless specifically FM Approved as a roof-PV system, an FM Approved Class 1A roof assembly has that rating negated once PV panels are placed above it. *(FM, 2026)*.

There is no contradiction between those two statements. The original test evidence still exists. FM's formal framework says that its Class 1A system rating no longer applies to the new roof-PV configuration.

Experimental evidence also shows why that distinction can be physically important.

CEN/TR 18326 identifies module geometry and distance from the roof as relevant parameters. OFR's review of Kristensen's work shows that changes of only a few centimetres in cavity height can alter flame-spread behaviour, while module frames can affect the retention of hot gases beneath the module.

More importantly, Kristensen's experiments provide an example of **contradicted** rather than merely unknown evidence. In the configurations tested, PV modules enabled substantial flame propagation over roof covering systems that satisfied the relevant conventional external-fire classification. OFR also reports rapid flame spread in tests involving roof covering classified B_{ROOF}(t4), where conventional classification alone did not predict the under-PV behaviour. *(Kristensen & Jomaas, 2018; Kristensen, 2023; OFR, 2026)*.

The correct evidence statement is therefore:

> *The claim that the roof classification also limits flame spread beneath PV is contradicted for the configurations tested by Kristensen; the original roof classification remains directly demonstrated for its own test configuration.*

That conclusion must not be universalised. It does not prove that every classified roof will exhibit rapid propagation beneath every PV system.

What it proves is narrower and more useful: the original classification cannot be assumed to control a mechanism that has been shown experimentally to change when PV is introduced.

Where a jurisdiction or approval route formally covers the combined configuration, the roof-PV application may still be formally covered. Where it does not, the connection requires engineering extrapolation or additional evidence.

The test result did not change. **The question and, in some frameworks, the formal validity of the rating did.**

Case 3: A gravel roof that is sufficient and unsuitable at the same time

A gravel-surfaced roof provides an even clearer example of why sufficiency only has meaning relative to a defined decision.

Under the Dutch regulatory route, NEN 6063 is used to determine whether the upper surface of a roof is fire hazardous. Current Dutch assessment documentation recognises a gravel layer with a thickness of at least twice the nominal aggregate diameter and a minimum thickness of 40 mm as a route by which the roof can be regarded as non-fire-hazardous.

No additional fire test of that individual roof is required for that route. For the regulatory question, this can therefore be sufficient.

Now change the question.

NEN itself states that NEN 6063 is not suitable for determining the fire behaviour of PV modules. The gravel route therefore does not demonstrate how a PV module, the cavity below it or the combined roof-PV system will behave in a PV-related fire.

That does not make the gravel route inadequate. It means the PV question lies outside the question that the route answers.

The evidence grammar changes accordingly:

> *Compliance of the gravel-surfaced roof with the Dutch non-fire-hazardous roof requirement is formally covered by the applicable NEN 6063 route and is sufficient for that regulatory decision. The fire behaviour of a PV system installed above it is unknown within that evidence.*

Now change the decision again.

FM DS 1-15 recommends that PV panels should not be installed on roofs with aggregate or other loose ballast. The recommendation appears within FM's wind-loss provisions, while the explanatory section discusses loose aggregate as potential windborne debris and addresses the sliding resistance of PV systems on such roofs. *(FM, 2026, §2.1.2.3.1 J and §3.4.13)*.

The concern is therefore not that the Dutch external-fire route is wrong. It is a different loss-prevention question.

The same physical roof can therefore produce three different conclusions: sufficient for the Dutch roof-surface fire requirement, not answered by that evidence for the roof-PV fire question and contrary to FM's loss-prevention recommendation for a different hazard.

There is no contradiction between those outcomes.

> **The Dutch route can be sufficient for the Dutch regulatory decision and still be unsuitable for a different insurer decision based on a different hazard.**

This is the practical meaning of Chapter 3. The evidence does not become stronger or weaker when the decision changes. What changes is the question the evidence is being asked to answer.

Case 4: a valid vegetated-roof result with a limited scope

Peutz report C 2229-5-RA-001 (13 January 2025), commissioned by Rijksvastgoedbedrijf, describes four tests with two glass-backsheet modules, dried vegetation, an EPDM/EPS roof at approximately 15 degrees and a 6 kW propane burner. Only one test used plastic vegetation trays. Rail geometry, source position and airflow varied; test 4 reused a module already damaged in test 2. These are not matched comparisons isolating a single variable. [Peutz, 2025, §§2, 4–5]

In the tray test, damage extended down to the steel deck and the fire was extinguished after approximately 14.5 minutes. Damage and discolouration were observed on the adjacent module; this does not by itself establish independent flaming involvement. Peutz's expectation of fire propagation into the compartment below is an interpretation of the results, not an observed compartment breach. The expected absence of propagation for the tested mat arrangements is likewise bounded by those arrangements. These findings should be read separately from the broader wording in RVB's news item of 31 January 2025 (https://www.rijksvastgoedbedrijf.nl/actueel/nieuws/2025/01/31/brandtesten-op-groendaken).
The bounded conclusion is DEMONSTRATED for the observed specimen responses, as tested. Applying the result to another vegetation system, roof slope, module arrangement or commercial roof field is engineering extrapolation unless formally covered. The report does not establish that every green roof prevents PV fire escalation and does not issue a generic roof-PV classification. The author's lesson is to retain the successful result while resisting a broader claim than the configurations support.

These four cases show why the method is deliberately decision-first. The same classification can be sufficient, incomplete or irrelevant depending on the claim being made. A formal route can answer a regulatory question without answering an insurer question. A valid roof classification can remain valid evidence of its original test while leaving the combined roof-PV system outside its evidence envelope.

The next chapter applies exactly the same discipline to our own evidence for BarrierSheet.

11 The same method applied to BarrierSheet

A method for reading evidence is only credible if it is applied to the author's own evidence with the same discipline used for external products, systems and standards.

I am Chief Commercial Officer of AllShield and co-designed the set-ups of AllShield test programmes discussed in this chapter. These reports were commissioned by AllShield.

That relationship does not make the results invalid, but it makes provenance part of the evidence. The purpose of this chapter is therefore not to present a body of AllShield-sponsored testing as an independent commercial endorsement. It is to establish what each piece of evidence demonstrates, where formal coverage exists and where its boundaries remain.

BarrierSheet has several different evidence routes. They should not be collapsed into a single statement that the product is “fire tested” or “approved”. Its reaction-to-fire classification, external-roof-fire classification, FM Approval and roof-PV research each answer a different question.

Different evidence, different claims

The current 2.5 mm BarrierSheet product is classified **A1 according to EN 13501-1:2018** by Efectis for the defined product of approximately 3.0 kg/m². *(Efectis, 2026)*.

That establishes a product-level claim:

> *BarrierSheet's A1 reaction-to-fire classification is directly demonstrated for the defined product and formally covered within the classification's field of application.*

It does not demonstrate the behaviour of an arbitrary roof-PV system containing BarrierSheet. Nor does A1 by itself demonstrate long-duration integrity, resistance to every form of smouldering or the ability of a joint or mechanical fixing to resist a developed roof fire. The same limitation applied to mineral wool in Chapter 6 applies here as well.

A separate Efectis programme addressed external fire exposure of a defined roof build-up. Four specimens were tested according to CEN/TS 1187 Test 1 at a roof pitch of 15°. The tested construction contained a Rhenofol CV membrane, BarrierSheet 2.5 mm, PIR insulation 140 mm, a second BarrierSheet 2.5 mm, PE foil and a steel deck. The subsequent classification report assigned **B_{ROOF}(t1)** and used CEN/TS 16459 to define the direct and extended field of application. *(Efectis, 2025a; 2025b)*.

The classification covers the tested double-layer construction and the variations permitted by CEN/TS 16459. **It does not formally cover a build-up with a single BarrierSheet layer; external-fire classification of that configuration would require its own evidence route.** For a single-layer build-up, reliance on this classification is therefore engineering extrapolated. A separate test would make it as tested; project-specific acceptance would make it sufficient for that party's decision, not formally covered.

The evidence grammar is therefore:

> *$B_{ROOF}(t1)$ is directly demonstrated for the as-tested roof construction and formally covered for the variations permitted by the Efectis classification and CEN/TS 16459.*

Whether that evidence is sufficient depends on the regulatory or project criterion being applied. The classification does not by itself demonstrate the behaviour of PV installed above the roof.

FM provides a third route. BarrierSheet is included as a cover board in RoofNav assembly 568563-0-0 under FM Approvals report PR472014, covering FM 4470 and FM 4478. The listed assembly is a **new-build roof configuration on a steel deck**. That point matters when evidence is later considered for an existing roof in which the retained deck, insulation, attachment or other layers differ from the listed construction. *(FM Approvals, 2025)*.

The distinction developed earlier in this paper also matters. The approval is real formal coverage. PR472014 does not, however, document a separate fire test in which PV was installed above the BarrierSheet roof and exposed to fire. The fire test described in the report is an ASTM E108 spread-of-flame test without PV, on a construction that differs from the listed RoofNav assembly: one layer of 2.5 mm BarrierSheet beneath a mechanically fastened TPO membrane, on 50 mm PIR insulation and a plywood deck. Two samples achieved Class A. For the FM 4478 *Combustibility From Above* requirement, FM accepted earlier data and prior FM 4470 evidence rather than requiring that specific test to be repeated.

That is not a defect in the approval. It is an example of how an approval system legitimately combines direct testing, earlier accepted evidence and the judgement of the approving body.

The correct statement is therefore:

> *The roof-PV application is formally covered by FM 4478 within the listed RoofNav configuration; a fire test with PV installed is not directly demonstrated in PR472014.*

For a project that matches the listing and is accepted through FM's project review, that route can be sufficient for the FM decision.

For an existing roof outside the listed new-build configuration, the listing does not automatically become formal coverage for the retained roof. If FM accepts a project-specific engineering solution, the route remains **engineering extrapolated** and FM's acceptance is the decision outcome. This is exactly the distinction made in Chapter 9.

That ASTM E108 construction also answers a narrower question about layers. It used a single layer of the current product, so Class A spread-of-flame performance is directly demonstrated, as tested, for that specified single-layer construction without PV. It is a US roof-covering classification route. It does not establish $B_{ROOF}(t1)$ for a single-layer build-up and it does not show behaviour with PV installed.

What the ZAG programme demonstrates

The ZAG programme asks a different question again.

Report 448/25-560-1-EN describes four roof-PV configurations using BarrierSheet. AS-1 used a TPO membrane and AS-2 to AS-4 a PVC membrane. In all four, a single anchored layer of BarrierSheet was

installed over bitumen on 100 mm EPS; AS-2 and AS-4 added 60 mm and 120 mm PIR respectively between BarrierSheet and the bitumen. AS-1 and AS-3 therefore represent a renovation case in which BarrierSheet and a new membrane are laid directly over a retained bituminous roof. The intermediate-scale rigs were approximately 2.5 × 2.5 m and the larger rigs approximately 3.5 × 4 m. The specimens were constructed with support from AllShield and AllShield Holding B.V. commissioned the work. *(ZAG, 2025b)*.

The programme used the published ZAG roof-PV fire methodology as its reference framework. That methodology is intended to investigate fire propagation and resulting damage after a fire has been established beneath PV. It is not an ignition-propensity test and permits enlargement of the ignition source where necessary to establish propagation. *(ZAG, 2025a)*.

In the BarrierSheet programme, the initial crib did not produce the required development in some configurations. Enlarged wood cribs were therefore used, including configurations with two enlarged cribs. The report estimates the corresponding heat-release rates with considerable uncertainty. Those sources should therefore be described as **wood cribs**, not as electrical arcs, and the approximate heat-release values should not be treated as precisely controlled fire powers.

Where propagation was established, significant fire developed in the PV-covered area. ZAG concluded that direct flame penetration into deeper structural layers was prevented during the documented test periods. ZAG also recorded localised burn-through of the sheet in AS-2 and in the first AS-3 run, and gaps at joints in AS-2 and AS-4. It describes those gaps and burn-through areas as allowing some heat transfer to deeper layers. Local loss of sheet integrity nevertheless remains relevant to joints, fixings and longer exposure.

At the same time, substantial heat transfer and thermal damage occurred below the sheet. Local temperatures immediately beneath BarrierSheet reached approximately 430°C to above 800°C in reported locations. In the EPS configuration with 100 mm insulation, the EPS locally melted through its full thickness, while PIR showed deformation and decomposition in the relevant configurations.

Those observations are important because they prevent a stronger claim than the evidence supports. The tests do **not** demonstrate that combustible layers beneath BarrierSheet remained thermally unaffected. They demonstrate separation from direct flaming penetration during the documented tests while substantial thermal effects could still occur beneath the barrier.

There was also no matched unprotected reference specimen in the programme. The tests therefore cannot quantify the improvement relative to an otherwise identical roof without BarrierSheet.

The bounded conclusion is:

> *Prevention of direct flaming penetration into the layers beneath BarrierSheet, as concluded by ZAG, is directly demonstrated in the as-tested configurations during the documented test period. Localised burn-through of the sheet itself is also directly demonstrated, in two configurations. The degree of improvement relative to an identical unprotected roof is unknown within this programme.*

Duration is part of the evidence boundary

The duration issue from Chapter 6 has to be applied here as strictly as it was applied to the Kristensen evidence.

Three of the reported tests were terminated at approximately 30 minutes and one at approximately 40 minutes. Report 448/25 states that the cooling phase was not registered.

The published January 2025 ZAG procedure goes further. It specifies continued temperature registration through the cooling phase and a detailed forensic inspection at least 150 minutes after flaming combustion has ceased. *(ZAG, 2025a)*.

Report 448/25 does not document that extended cooling-phase observation. Nor does the report state that the programme was performed as an accredited test under the January 2025 procedure. For that reason, this paper does not describe report 448/25 as an accredited test performed in full accordance with the published ZAG procedure. The precise description is:

> *The programme used the ZAG roof-PV fire methodology as its reference framework; the report does not document the full cooling-phase observation specified in the published procedure or accreditation for that procedure.*

The consequence for the evidence grammar is clear:

> *BarrierSheet's behaviour during the documented 30–40 minute test periods is directly demonstrated for the configurations tested. Long-duration behaviour beyond the documented observation period is unknown within that evidence.*

That is not a prediction that BarrierSheet would fail later. It is equally not evidence that it would remain unchanged indefinitely.

The Kristensen work shows why the distinction matters. A governing mechanism can change after a protective system has already performed for a substantial period. The correct response is therefore to preserve the duration boundary rather than extrapolate in either direction.

Scale and product drift

Scale creates another boundary.

The larger ZAG set-up included only a limited number of PV modules. It is substantially more representative of a roof-PV interaction than a coupon or isolated material test, but it still does not reproduce a commercial roof field containing hundreds or thousands of modules.

This deserves particular care because FM's current loss-prevention framework states that the roof-PV fire question cannot be resolved by testing individual components or by small-scale testing. *(FM, 2026)*.

The ZAG programme should therefore not be presented as an alternative to the FM 4478 system approval route. It answers a research question about fire development and barrier behaviour in specific roof-PV specimens. The FM route separately establishes formal coverage for a specified RoofNav system.

Earlier development testing also illustrates product drift. A Kiwa-BDA programme used an earlier BarrierSheet generation with a nominal thickness of 1.2 mm, while the current product is 2.5 mm. Those results remain useful as development evidence, but they should not silently be treated as direct test evidence for the present product. *(Kiwa-BDA, 2024)*.

The same discipline used for external products, insulation materials and standards therefore leads to a deliberately bounded conclusion for BarrierSheet.

- Its A1 classification directly demonstrates the defined product's reaction-to-fire class.
- Its $B_{ROOF}(t1)$ evidence directly demonstrates and formally extends the external-fire classification of the specified **double-layer** roof construction. It does not formally establish $B_{ROOF}(t1)$ for the ordinary single-layer BarrierSheet configuration.
- Its FM Approval formally covers the listed new-build RoofNav roof-PV configuration, even though a PV fire test is not directly documented in PR472014.
- The ASTM E108 test in the FM report directly demonstrates Class A spread-of-flame performance for one specified single-layer construction without PV.
- The ZAG programme directly demonstrates that, in the tested roof-PV configurations and during the documented 30–40 minute test periods, BarrierSheet prevented direct flaming penetration into the underlying layers, while localised burn-through of the sheet and significant thermal effects still occurred.

None of those statements demonstrates that every roof containing BarrierSheet is non-combustible, that every PV fire will be contained, that combustible insulation beneath it cannot become involved under a different or longer exposure, that the ZAG observations automatically scale to a commercial roof field or that a product approval automatically transfers to a different existing roof.

That is not a weaker description of the evidence. It is the description that survives the method used throughout this paper.

12 What the method does not claim

The method in this paper is intended to make fire evidence more precise, not to make every project more complicated.

Its purpose is not to replace established classifications, to demand a new test for every variation or to turn every untested mechanism into a reason to reject a roof. It is to make clear what evidence answers, where its boundaries lie and whether those boundaries matter to the decision being made.

Not every unknown requires another test

Every fire test has blind spots. Every real building differs in some way from a laboratory specimen. Neither fact means that further testing is automatically required.

If the applicable regulatory route asks whether a defined roof construction satisfies a particular classification and the construction falls within that classification's field of application, the evidence can be sufficient for that decision even though other fire scenarios have not been tested.

An insurer or owner may ask an additional question, but that does not retrospectively weaken the regulatory evidence.

Likewise, a difference between the test specimen and the real roof matters only when it falls outside formal coverage and can influence the governing mechanism relevant to the decision.

> **Uncertainty only matters when it is connected to the decision being made.**

This is why the method deliberately stops when the acceptance criterion has been answered. The objective is not to eliminate uncertainty from the building. That is impossible. The objective is to know whether the remaining uncertainty can affect the decision being made.

Robustness is another response to uncertainty

Where a relevant mechanism is not sufficiently demonstrated, obtaining more evidence is one response. Another is to make the design less dependent on that mechanism.

This is not only the author's conclusion. Independent loss-prevention guidance and government-sponsored research point in the same general direction, although through different formal frameworks.

FM DS 1-15 includes routes for existing roofs in which a re-cover incorporates a **non-combustible cover board directly below the membrane**. For new roof covering installations without PV, FM also recommends considering a roof assembly incorporating a non-combustible cover board so that future installation of PV can be accommodated with lower loss potential. *(FM, 2026)*.

OFR's review for the Building Safety Regulator reaches a similar conclusion through a different evidence route. For an existing roof with EPS insulation, it states that a mitigation layer is required to prevent involvement of the EPS and the resulting potential for a large fire. Citing the ZAG/FRISSBE guidance on which this recommendation is based, OFR notes that under most insurer standards such a layer generally consists of non-combustible insulation with a new roof covering. Because the behaviour of the

complete system is decisive, OFR also recommends that the performance of the mitigation layer be supported by reliable experimental data or statistics. *(OFR, 2026, citing ZAG/FRISSBE, 2024)*.

Those sources do not establish that every roof requires such a layer, nor do they make the FM and OFR approaches equivalent. They illustrate the broader robustness principle:

> **A robust design is not necessarily the design with the most fire-test evidence. It is the design that depends least on an uncertain mechanism becoming favourable.**

Robustness can be created in different ways. Combustible material can be reduced or replaced. A roof build-up with non-combustible insulation can reduce the available fuel. Combustible layers can be separated from the relevant exposure. Array geometry and separation can be changed. A formally approved roof-PV assembly can be selected. Active protection can be introduced.

Those alternatives also have boundaries.

FM, for example, recognises increased PV clearance as one possible route in specified circumstances, including a clearance of at least approximately 0.9 m. Increasing the height is not a free design change: FM also notes that standard wind-pressure coefficients no longer apply once the panel height exceeds approximately 0.6 m, requiring additional wind engineering. *(FM, 2026)*.

FM also provides a water-spray protection route beneath PV. That can address the fire mechanism actively, but it introduces another system that must function as intended, including detection, deluge control, an adequate water supply for the specified duration and consideration of the resulting roof load.

These are not arguments against clearance or water spray. They demonstrate the same principle applied throughout this paper: every mitigation strategy solves a defined problem within its own boundary conditions.

Passive separation has boundaries as well. What a non-combustible separation layer changes in a roof fire, and where its limits lie, is examined in *Beyond flame spread*.

The method does not lead inevitably to BarrierSheet

This methodology does not make BarrierSheet the inevitable conclusion.

If an applicable roof-PV assembly is already formally approved and sufficient for the decision, no additional BarrierSheet layer follows from this method.

If a roof build-up with non-combustible insulation is practical, structurally feasible and compatible with the project objectives, reducing combustible material may be the more direct route.

If greater clearance, layout changes, separation distances or an active protection system satisfy the acceptance criterion, those can be legitimate solutions as well.

And if the existing evidence already answers the decision, the correct outcome may simply be to do nothing further.

BarrierSheet becomes relevant to a narrower problem: a roof contains combustible layers that cannot or will not be removed, and the chosen fire-safety or property-protection objective calls for an additional non-combustible separation between the roof-PV fire exposure and those combustible layers.

The limits identified in Chapter 11 remain part of that statement. The ZAG evidence documents performance during the reported 30–40 minute test periods, not indefinite long-duration behaviour. The current $B_{ROOF}(t1)$ classification formally covers the tested double-layer construction and its permitted variations, not a generic single-layer roof build-up. The available roof-PV tests are still much smaller than a full commercial PV field.

Those limitations do not erase the demonstrated performance. They define the boundary within which the evidence should be used.

> **BarrierSheet is one evidenced way of creating non-combustible separation. Whether it is the appropriate route depends on the roof, the applicable evidence framework and the decision being made.**

Fire evidence does not become more useful by asking it to prove more than it was designed to prove. Nor does uncertainty automatically justify another test or another product.

The practical task is to define the decision, understand the evidence, identify where the relevant mechanism is demonstrated or remains uncertain and then choose either to justify that mechanism or make the design less dependent on it.

> **The objective is not maximum evidence. It is sufficient evidence for a defensible decision.**

Appendix A. One-page method

Before asking whether a roof passed a fire test, ask what failure would have looked like in that test.

1. Define the decision

What decision is being made? What fire-safety objective is relevant? Who sets the acceptance criterion? Who carries the consequence? What fire scenario is being considered?

2. Verify the evidence

Is the document authentic and current? Does it apply to the product generation being supplied? Who commissioned the work? Who selected and prepared the specimen? Was the laboratory accredited for the specific method? Were deviations recorded? Are there relevant adverse or contradictory results?

3. Reconstruct the test question

test object → exposure → construction → observation → failure criteria → duration → result

Rewrite the result: *this object*, *in this construction*, *under this exposure*, *was observed in these ways*, *against these criteria*, *for this period*, *and produced this result*. Then ask what the test could not see.

4. Compare with the intended system

What is the evidence envelope? Is the intended construction **as tested**, **formally covered** or **engineering extrapolated**? If it differs, do not count deviations. Ask whether the difference changes the governing mechanism relevant to the decision. Check for evidence drift: has the product, construction or applicable evidence framework changed?

5. Conclude and act

For the claim: **directly demonstrated, physically supported, contradicted** or **unknown**. For the route: **as tested, formally covered** or **engineering extrapolated**. For the decision: **sufficient, requires additional justification** or **insufficient**.

> THE FIXED SENTENCE
>
> **[Claim] is [directly demonstrated / physically supported / contradicted / unknown] in [as-tested / formally covered / engineering-extrapolated] configurations; for [decision] this is [sufficient / requires additional justification / insufficient].**

If the acceptance criterion has been answered, stop.

Appendix B. Fire-test and evidence-route map

This map distinguishes test methods, classification standards, approval routes and deemed-to-satisfy provisions. It describes scope and formal role. Detailed criteria have not been reconstructed from secondary summaries where the full standard was not consulted.

The table is a map, not a substitute for the standards themselves. Where a criterion is described as defined in a standard, the standard should be consulted for the exact requirement.

Evidence level	Method / route	What it addresses	Exposure / question	Result / criterion addressed	Formal role	Important boundary
Material	EN ISO 1182	Non-combustibility characteristics	Furnace exposure	Criteria as defined in EN ISO 1182	Test method feeding EN 13501-1	Not assembly or roof-PV behaviour
Material	EN ISO 1716	Gross heat of combustion	Bomb calorimetry	PCS as defined in the standard	Test method feeding EN 13501-1	Calorific potential, not fire development
Material	EN 13823 (SBI)	Contribution to fire growth	Corner exposure with burner	FIGRA, heat release, smoke and associated criteria	Test method feeding EN 13501-1	Controlled reaction-to-fire scenario, not roof-PV exposure
Classification	EN 13501-1	Reaction to fire of construction products	Uses underlying test evidence	Euroclass A1–F and applicable subclasses	Classification standard	Does not establish arbitrary assembly performance or long-duration integrity
Fire resistance	EN 13501-2	Fire-resistance classification	Uses applicable resistance tests	R/E/I and other classifications as defined	Classification standard	Different question from reaction-to-fire A1
Smouldering	EN 16733	Continuous smouldering propensity	Defined smouldering exposure	Criteria defined by the standard	Test method	Not part of every A1 classification; application dependent
Roof, external fire	CEN/TS 1187 t1	Roof under external fire	Burning brands	Method-specific observations	Test method	No PV above the roof
Roof, external fire	CEN/TS 1187 t2	Roof under external fire	Burning brands + wind	Method-specific	Test method	Different scenario from t1/t3/t4
Roof, external fire	CEN/TS 1187 t3	Roof under external fire	Burning brands + wind + radiant heat	Method-specific	Test method	Different scenario
Roof, external fire	CEN/TS 1187 t4	Roof under external fire	Two-stage brands, wind and radiant heat	Method-specific	Test method	Different scenario
Roof classification	EN 13501-5	External-fire classification of roofs	Uses applicable CEN/TS 1187 method	B_{ROOF}/C_{ROOF} etc. with test-method suffix	Classification standard	No generally acceptable EU-level hierarchy between t1–t4; national hierarchies may apply
Extended application	CEN/TS 16459	Extended application of external-fire roof results	Permitted variation from test evidence	Formal EXAP rules	Extended-application route	Formal coverage only for variables permitted by the route
EU deemed route	Decision 2000/553/EC	Defined roof coverings and configurations	No test where conditions are met	Deemed to satisfy	Formal EU route	Conditions and national implementation matter
NL roof route	NEN 6063:2019	Whether the roof surface is fire hazardous	Dutch external-fire assessment	Fire hazardous / not fire hazardous (Bbl Article 4.47)	National test and regulatory route	Not suitable for determining PV-module fire behaviour (NEN)

Evidence level	Method / route	What it addresses	Exposure / question	Result / criterion addressed	Formal role	Important boundary
NL deemed route	Gravel route (NEN 6063 practice)	Qualifying gravel-covered roof	No individual test where conditions are met	≥ 2× nominal aggregate diameter, minimum 40 mm	Accepted national route	Answers the roof-surface question, not roof-PV behaviour
US roof, external fire	ASTM E108	Roof-covering external-fire performance	Spread of flame / brand / intermittent flame as applicable	Class A/B/C	Test and classification basis	Required subtests depend on the intended deck (see Chapters 8 and 10)
US roof, external fire	UL 790	Roof-covering external-fire performance	US external-fire exposure	Class A/B/C	Test standard	Closely related to ASTM E108; route details as defined in the standard
US surface	ASTM E84	Surface-burning characteristics	Tunnel exposure	Flame-spread and smoke-developed indices	Test method	Not complete roof behaviour
US material	ASTM E136	Behaviour in a furnace	Vertical tube furnace	Criteria as defined	Test method	Not roof or roof-PV assembly performance
PV module	IEC 61730-1/-2	PV-module safety qualification	Electrical, mechanical and fire-related hazards	Module safety qualification	International product safety standard	Installation- and jurisdiction-specific requirements remain separate
PV module (US)	UL 61730	PV-module safety	Module-level hazards	Listing / qualification	US product standard	Does not classify the combined roof-PV system
Roof-PV (US)	UL 2703	PV mounting and system fire classification	Specified module + mounting configuration	System fire classification	Listing standard; referenced by IBC §1505.9	Applies to listed combinations only
FM roof	FM 4470	Roof assemblies and components	Several property-loss questions	FM Approval requirements	Approval standard	Approval may use accepted earlier data and engineering review
FM flexible PV	FM 4476	Flexible photovoltaic modules	Fire and other property-loss performance	FM Approval requirements	Approval standard	Distinct route from rigid PV
FM rigid roof-PV	FM 4478	Roof-mounted rigid PV systems	Modified ASTM E108 with roof cover and PV together	FM Approval	Approval standard	Formal approval does not mean every requirement was separately retested
Roof from below	FM 4450	Insulated roof decks	Interior fire exposure	FM Class 1 requirements	FM approval and test route	Not the external under-PV exposure
Roof from below	UL 1256	Roof-deck construction	Interior fire exposure	System criteria as defined	Test standard	Not the external PV exposure
Roof-PV guidance	CLC/TR 50670	External fire exposure to roofs in combination with PV	Technical assessment framework	No harmonised classification	Technical Report	Guidance, not a universal pass/fail classification
Roof-PV procedure	ZAG procedure (2025)	Propagation and damage beneath PV	Wood-crib developed fire	Observational; no pass/fail class	Pre-normative procedure	Cooling phase and forensic timing are part of the procedure
Roof-PV research	ZAG 448/25	BarrierSheet roof-PV specimens	Developed wood-crib fire beneath modules	Propagation, temperature and damage observations	Research test report	30–40 min documented; cooling phase not registered; accreditation not documented
Roof-PV (Italy)	CEI/TS 82-89:2023	Fire behaviour testing of PV modules installed on building roofs	As defined in the specification	As defined in the specification	National technical specification	National route; criteria not reproduced here

References

CEN (2019). *CEN/TS 16459:2019 External fire exposure of roofs and roof coverings – Extended application of test results from CEN/TS 1187.* Brussels: CEN.

CEN (2023). *EN 15725:2023 Extended application on the fire performance of construction products and building elements – Principles of EXAP standards and EXAP reports.* Brussels: CEN.

CEN (2026). *CEN/TR 18326:2026 Report on installation scenarios, available test methods and national legislation to be considered for the fire performance classification of roof systems with above roof mounted PV modules.* Brussels: CEN/TC 127. Approved 17 May 2026.

CEN. *CEN/TS 1187:2012 Test methods for external fire exposure to roofs.* Brussels: CEN.

CEN. *EN 13501-1:2018 Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests.* Brussels: CEN.

CEN. *EN 13501-5:2016 Fire classification of construction products and building elements – Part 5: Classification using data from external fire exposure to roofs tests.* Brussels: CEN.

de Paula, D.J., Rodrigues, J.P.C. & Camargo, A.L. (2026). Experimental tests on fire behaviour of roof covering systems. *Fire Safety Journal* 162, 104650.

European Commission (2000). *Commission Decision 2000/553/EC of 6 September 2000 implementing Council Directive 89/106/EEC as regards the external fire performance of roof coverings.* Official Journal of the European Communities.

European Commission (2001; 2005). *Commission Decision 2001/671/EC on the classification of the external fire performance of roofs and roof coverings, as amended by Commission Decision 2005/823/EC.* Official Journal of the European Communities / European Union.

FM (2026). *Property Loss Prevention Data Sheet 1-15: Roof-Mounted Solar Photovoltaic Panels.* Full revision, April 2026. Factory Mutual Insurance Company.

ICC-ES (n.d.). *ASTM E108 – Fire tests for roof coverings*, product testing guidance. ICC Evaluation Service. Retrieved October 2026.

ICC (2021). *International Building Code*, Section 1505.9: Rooftop mounted photovoltaic panel systems. International Code Council.

IEC. *IEC 61730-1 and IEC 61730-2: Photovoltaic (PV) module safety qualification.* Geneva: IEC.

Intertek (n.d.). *ASTM E108: Standard test methods for fire tests of roof coverings*, laboratory guidance. Retrieved October 2026.

ISO (2018). *ISO 23932-1:2018 Fire safety engineering – General principles – Part 1: General.* Geneva: ISO. Reviewed and confirmed 2024.

ISO (2019). *ISO/TR 17252:2019 Fire tests – Applicability of reaction to fire tests to fire modelling and fire safety engineering.* Geneva: ISO.

Kiwa (BRL 1511). *Beoordelingsrichtlijn BRL 1511*, provisions for gravel-covered roofs under NEN 6063. Rijswijk: Kiwa.

Kristensen, J.S. (2023). *Fire risk associated with photovoltaic installations on flat roof constructions: experimental analysis of fire spread in semi-enclosures.* PhD thesis, The University of Edinburgh.

Kristensen, J.S. & Jomaas, G. (2018). Experimental study of the fire behaviour on flat roof constructions with multiple photovoltaic (PV) panels. *Fire Technology* 54(6), 1807–1828.

Leppänen, P. & Malaska, M. (2019). Experimental study on the smouldering combustion of mineral wool insulation in chimney penetrations. *Fire Technology* 55, 2171–2194.

NEN (2019). *NEN 6063:2019 Bepaling van het brandgevaarlijk zijn van daken.* Delft: NEN.

NEN (2024). *Veilige afstand tussen PV-panelen?* News item on the DGMR investigation for the NEN working group on fire safety of PV panels in and on the building envelope, 23 February 2024.

OFR Consultants (2026). *Thermal exposure to roofs from fires involving photovoltaic panels.* Literature review for the Building Safety Regulator, Revision R02, 7 January 2026.

UL. *UL 2703: Mounting systems, mounting devices, clamping/retention devices and ground lugs for use with flat-plate photovoltaic modules and panels.* Northbrook: UL.

UL Solutions (n.d.). *PV mounting systems certification.* Retrieved October 2026.

ZAG (2025a). *Fire test method for flat roofs with photovoltaic (PV) modules.* First edition, January 2025. Ljubljana: ZAG / FRISSBE.

ZAG/FRISSBE (2024). Fire Safety Guideline for Building Applied Photovoltaic Systems on Flat Roofs. May 2024, English version v3. https://www.frissbe.eu/upload/files/FRISSBE-ZAG%20BAPV%20Fire%20Safety%20Guideline%20May%202024%20v3.pdf

Peutz (2025). Brandveiligheid van PV-systemen icm vegetatiedaken. Report C 2229-5-RA-001, 13 January 2025. Client: Rijksvastgoedbedrijf. §§2, 4–5. https://omgevingsweb.nl/wp-content/uploads/2026/10/definitief-rapport-Peutz-Dubbel-Duurzaam.pdf

Documents referred to in Chapter 11 and the author's perspective

Efectis (2025a). *Report 2025-Efectis-R000982: Exposure to external fire to roofing membrane + BarrierSheet on PIR according to CEN/TS 1187:2012, Test 1.* July 2025. Sponsor: AllShield Coatings B.V.

Efectis (2025b). *Classification 2025-Efectis-R000983: Classification of external fire performance in accordance with EN 13501-5:2016.* July 2025. Sponsor: AllShield Coatings B.V.

Efectis (2026). *Classification 2026-Efectis-R000318: Classification of reaction to fire performance in accordance with EN 13501-1:2018, AllShield BarrierSheet.* March 2026. Sponsor: AllShield Coatings B.V.

FM Approvals (2025). *Approval Report PR472014: AllShield BarrierSheet.* FM 4470 and FM 4478. Date of approval 11 December 2025. RoofNav assembly 568563-0-0.

Kiwa-BDA (2024). *Report 24L0241/1.* Development testing with an earlier 1.2 mm BarrierSheet generation.

ZAG (2025b). *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.

[N1] DIN Media. Introduction to DIN CEN/TS 1187:2012-03 (DIN SPEC 91187), including Germany's method-1 building-control route. https://www.dinmedia.de/de/vornorm/din-cen-ts-1187/123603530

[N2] France. Arrêté du 14 février 2003 relatif à la performance des toitures et couvertures de toiture exposées à un incendie extérieur, Article 2 (method 3). https://www.legifrance.gouv.fr/loda/id/LEGITEXT000005634084/

[N3] England. Approved Document B, Volume 2: Buildings other than dwellings, 2019 edition incorporating amendments collated in 2026, §14 and Table 14.1. https://assets.publishing.service.gov.uk/media/6aa3bb7492e72b8ac437f145/AD_B2_2026.pdf

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.

Key source boundaries

FM's public Power & Renewables release of 5 October 2026 supports early engineering input while site, technology and design decisions can still be changed. Its survey concerns the wider energy sector and does not establish rooftop-PV incident or performance data. Source: FM, "With Power and Renewables Risks Evolving, Engineering Must Move Upstream", 5 October 2026, https://www.fm.com/newsroom/news/2026/fm-power-and-renewables-press-release.
Approval Report PR472014 (11 December 2025), §§1.3, 3.2 and 9, identifies the applicable standards and evaluated assemblies and refers to RoofNav for the listing. The programme uses previous test data and waivers, including the 4478 external-fire requirement based on 4470 evidence. It does not document a new fire test with PV. Approval of a listed assembly and project-specific engineering acceptance are distinct decisions.
ZAG Report 448/25-560-1-EN, summary p. 3 and conclusion p. 46, reports prevention of direct flame penetration into deeper structural layers in the tested configurations during the documented test periods. Heat transfer, local gaps or burn-through and damage to underlying insulation were also recorded. These observations do not mean that all underlying layers remained undamaged. The programme has no unprotected reference from which a quantified reduction in risk can be calculated.

Scope and selection

This paper synthesises what classifications, approvals and fire-test reports establish for a real roof-PV decision. Methods, scope-of-application rules, guidance and contrasting cases are included to explain evidence boundaries. The five-step reading method is an author proposal. This is not a new test method or a full legal survey of every jurisdiction.

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

The examples do not create generic approvals. Formal application still requires the actual classification, approval and intended assembly to be checked. The Peutz case does not establish performance for all vegetated roofs.

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
1.4	21 October 2026	Added the decision question to step 1 of the method. Corrected the description of the ASTM E108 test in FM Approval Report PR472014 and added its single-layer result. Specified the membrane and build-up per ZAG specimen and added the localised burn-through and joint observations reported by ZAG. Added the DC arc papers to the series overview. Revision history introduced with this version.
1.41	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: Read the primary Peutz C 2229-5-RA-001 report and added a bounded vegetated-roof case. Checked the English May 2024 ZAG/FRISSBE guideline and replaced its secondary citation.
1.42	1 November 2026	Ch. 8: EU-level hierarchy and Germany t1, France t3, England t4 examples added (Decision 2001/671/EC Annex; DIN introduction; French arrêté Art. 2; ADB Vol. 2 §14/Table 14.1). Ch. 10: Peutz C 2229-5-RA-001 §§2, 4–5 observations separated from inferred compartment consequences.
1.43	1 November 2026	Ch. 8 and Appendix B: hierarchy wording edited as publication prose; country sources added to references. Ch. 10: four cases identified and Peutz case moved before transition. Ch. 11: ZAG conclusion terminology aligned to p. 46. Authorship and specific revision entries 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? (this paper)	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	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.

All papers and their latest versions: allshield.com/en/olivier-langejan

Comments, corrections, missing sources, evidence that contradicts a conclusion and field experience are welcome at ol@allshield.com. Relevant input is used in future versions. To be notified of new papers and versions, send a short email to the same address.

This paper may be shared freely, unchanged and with attribution.