THE ROOF COMES FIRST · WHITEPAPER

The economics of the rooftop PV decision

A lifecycle approach to probability, consequence and the real cost of fire risk

CENTRAL QUESTION

How do I achieve an acceptable probability × consequence at the lowest lifecycle cost over the life of the asset?

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Prepared for asset owners, CFOs, risk managers, insurers, property managers, roofing specialists and rooftop PV project teams.

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Author’s perspective

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

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

These papers are prepared by Olivier Langejan as lead author with support from a small team. His own professional focus is building and roof design; specialist findings are drawn from the cited evidence, with AI assistance disclosed separately in Method and sources.
I am affiliated with AllShield, which develops BarrierSheet and other roof fire-protection solutions. That commercial relationship is relevant and is therefore stated explicitly. The analysis does not assume that an AllShield product provides the effects discussed. 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 the same roof-first thinking to economics. The central question is not whether every additional fire-safety measure can be justified, but how an asset owner should compare expenditure on ignition prevention, consequence limitation and residual loss over the life of the building. The analysis deliberately allows different outcomes for different assets, including the conclusion that an additional measure is not economically justified.

Executive summary

Rooftop PV is normally presented as an energy investment. The business case typically contains capital expenditure, expected electricity production, energy savings, payback period and return on investment. For the asset owner, however, this represents only part of the economic decision. The PV system is installed on a building that may remain in use long after the first generation of solar equipment has reached the end of its economic life. The property risk remains with the owner throughout those changes.

This paper focuses specifically on the fire-risk economics within the wider rooftop PV decision. Structural capacity, roof condition, remaining roof life, fixing strategy and insurability are important boundary conditions that should be understood before the risk-economic comparison begins.

Fire risk has two distinct dimensions. Good components, competent design, correct installation, inspection, maintenance and appropriate monitoring can reduce the probability of ignition but cannot make that probability zero. If ignition nevertheless occurs, the complete roof-PV assembly influences the consequence. PV modules can change heat transfer and flame behaviour at the roof surface while the materials below them can influence whether the incident remains relatively local or develops into a substantially larger property loss.

The economic question should therefore not be limited to how far the probability of a PV fire can be reduced. A more complete question is how an acceptable level of rooftop PV fire risk can be achieved at the lowest lifecycle cost. In this paper I separate baseline prevention cost, additional probability-reduction cost, consequence-limitation cost and residual expected loss.

Existing research provides important parts of this framework. Jahn et al. developed a methodology for comparing the economic impact of technical PV risks and the cost of mitigation while explicitly considering cost and risk ownership [1]. IEA-PVPS has subsequently expanded lifecycle O&M, technical-risk and economic decision-making methodologies [2,3]. Property-risk guidance from Swiss Re, FM, ZAG/FRISSBE and the UK Building Safety Regulator-commissioned research increasingly treats PV and the roof as an interacting fire system rather than unrelated products [5,7,8,9].

> **The central question: how do I achieve an acceptable probability × consequence at the lowest lifecycle cost over the life of the asset?**

In this paper I apply established risk-economic principles to that asset-owner decision. I do not attempt to prove that one measure is always superior. Instead, I provide a framework for deciding where each additional euro of risk-management expenditure creates the greatest lifecycle value.

Scope and limitations

This paper presents a decision framework rather than an actuarial fire-risk model. It does not establish a universal annual probability of rooftop PV fire and it does not assign a universal loss-reduction factor to any particular roof construction, coverboard or fire-safety intervention. Fire probability and consequence depend on system design, installation quality, building use, roof construction, maintenance practice, fire detection, firefighting conditions and other variables.

The paper also does not assume that general PV operation and maintenance expenditure can be treated as fire-prevention expenditure. O&M protects energy yield, reliability and asset performance as well as safety. Similarly, no assumption is made that a particular fire-safety measure will automatically reduce insurance premiums or guarantee insurability.

No exhaustive literature cut-off is asserted. The cited publications and the targeted source checks documented in the revision history define the evidence available for this paper.

1. The rooftop PV decision from the asset owner's perspective

Consider a distribution centre with approximately 20,000 m² of flat roof. A proposal is made to install a large rooftop PV system and the economics initially appear straightforward. The available roof area is substantial, electricity consumption is high, the projected energy yield is attractive and the calculated payback falls within the company's investment criteria.

As the project develops, several specialists become involved. The PV EPC evaluates module layout, electrical design, yield, system cost and installation. The roofing consultant examines the remaining life of the waterproofing system and insulation. The structural engineer calculates the additional load. The controller evaluates capital expenditure and return. The risk manager considers potential losses and the insurer may impose requirements intended to reduce likelihood or severity.

Figure 1

Rooftop PV in the real world

Rooftop PV is installed into an existing building system, not onto an empty test surface.
Roof construction, PV geometry, skylights, access routes and structural constraints all form part of the asset-owner decision.



Each party is performing a legitimate function but is also optimising a different part of the decision. The asset owner is the only party that ultimately inherits all of them together. After commissioning, the EPC's construction phase ends, warranties eventually expire, contractors change, the roof ages and equipment is replaced. The owner continues to carry property exposure, maintenance obligations, Business Interruption consequences and long-term economic risk.

The governance problem is therefore not that one participant is irrational. Every participant may be making a rational decision within their own scope while the combined decision is still economically suboptimal for the asset owner.

2. The same roof, six different economic lenses

The same rooftop PV project can produce different rational recommendations depending on who is looking at it. Understanding these perspectives matters because many investment decisions are effectively made in organisational silos.

The PV EPC primarily optimises yield, component reliability, electrical performance, installation cost and project return. The roofer or roofing consultant focuses on waterproofing, insulation, drainage, wind uplift, remaining service life and future refurbishment. The structural engineer focuses on structural reserve, load paths, reinforcement and the feasible load available for the complete roof-PV intervention. The controller or CFO sees current CAPEX and future cash flow. The risk manager or insurer evaluates probability, severity, controls and residual risk. The technical or property manager inherits the project after handover and carries the operational burden of inspection, maintenance and continuity.

Stakeholder	Primary economic focus	Risk of a silo decision
PV EPC / developer	PV yield, CAPEX, system performance and project return	Optimises the solar asset rather than the total property exposure
Roofer / roofing consultant	Roof life, waterproofing, refurbishment and construction	May optimise the roof without fully pricing the changed fire environment created by PV
Structural engineer / building engineer	Structural reserve, load paths, reinforcement and feasible PV capacity	May verify a proposed load case without optimising roof life, fire strategy or total asset economics
Controller / CFO	CAPEX, payback and return	Sees current expenditure more clearly than uncertain residual loss
Risk manager / insurer	Probability, severity and residual risk	Can recommend protection without necessarily optimising total project economics
Technical / property manager	Long-term operation, maintenance and continuity	Carries the operational burden of controls long after project approval

The asset owner’s task is to determine which combination produces the best result for the complete asset over its remaining economic life.

3. Probability × consequence as a decision framework

Professional risk analysis is more sophisticated than a simple multiplication. For the purpose of this paper, however, one simplified relationship is useful:

> **Risk ≈ probability × consequence**

This is a decision heuristic rather than an actuarial formula. Its value is that it makes two different risk-management levers visible.



The first lever is probability reduction. Component quality, connector compatibility, electrical design, competent installation, commissioning, inspection, maintenance and appropriate monitoring can all reduce the probability that a defect develops into an ignition. These measures remain fundamental.

The second lever is consequence limitation. Once an electrical failure does produce an ignition, the materials and geometry surrounding the fire influence what happens next. In rooftop PV this includes modules and electrical components as well as waterproofing, insulation, coverboards, mounting system and the complete roof construction.

The ZAG/FRISSBE Fire Safety Guideline for Building Applied Photovoltaic Systems on Flat Roofs, published in May 2024, was developed specifically to address the wider fire behaviour of rooftop PV systems [7]. The asset-owner question therefore becomes how an acceptable probability × consequence can be achieved at the lowest lifecycle cost.

Where this framework builds on existing research

Jahn et al. developed the Cost Priority Number methodology to translate technical PV risks into economic impact and compare mitigation measures. Their cost-benefit approach adds residual economic impact after mitigation to the cost of the mitigation itself and explicitly considers who bears cost and risk [1].

IEA-PVPS has continued this line of work by connecting PV technical performance, O&M, risk and economic decision-making [2,3]. The property-risk literature approaches the same system from another direction. Swiss Re looks at rooftop solar from value at risk and Business Interruption while FM, ZAG/FRISSBE and the UK Building Safety Regulator-commissioned research focus on how PV changes the fire environment of the roof [5,7,8,9].

4. The recurring economics of prevention and risk drift

Probability reduction is not only a design-stage cost. Inspections need to take place, defects need to be identified, repairs completed and failed components replaced. Monitoring systems, where used as part of the control strategy, need to remain functional and their output acted upon.

IEA-PVPS reports typical base O&M costs, including soiling mitigation, of approximately €6.5 to €16.5/kWp per year. It separately reports approximately €0.50 to €3 per PV module or array for advanced diagnostics and analytics based on biannual aerial infrared scanning [2]. These figures are not fire-prevention costs. They illustrate the recurring economic character of PV asset management.

NREL's 2024 commercial PV benchmark illustrates the same principle in a different market. Its fixed O&M benchmark includes system and administrative categories such as asset management, insurance, security, cleaning and component failure [4].

Recent UK incident data reported by QBE also shows why ignition probability remains an operational issue rather than a purely design-stage problem. The data should not be converted into a building-specific annual fire probability but it confirms that incidents continue as deployment grows [6].

Risk drift

In this paper, risk drift describes the gradual divergence between the original risk-management strategy and the way the asset is actually managed later in life. In year one, the monitoring platform is new, records are complete and responsibilities are clear. Fifteen years later, contractors may have changed, inverters and connectors may have been replaced and responsibilities may have moved between departments. Relevant dependencies include inspection, maintenance, alarm follow-up, installation quality and reinstatement of physical protection after later work. Their comparison is an appraisal input, not evidence by itself of a lower lifecycle cost, lower premium or higher asset value.

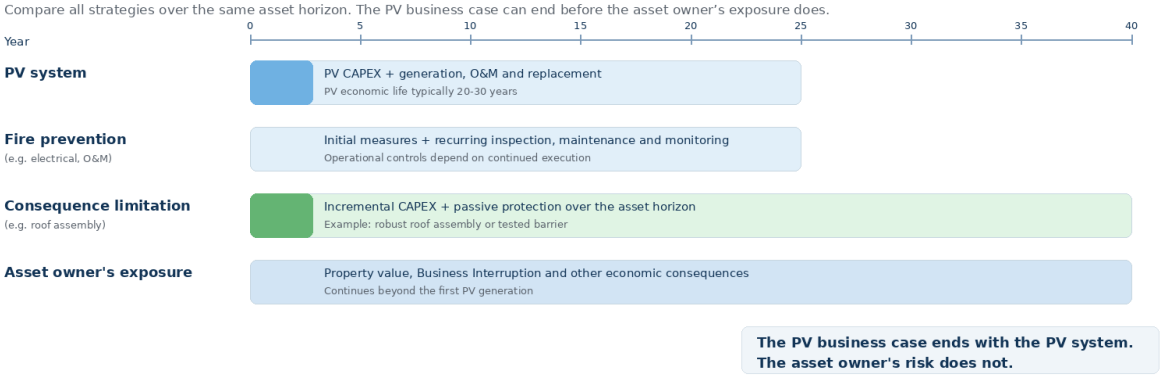
Risk drift is not an argument against inspection, monitoring or maintenance. It is precisely a reason why they matter. Their effectiveness depends on an organisation continuing to perform them correctly over decades. A measure that requires correct action every year has a different lifecycle profile from a physical feature incorporated into the building.

5. Investment horizon versus asset horizon

A rooftop PV project may be modelled over 20, 25 or 30 years while the building underneath it remains in productive use for significantly longer. This mismatch matters because removing PV equipment later to undertake major roof work creates cost, disruption and project risk.

Figure 4. Lifecycle view: costs and risk over the asset horizon

Compare all strategies over the same asset horizon. The PV business case can end before the asset owner's exposure does.



The first generation of PV is not necessarily the lifecycle of the asset. Modules may eventually be replaced with a higher-capacity generation, inverters are likely to be replaced sooner and the waterproofing membrane may be renewed. The building itself remains exposed to property risk throughout these changes.

This creates a critical distinction between the investment horizon and the asset horizon. A measure with a useful service life extending beyond one PV generation should not automatically be valued only over the financial horizon of the first PV investment. Conversely, a strategy that depends on repeated inspection, maintenance, software, replacement or contractual services must include those recurring costs.

There is also a management horizon. The people approving the project today are unlikely to remain responsible when the next roof or PV system is installed. That raises a governance question: who will still be accountable for today's decision when the second generation of PV is installed?

6. The economics of consequence limitation

The second side of the economic equation only matters if the consequence of ignition can be influenced. Research increasingly shows that it can. PV panels create a semi-enclosed cavity that can trap heat and redirect flames towards the roof surface. Panel inclination, gap height, array geometry and underlying materials can all influence fire behaviour.

The UK Building Safety Regulator-commissioned review reports experimental heat fluxes up to approximately 50 kW/m² beneath PV arrays compared with 12.5 kW/m² considered in the standard test methods discussed in the report. It concludes that existing classification tests do not fully capture the modified fire scenarios created by PV arrays and recommends, among other measures, non-combustible roof coverings beneath PV arrays and more representative testing [8]. The conclusions are those of the research authors and do not themselves constitute UK government policy.

Establishing the prevention baseline

Consequence limitation should not be presented as an alternative to competent electrical design, installation, commissioning, inspection or maintenance. Baseline prevention means the level required by applicable regulation, insurer requirements, contractual obligations and the asset owner's own technical standards. Economic optimisation begins after that baseline has been established.

The preferred technical route and the economic constraint

If a non-combustible roof construction is technically straightforward and economically proportionate, it represents a robust consequence-limiting route. Existing lightweight industrial buildings can impose constraints that change the economic answer. Structural capacity is a finite design budget: every kilogram allocated to the roof build-up, fire-protection strategy or mounting system reduces the capacity available for PV or may trigger structural reinforcement. On some lightweight existing buildings, a technically preferred roof solution can therefore become economically unattractive or structurally infeasible once the available load reserve is established. Structural feasibility should be established before economic optimisation begins.

Consequence-limiting route	Potential economic advantage	Potential economic constraint
Fully non-combustible roof build-up	High inherent fire robustness and limited combustible contribution	Weight, roof replacement cost and possible structural reinforcement
Existing robust roof-PV assembly	No additional mitigation CAPEX	Only rational if whole-system fire performance is already sufficient
Tested lightweight barrier strategy	Lower additional dead load and potentially lower intervention cost	Performance must be demonstrated for the relevant complete assembly
Additional probability reduction only	May avoid roof intervention	Does not directly reduce severity if ignition still occurs

A credible economic model must also allow the conclusion that no additional measure is required. If the existing roof-PV assembly already provides the desired fire robustness or the credible consequence is limited, further expenditure may not be justified.

7. The lifecycle risk economics model

The previous chapters can be combined into one simplified framework:

> **Total lifecycle risk cost = baseline prevention cost + additional probability-reduction cost + consequence-limitation cost + residual expected loss**

This is not intended as a complete actuarial formula. It is a structure for investment analysis in which measures that influence different parts of the risk can be compared on a common economic basis. Residual expected loss can include property damage, PV and roof reinstatement, damage to inventory or machinery, Business Interruption, temporary relocation, lost production or distribution capacity, clean-up and uninsured costs.

Scenario analysis rather than false precision

The largest uncertainty is probability. A credible annual fire probability for a particular commercial rooftop configuration cannot simply be derived from national incident counts. Rather than inventing a precise probability, the asset owner can use scenario and sensitivity analysis.

Scenario	Ignition probability	Consequence	Main cost profile
Baseline	Baseline	High	Required prevention only
Additional prevention	Lower	High	Additional recurring or technical controls
Consequence limitation	Baseline	Lower	Additional roof-related CAPEX
Combined strategy	Lower	Lower	Additional investment on both sides

The economics of the next euro

The most useful output may be the marginal value of additional expenditure. Once a sound prevention baseline is in place, there may be a point at which another euro creates more risk reduction by reducing consequence than by making an already small probability incrementally smaller. Conversely, if the roof is already robust and the remaining consequence small, additional probability reduction may create more value.

Present value and avoiding double counting

The timing of expenditure matters. An additional roof layer may largely be paid for at the beginning of the project while inspection, maintenance and monitoring occur over many years and potential loss occurs at an uncertain future date. A complete model should therefore compare costs using net present value and avoid double counting general O&M, insurance, Business Interruption or roof-renewal costs.

Worked example: a 20,000 m² distribution centre

The framework becomes more useful when applied to a building rather than discussed only in abstract terms. Consider the 20,000 m² distribution centre introduced earlier. The roof supports approximately 4 MWp of PV and the asset owner evaluates the property over a 40-year horizon using a 6% discount rate.

The calculation below is deliberately illustrative. It demonstrates how the model works; it does not establish a universal fire probability, market price or guaranteed mitigation effectiveness. A real investment decision requires project-specific quotations, credible loss estimates and technical evidence for the expected performance of each strategy.

For this example, the credible significant-loss scenario consists of €12 million in direct property damage, €18 million in Business Interruption and €2 million in other recovery or uninsured costs. Total credible consequence is therefore €32 million. Business Interruption represents more than half of the assumed loss, illustrating why a conventional PV business case can materially understate the economic exposure carried by the building owner.

Illustrative input	Assumption
Roof area	20,000 m²
PV capacity	4 MWp
Asset horizon	40 years
Discount rate	6%
Annual ignition probability after baseline controls	0.05%
Property damage	€12.0 million
Business Interruption	€18.0 million
Other recovery and uninsured loss	€2.0 million
Total credible consequence	€32.0 million
Additional prevention	€150,000 CAPEX + €50,000/year
Assumed additional probability reduction	50%
Lightweight consequence-limiting route	€25/m² incremental CAPEX
Assumed consequence reduction - lightweight route	70%
Full non-combustible roof route	€120/m² + €600,000 other CAPEX
Assumed consequence reduction - full non-combustible route	90%

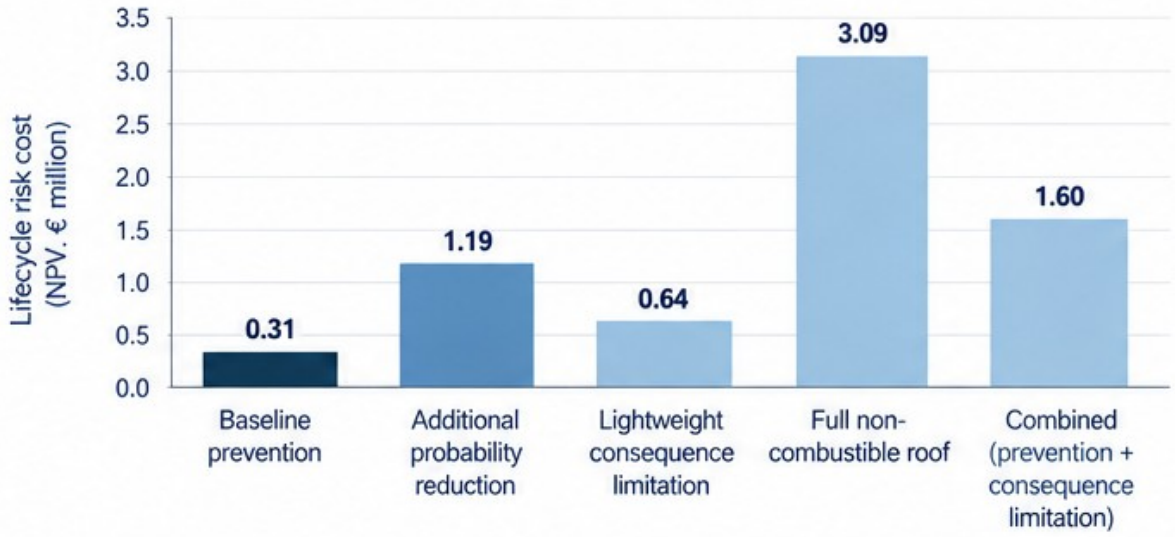
The €25/m² and €120/m² figures are scenario inputs rather than AllShield pricing or general market benchmarks. The same applies to the assumed 50%, 70% and 90% effectiveness values. Their purpose is to expose the economics so the reader can replace them with project-specific evidence.

Figure 5

Worked example: lifecycle risk cost (NPV)

20,000 m² distribution centre | 4 MWp PV | 40-year horizon | 6% discount rate

Illustrative results – see Chapter 7 for full assumptions



In this illustrative case, baseline prevention has the lowest lifecycle risk cost.
The model is deliberately capable of concluding that additional fire-protection investment is not economically justified. Different assumptions can lead to a different result.

Under these particular assumptions, baseline prevention has the lowest lifecycle risk cost. This result is important. I have deliberately built the model so that it can conclude that additional fire-protection expenditure is not economically justified. If it were constructed so that one mitigation measure always won, it would be a sales calculation rather than an asset-owner risk model.

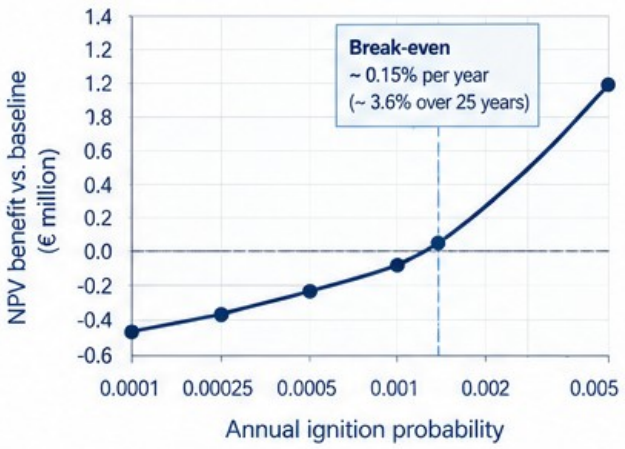
Break-even probability

Rather than pretending that the precise annual probability of a serious rooftop PV fire is known, the model can calculate the annual probability at which a particular investment becomes economically rational. This is the break-even ignition probability: the point at which the present value of avoided expected loss equals the lifecycle cost of a particular mitigation strategy.

Figure 6

Sensitivity and break-even analysis

A. NPV economic benefit vs. annual ignition probability
(lightweight consequence-limiting route)



B. Break-even probability by consequence size
(lightweight consequence-limiting route)

Credible consequence (€)	Break-even annual probability		
	30% reduction	70% reduction	90% reduction
5,000,000	2.22%	0.95%	0.74%
10,000,000	1.11%	0.47%	0.37%
20,000,000	0.55%	0.24%	0.18%
32,000,000	0.35%	0.15%	0.12%

The lower the credible consequence or the higher the expected effectiveness, the lower the probability at which the investment becomes economically preferable to the baseline (under the assumptions entered into the model).

Break-even probabilities are decision thresholds, not predictions.
If the asset owner considers the credible probability to be above a route's break-even threshold, that route becomes economically preferable to the baseline under the assumptions entered into the model. It must still be compared with other strategies to determine which option has the lowest total lifecycle risk cost.

For the lightweight consequence-limiting route in the illustrative case, the break-even annual ignition probability is approximately 0.15%. If that probability were constant over 25 years, it corresponds to a cumulative probability of approximately 3.6% of at least one such event. The full non-combustible roof route has a much higher break-even annual probability of approximately 0.69%, equivalent to approximately 15.9% cumulative probability over 25 years under the same constant-probability assumption.

These percentages are not estimates of actual rooftop PV fire frequency. They are economic decision thresholds created by the model assumptions. If the asset owner considers the credible probability to be above a route's break-even threshold, that route becomes economically preferable to the baseline under those assumptions. It must still be compared with the other strategies before determining which option has the lowest total lifecycle risk cost.

Why Business Interruption can change the answer

If the distribution centre contained low-value goods, had substantial spare capacity elsewhere and could resume operations quickly, the credible consequence could be much lower than €32 million. The economic case for consequence limitation would weaken. If the site were instead a critical manufacturing plant, pharmaceutical facility or high-throughput logistics hub where a major roof fire could stop operations for many months, Business Interruption could materially exceed physical property loss and the break-even probability for consequence limitation would fall.

> **The investment question changes from "How much does additional fire protection cost?" to "At what probability and consequence does not installing it become more expensive?"**

Evidence example: one tested lightweight barrier route

AllShield BarrierSheet is one example of a lightweight consequence-limiting route. FM Approval Report PR472014 identifies the current product as a 2.5 mm formulated cementitious coverboard evaluated under FM Approval Standards 4470 and 4478 in defined assemblies, including a specific RoofNav assembly [10]. The Approval applies to the evaluated assembly and should not be represented as generic approval of every roof construction. The programme uses previous test data and waivers, including the FM 4478 external-fire requirement; PR472014 does not document a new fire test with PV (PR472014, §3.2, Table 1).

ZAG testing in report 448/25-560-1-EN, commissioned by AllShield, examined BarrierSheet in several rooftop PV fire configurations. In the tested scenarios ZAG concluded that the barrier prevented direct flame penetration into deeper structural layers, while substantial thermal effects still occurred below it and localised burn-through of the sheet was recorded in two runs. PIR experienced delamination, deposits and deformation and EPS melted beneath ignition locations in two tests [11].

The evidence therefore supports a consequence-limiting function within defined assemblies; it does not mean that combustible insulation becomes non-combustible or remains undamaged. This example is intentionally kept separate from the illustrative economic inputs in the lifecycle model: the €25/m² scenario cost and assumed consequence-reduction percentages are not BarrierSheet pricing or product-performance claims. None of the BarrierSheet evidence quantifies a reduction in loss: the ZAG programme contained no otherwise identical roof without the sheet.

8. Defensible design: the asset owner decision process

The economic framework becomes useful when the asset owner can convert it into a repeatable decision process. Defensible design is not a separate technical standard. It is the documented result of a decision process in which prevention, consequence, lifecycle cost and residual exposure are considered together.

Step 1. Establish the asset and roof baseline

Start with the existing building. Document the roof construction, waterproofing, insulation, structural capacity, remaining roof life, fixing constraints and known insurer requirements. At the same time, establish the economic horizon against which the alternatives will be compared, including the expected remaining life of the building, planned roof-renewal cycles, probable ownership period and the likelihood of a second generation of PV.

Step 2. Establish the baseline prevention strategy

Document which probability-reduction measures are fundamental for the project under regulation, insurer requirements, contracts and internal engineering standards. Necessary inspection, maintenance and electrical quality should not be traded against passive consequence limitation.

Step 3. Assess the complete roof-PV fire scenario

Evaluate how the complete system is expected to behave if ignition occurs, including PV geometry, roof covering, insulation, coverboards, deck and mounting configuration. Where whole-system evidence exists, prefer it over assumptions based solely on individual material classifications.

Step 4. Establish the credible economic consequence

Translate the physical escalation pathway into a business loss scenario. Include direct property damage, inventory or machinery, Business Interruption and other uninsured or recovery costs where relevant.

Value the direct damage per category rather than as one figure: PV installation, waterproofing, insulation, roof deck and structure, contents and machinery, and Business Interruption. A measure that does not prevent ignition can still change which of these categories a fire reaches. The decisive question is therefore what a fire costs above and below the roof, and which measure limits which part of that cost.

Step 5. Identify technically viable consequence-limiting routes

Compare retaining an already robust assembly, replacing the roof with a non-combustible build-up, introducing a tested lightweight consequence-limiting layer or another validated system-level intervention. Establish structural feasibility before economic optimisation.

Step 6. Evaluate additional probability reduction

Assess optional investments above baseline and compare their lifecycle cost with the additional probability reduction they can reasonably deliver. This is where the economics of the next euro becomes relevant.

Step 7. Build one lifecycle business case

Bring initial CAPEX, recurring OPEX, roof-renewal timing, structural implications, changes in PV capacity, residual loss scenarios and useful life of controls into one discounted model. Use scenario and sensitivity analysis rather than artificial precision.

Step 8. Convert the decision into an asset standard

Document why the selected solution was rational, which assumptions were used and what future changes should trigger reassessment. Carry relevant requirements into roof renewal, maintenance contracts and future PV replacement.

Asset owner question	Required outcome
What is the remaining economic life of the asset?	Define the lifecycle horizon
What prevention measures form the project baseline?	Establish what will be done regardless of roof strategy
What happens if ignition still occurs?	Understand the roof-PV escalation pathway
What is the credible financial consequence?	Quantify property, Business Interruption and other exposure
Which consequence-limiting routes are technically feasible?	Establish realistic design alternatives
What does additional probability reduction achieve?	Calculate marginal risk reduction above baseline
Which combination has the lowest lifecycle risk cost?	Make the investment decision
How will this decision survive future management and PV generations?	Incorporate the outcome into the asset standard

The asset owner does not need to become the PV designer, roofer, structural engineer or fire specialist. The owner does need to ensure that those disciplines answer parts of the same economic question. That is the basis of defensible design.

Conclusion

Rooftop PV is normally approved as an energy investment. For the asset owner, it is also a long-duration property-risk decision. That distinction matters because the different elements of the system do not share the same lifecycle. PV components age, maintenance strategies change, roof coverings are replaced, management teams change and a second generation of PV may eventually replace the first. The building and its economic exposure remain.

Risk drift adds a further lifecycle dimension. Controls that depend on repeated inspection, maintenance, software, contracts or organisational action can diverge from the original strategy as the asset changes hands, contractors change and equipment is replaced. A physical measure incorporated into the building has different lifecycle dependencies. A project appraisal should compare inspection, maintenance, alarm follow-up, installation quality and reinstatement of physical protection after later work. These different dependencies are appraisal inputs; they do not by themselves demonstrate lower lifecycle cost, a premium reduction or a higher asset value. Any such benefit requires project data or an explicitly stated scenario.

A credible fire-risk strategy therefore needs to address both sides of the risk equation. It should reduce ignition probability through competent design, installation and lifecycle management while also considering what happens when those measures do not prevent ignition. Research from FM, ZAG/FRISSBE and the UK Building Safety Regulator-commissioned review shows why the second question matters: PV changes the fire environment at the roof and the complete roof-PV assembly influences fire propagation and potential loss [7,8,9].

My conclusion is that the economically optimal solution will not be identical for every asset. For some buildings, a non-combustible roof construction will be the most rational approach. For some existing lightweight roofs, a tested consequence-limiting solution may achieve the required resilience with lower structural impact and a more favourable lifecycle cost. For other buildings, the existing construction may already provide an acceptable level of risk and further expenditure may not be justified.

The objective is neither maximum prevention at any cost nor minimum initial CAPEX. It is to identify the combination of probability reduction, consequence limitation and residual exposure that gives the asset owner an acceptable risk at the lowest lifecycle cost.

> **The PV business case ends with the PV system. The asset owner’s risk does not.**

Next steps for the asset owner

A whitepaper should not leave the asset owner with theory alone. The next step is to apply the same framework to the actual building. Start with the existing roof rather than with a preferred product. Establish the roof construction, waterproofing membrane, insulation, structural capacity, remaining roof life, fixing constraints, PV configuration and insurer requirements. Document the existing prevention baseline and develop a credible significant-loss scenario that includes both physical property damage and Business Interruption.

Technically viable consequence-limiting alternatives can then be compared using the same asset horizon and discount rate. Where possible, expected performance should be supported by complete roof-PV assembly evidence rather than inferred solely from individual material classifications.

Asset owners can use the Defensible Design Lifecycle Risk Model accompanying this whitepaper to perform the economic comparison. Its inputs must be replaced with project-specific data.

> **The companion Defensible Design Lifecycle Risk Model is available on request from AllShield at ol@allshield.com. Use project-specific assumptions for the economic comparison.**

About the author and transparency

Olivier Langejan is Chief Commercial Officer of AllShield. His architectural and building engineering background informs the series' focus on commercial roof and PV decisions. Authorship, contributions and specialist evidence boundaries are described in Method and sources.

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[3] IEA PVPS Task 13 (2026). Photovoltaic Project Decisions: Quality, Performance, and Economic Value.

[4] National Renewable Energy Laboratory (2024). Annual Technology Baseline: Commercial PV.

[5] Swiss Re Institute (2024). Rooftop solar: Emerging risk control needs for properties.

[6] QBE European Operations (2026). Solar panel fires increasing at more than double the rate of installations.

[7] ZAG / FRISSBE (May 2024). Fire Safety Guideline for Building Applied Photovoltaic Systems on Flat Roofs.

[8] Building Safety Regulator / OFR Consultants (Revision R02, 7 January 2026; publication page updated 13 February 2026). Fire safety: Thermal exposure to roofs from fires involving photovoltaic panels.

[9] FM. Property Loss Prevention Data Sheet 1-15: Roof-Mounted Solar Photovoltaic Panels. Current 2026 revision.

[10] FM Approvals (11 December 2025). Approval Report PR472014: AllShield BarrierSheet.

[11] ZAG (1 August 2025). Report 448/25-560-1-EN: Performance comparison of lightweight non-combustible sheet in rooftop PV-related fires.

Companion tool: Defensible Design Lifecycle Risk Model (Excel). Illustrative default inputs are intentionally editable and should be replaced with project-specific data before an investment decision is made.

[A1] Efectis Nederland BV. Classification report 2026-Efectis-R000318, March 2026. Reaction-to-fire classification A1 under EN 13501-1 for the specified BarrierSheet product and field of application. Product classification does not establish E, EI or REI roof fire resistance.

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

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 the asset owner's lifecycle comparison of ignition prevention, consequence limitation and residual fire loss. PV risk-economic literature, O&M guidance and roof-PV fire evidence are used to build an illustrative decision framework. Energy yield, structural design and insurance pricing are boundary conditions rather than independently validated models here.

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

Ignition probabilities, loss-reduction factors and future insurance savings are not established by this model. Its editable scenarios require project-specific inputs.

Relationships and commissioning

AllShield commissioned the product-specific ZAG programme 448/25-560-1-EN and other AllShield test programmes cited in this paper. The May 2024 ZAG/FRISSBE guideline is a separate publication; its acknowledgements identify support from ROCKWOOL and the EU-funded FRISSBE project. Sharing an institute or a co-author does not make these different programmes one evidence source. Commissioning and funding are stated where known; unknown funding is not treated as evidence of independence.

Reading evidence

The series distinguishes claim status (DEMONSTRATED, PHYSICALLY SUPPORTED, CONTRADICTED or UNKNOWN) from the route to the intended roof (as tested, formally covered or engineering extrapolated). A cited test demonstrates its observed outcome for the specimen and exposure. Guidance is a recommendation and a proposed framework is author analysis; neither demonstrates a product outcome. A project acceptance decision does not extend the formal scope of evidence.

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.

About AllShield

AllShield develops passive fire-protection solutions for commercial and industrial roof assemblies, including BarrierSheet. The author is its Chief Commercial Officer.

Support from AllShield

AllShield can support this process by reviewing the roof build-up and available system evidence and by helping the project team evaluate where a tested consequence-limiting layer may fit within the overall roof strategy.

Test the lifecycle economics for your own asset. Request the Defensible Design Lifecycle Risk Model from AllShield at ol@allshield.com to discuss a project-specific rooftop PV risk assessment.

REVISION HISTORY

Version	Date	Changes
5.3	21 October 2026	Added valuation of direct damage per category, from PV installation to Business Interruption, and the question of which measure limits which part of the cost. Stated that no BarrierSheet evidence quantifies a loss reduction, attributed the ZAG conclusion to ZAG and added the localised burn-through and the commissioning of the test programme. Corrected the author description. Revision history and series overview introduced with this version.
5.31	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: Checked the English May 2024 ZAG guideline, its funding context and the distinction between the OFR R02 report date and its publication-page update. The economic scenarios and loss factors have not been recalibrated.
5.32	1 November 2026	Conclusion: risk-drift dependencies and project-data limits made explicit; no premium, value or cost saving inferred from dependency differences alone. Method and sources: PR472014 §3.2 and ZAG pp. 3, 46 boundaries added.
5.33	1 November 2026	Ch. 4: risk-drift dependencies stated at first definition. Ch. 6: FM §3.2 limitation added beside evidence example; ZAG terminology aligned to p. 46. Removed unverified literature cut-off; model availability aligned. Added A1 reference, authorship and corrected running stamp.

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 (this paper)	Asset owners, CFOs, risk managers	Probability, consequence and lifecycle cost from the asset owner's perspective, including Business Interruption.
From risk models to design requirements	Risk engineers, insurers, designers	An application of five established risk frameworks to consequence-limiting design for roofs with PV.
Beyond flame spread	Risk engineers, insurers, fire engineers	How far a rooftop PV fire can travel into the roof before it becomes a building loss, and what a separation layer changes.
What does a fire test actually prove?	Insurers, risk engineers, specifiers	What a fire test result does and does not demonstrate about a real roof with PV.
DC arcs as a heat source	Insurers, risk engineers, PV designers	How DC arc faults start, persist and end in rooftop PV.
DC arcs at the roof-PV interface	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.

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