AUTOSPRAY SYSTEMS

# Applying Net Risk to **Protected Horticulture**

## Reducing Occupational Harm in Greenhouse Operations Through Controlled Risk Substitution

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# FOREWORD

Over the past decade, my work has focused on introducing unmanned aircraft systems into some of the most hazardous working environments in the United Kingdom. That work has spanned aviation, agriculture, environmental management and regulation, and has consistently involved close engagement with regulators, policymakers, insurers and industry leaders.

In my previous white paper, Applying Net Risk: The Safety Case for UK Drone Regulations, I posed a simple but persistent question:

Why do we continue to assess the safety risks introduced by operating drones without taking into account the safety benefits achieved by removing workers from hazardous activities.

This paper is a direct continuation of that challenge.

As an example, within the Horticulture sector, greenhouse shading, cleaning and maintenance remain routine activities. These activities are hazardous as they place workers at height, on fragile glass structures, in wet conditions, and in proximity to chemical products. These hazards are not speculative. They are the same harm mechanisms that appear year after year in Health and Safety Executive statistics: falls from height, fragile surface failures, slips during maintenance, and exposure during cleaning and treatment activities.

The rise of drone technology has provided alternative solutions to conduct these same activities. Activities that once required routine roof access can now be carried out remotely using drones, with the operator physically separated from the hazard.

**By shifting these structural maintenance requirements to uncrewed systems, we realise a compounding safety dividend. Every hectare treated remotely represents a high-severity exposure pathway that has been permanently closed, creating a cumulative reduction in harm that grows throughout the operational life of the facility.**

Despite this clear safety gain, our regulatory system is designed to be siloed. There is no way to trade-off the safety risks with the safety benefits because there are multiple regulators involved. The UK CAA authorises operations based on long-standing aviation rules that are not yet tuned for emerging technologies like drones. The CAA is unable to recognise any benefits that come from the removal of hazards that are managed today by the Health and Safety Executive.
The claim in this paper is that the drone industry would be able to realise the significant benefits if there was a mechanism to be able understand the ‘net-risk’ of operations.
The challenge is that we need to develop principles that allow us to compare the decrease of risk in carrying out work with the increase in risk to aircraft accidents i.e. a drone hitting an aircraft or increase in risk to members of the public who are nearby to the work-site.

## **FOREWORD** (continued)

That imbalance is not benign. By focusing narrowly on what might go wrong with drones, we risk overlooking what already goes wrong in conventional greenhouse operations. In doing so, we tolerate known, high-severity occupational risks, slow the adoption of safer working practices, and impose avoidable human and economic costs across the sector.

This paper therefore applies the same net-risk perspective as the earlier work, aligned with the framework articulated by PwC and with established safety principles. It does not argue that drone operations are risk-free. It demonstrates instead that their failure modes are fundamentally different from, and often less severe than, those associated with routine human exposure at height in greenhouse environments.

By focusing specifically on protected horticulture, and on greenhouse shading, shading removal and glasshouse cleaning, this paper narrows the question further:

**If safer substitutes exist for routine high-risk work, what justifies continuing to place people in the hazard zone by default?**

Ultimately, this is a call for proportionate, evidence-led policy. If we fail to recognise avoided harm alongside introduced risk, we allow preventable injuries to persist not because safer alternatives are unavailable, but because our regulatory frameworks have not yet learned how to measure what is no longer happening.

# EXECUTIVE SUMMARY

Greenhouse shading, shading removal and glasshouse cleaning are routine, necessary activities across the UK protected horticulture sector. They are also activities that consistently place people in harm's way.

In practice, these tasks require individuals to work at height, on or near fragile glass structures, often in wet conditions and in close proximity to chemical products. UK injury and fatality data [1] shows that falls from height remain the leading cause of workplace death, and that maintenance and cleaning activities on fragile surfaces account for a disproportionate share of serious injuries. While national datasets do not routinely categorise incidents as "greenhouse-specific", the underlying harm mechanisms are already well understood and recognised by regulators.

This paper applies a net-risk substitution approach. It compares traditional greenhouse methods that rely on human exposure at height with drone-enabled alternatives that remove routine roof access, reduce exposure time and place risk within controlled, auditable systems. This is not an argument that drone operations are risk-free. It is an argument that they materially reduce exposure to higher-severity hazards, in line with the hierarchy of control and ALARP principles.

The approach taken here builds directly on the PwC Net Risk framework[2] and on Applying Net Risk: The Safety Case for UK Drone Regulations (AutoSpray Systems, January 2026), which demonstrated how drone-enabled operations can substitute workers away from high severity harm pathways identified within national injury statistics.

AutoSpray Systems first deployed drone-enabled greenhouse shading in 2022. Since then, the scope has expanded to include shading removal and, by mid 2026, a route to commercial glasshouse cleaning using a biocidal product applied by drone.

That biocidal application:

- uses a long-approved, naturally derived active substance (nonanoic acid / pelargonic acid);
- has been supported by GLP-compliant drone drift studies submitted to the Health and Safety Executive; and
- followed a staged regulatory pathway in which exposure control was addressed before efficacy and commercial deployment.

**This paper does not seek deregulation. It sets out a clear case for regulatory prioritisation where approval enables the reduction of foreseeable occupational harm.**

1 Health and Safety Executive (HSE), Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR), Great Britain, available at: Available at: https://www.hse.gov.uk/riddor/

2 PwC, UK Drone Regulations and Net Risk, balancing risk to unlock growth and save lives, available at: https://www.pwc.co.uk/intelligent-digital/drones/drone-regulations-and-net-risk.pdf

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# 1. PURPOSE AND SCOPE

This paper has a clear and deliberately limited purpose: to examine whether routine high-risk activities within protected horticulture can be carried out in a way that materially reduces occupational harm through risk substitution.

Its scope is confined to three specific greenhouse activities:

- greenhouse shading,
- greenhouse shading removal, and
- glasshouse exterior surface cleaning.

These activities have been selected because they are:

- routinely undertaken,
- operationally mature,
- and repeatedly associated with work at height, fragile surfaces, wet conditions, and chemical exposure.

Because these tasks are structural maintenance requirements that recur across the operational life of the facility, drone substitution delivers a compounding safety dividend. Every cycle completed remotely removes a worker from a high-severity hazard zone, creating a cumulative reduction in total sector harm that grows with every hectare treated.

The paper does not argue for unrestricted drone use, generic permissions, or a relaxation of regulatory oversight. Nor does it seek to establish a precedent for wider applications beyond the tasks described.
Instead, it applies a task-specific, evidence-led assessment of whether established methods that place people in high-severity hazard zones should continue to be treated as the default where safer, controlled alternatives now exist.

All conclusions are framed around:

- clearly defined operational tasks,
- method-controlled delivery rather than generalised technology approval,
- demonstrable operator competence and organisational oversight, and
- auditable systems of work capable of regulatory scrutiny.

By maintaining this narrow focus, the paper provides a framework that regulators can engage with without unintended spill-over, while still addressing a broader and more fundamental question:

**when risk can be demonstrably reduced through substitution, what justification remains for maintaining higher-severity exposure as standard practice?**

## 1.1 SECTOR CONTEXT AND SCALE OF IMPACT

Protected horticulture represents a substantial and economically significant component of UK food production. Greenhouse operations within this sector are not niche or experimental activities; they are mature, capital-intensive systems operating at national scale.

Recent mapping and industry analysis indicate that the UK greenhouse estate comprises approximately 2,000 hectares of commercial glasshouse infrastructure[3], with estimates for England alone in nearly 1,000 hectares[4]. These facilities are typically high-value assets, operating year-round and supporting a wide range of crops critical to domestic supply chains.

From an economic perspective, the commercial greenhouse sector represents a market measured in hundreds of millions of pounds annually, with longer-term projections placing the wider greenhouse horticulture market at over £1 billion in value and growing. The broader UK horticulture sector, within which protected horticulture sits, is valued in the multi-billion-pound range and employs a significant workforce across production, maintenance, and support functions.

This scale matters from a safety and policy standpoint. Greenhouse shading, cleaning, and maintenance activities are not isolated or infrequent tasks. They are carried out repeatedly, across thousands of hectares of glasshouse infrastructure, often under time pressure and in environments where access at height and fragile surfaces are unavoidable under conventional methods.

As a result, even modest reductions in exposure to high-severity hazards - such as work at height on fragile roofs - have the potential to deliver disproportionate benefits in terms of worker safety, operational resilience, and economic continuity.

Framing risk substitution within protected horticulture therefore has implications well beyond individual sites or operators. It speaks to the safety performance of a sector that is nationally significant, labour-intensive, and strategically important to food security. In this context, regulatory decisions that enable the reduction of foreseeable harm have impact at both human and systemic levels.

3 Protected and Productive – How Greenhouses should deliver UK Food Security - https://nph.onlinelibrary.wiley.com/doi/full/10.1002/ppp3.70110

4 Agricultural Land use in England 01/06/2026 - https://www.gov.uk/government/statistics/agricultural-land-use-in-england

## WEATHER VOLATILITY AND SUPPLY RESILIENCE

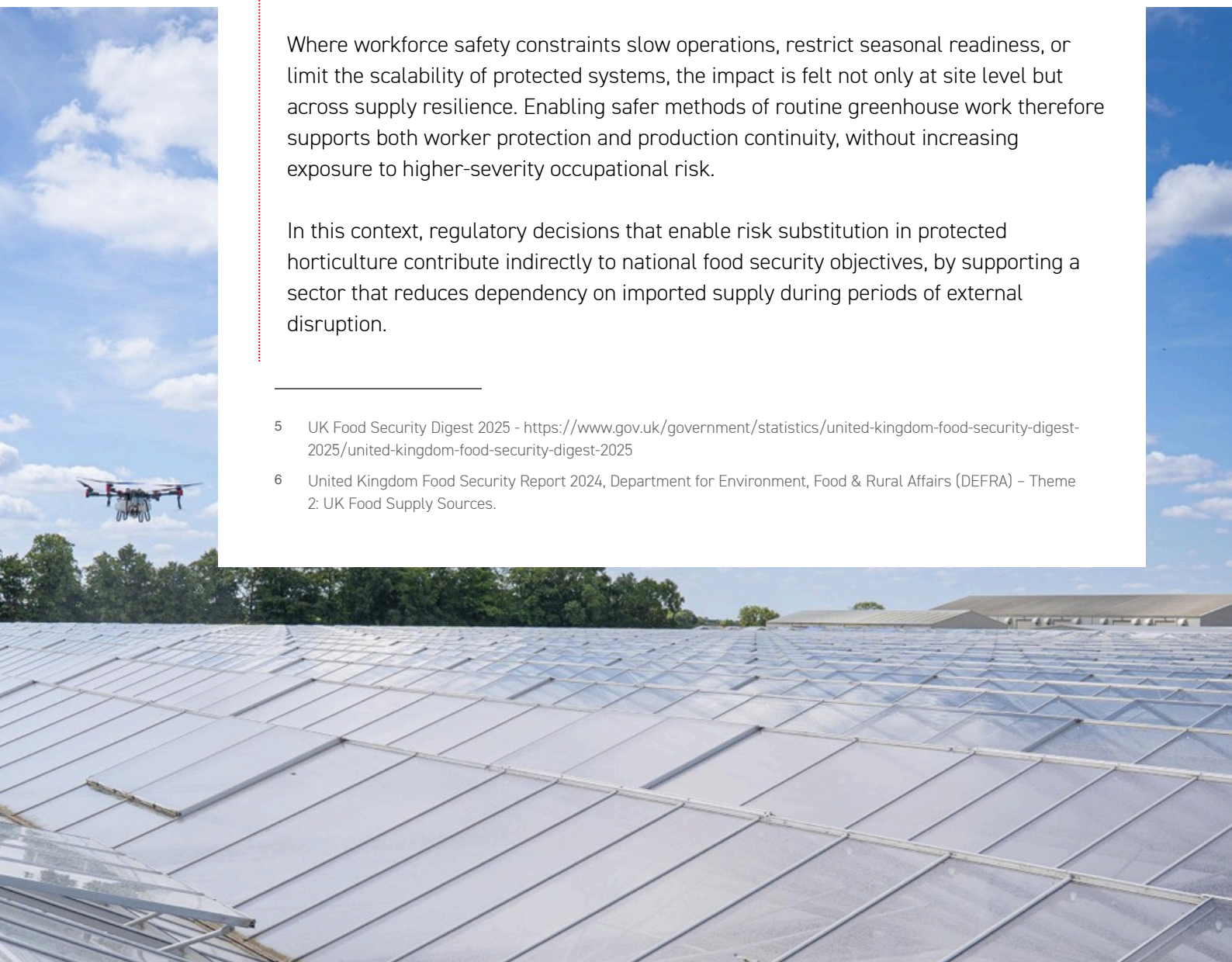
Recent seasons have highlighted the increasing exposure of European horticultural supply chains[5] to weather volatility, including prolonged periods of rainfall in southern Spain that have disrupted production and harvest schedules in key exporting regions.

For the UK, this has reinforced a well-established policy concern: reliance on imported horticultural produce[6] introduces vulnerability to external shocks, whether climatic, logistical, or geopolitical. Protected horticulture within the UK plays a critical role in mitigating that exposure by providing controlled, year-round production closer to market.

The relevance to this paper is not environmental policy, but operational resilience. As domestic protected horticulture becomes more strategically important, the safe and reliable operation of greenhouse infrastructure - including shading, cleaning and maintenance - takes on greater significance.

Where workforce safety constraints slow operations, restrict seasonal readiness, or limit the scalability of protected systems, the impact is felt not only at site level but across supply resilience. Enabling safer methods of routine greenhouse work therefore supports both worker protection and production continuity, without increasing exposure to higher-severity occupational risk.

In this context, regulatory decisions that enable risk substitution in protected horticulture contribute indirectly to national food security objectives, by supporting a sector that reduces dependency on imported supply during periods of external disruption.



5 UK Food Security Digest 2025 - https://www.gov.uk/government/statistics/united-kingdom-food-security-digest-2025/united-kingdom-food-security-digest-2025

6 United Kingdom Food Security Report 2024, Department for Environment, Food & Rural Affairs (DEFRA) – Theme 2: UK Food Supply Sources.

# 2. OCCUPATIONAL HARM CONTEXT AND FORESEEABILITY

## 2.1 NATIONAL INJURY EVIDENCE

HSE statistics consistently show that falls from height remain the dominant cause of fatal occupational injury in Great Britain. Maintenance and cleaning activities, particularly those involving fragile surfaces, continue to be over-represented in serious incidents.

HSE guidance is explicit on two points that are directly relevant to protected horticulture:

- glass and rooflights are classed as fragile surfaces; and
- short-duration maintenance and cleaning tasks account for a disproportionate share of severe outcomes.

Greenhouse environments within protected horticulture combine extensive roof structures, wet or treated surfaces, overhead application and repeated access cycles. From a regulatory perspective, this establishes reasonable foreseeability of harm.

## 2.2 ABSENCE OF GREENHOUSE-SPECIFIC FATALITY TABLES

This paper does not rely on a discrete dataset of "greenhouse roof fatalities". Instead, it applies a principle already used across health and safety regulation: where task characteristics match known high-severity injury mechanisms, risk is material even when incident frequency is low.

This is how regulators already treat other low-frequency, high-consequence hazards.

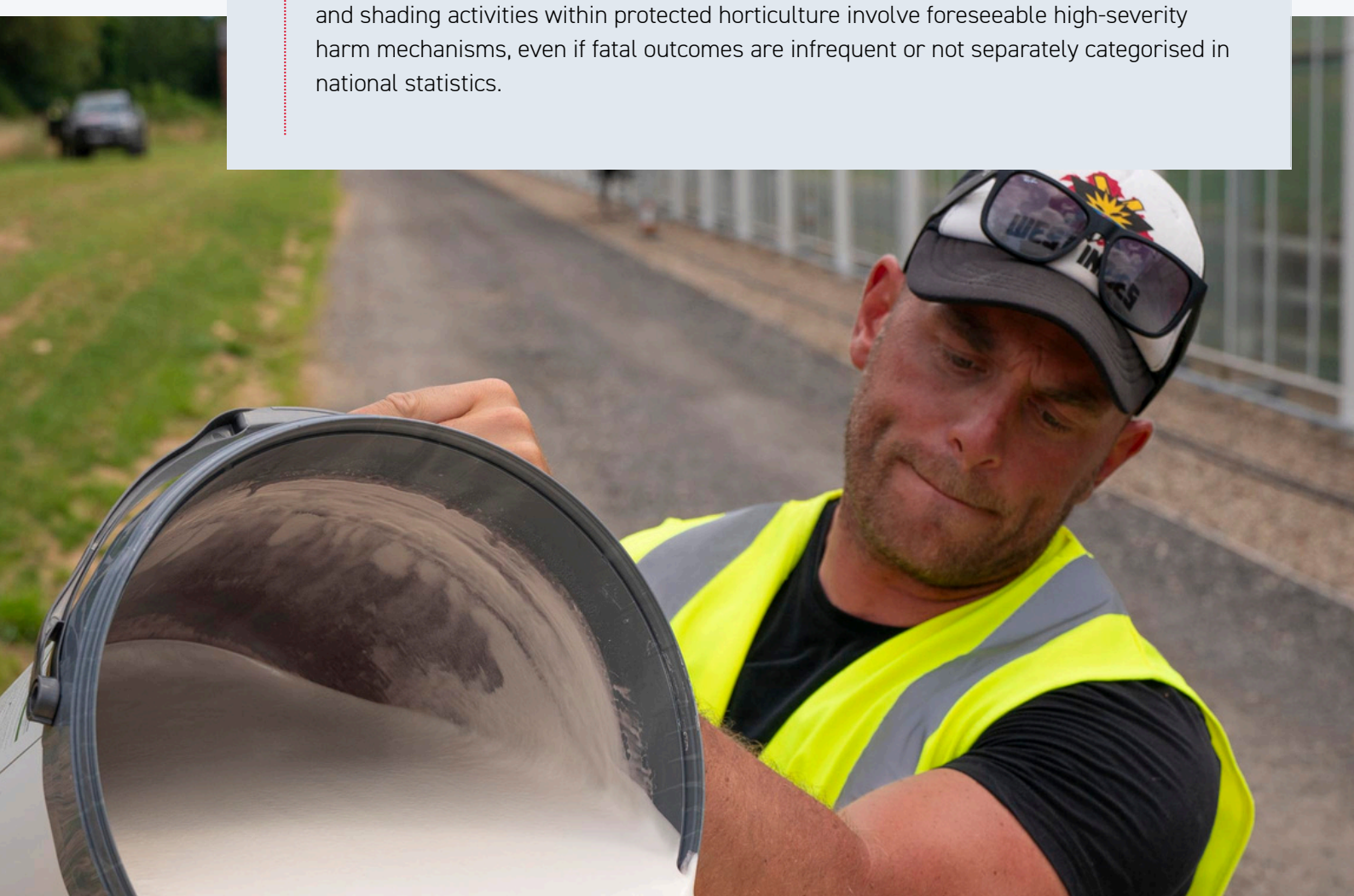
## 2.3 GREENHOUSE-SPECIFIC INCIDENTS AND NEAR-MISS EVIDENCE

Although national datasets do not routinely label incidents as "greenhouse roof falls", there are documented cases and enforcement actions that demonstrate the real risk associated with glasshouse structures.

In the UK, a horticultural business was prosecuted after a worker fell through a greenhouse roof during routine work, sustaining serious injuries. The case confirmed greenhouse roofs as fragile surfaces and demonstrated the severity of harm that can result from falls during maintenance activities.

In the Netherlands, a large commercial greenhouse complex collapsed during renovation works. The structure covered several hectares and failed suddenly. No injuries were reported, but only because workers were not present beneath the structure at the time. From a safety perspective, this constitutes a near-miss of high potential severity. It demonstrates that greenhouse structures can fail unpredictably and that human presence beneath or on roof structures materially increases exposure to catastrophic outcomes.

Taken together, these cases support the position that greenhouse maintenance, cleaning and shading activities within protected horticulture involve foreseeable high-severity harm mechanisms, even if fatal outcomes are infrequent or not separately categorised in national statistics.



# 3. NET RISK AS AN ESTABLISHED POLICY FRAMEWORK

Net risk is not a novel or speculative concept. It is a well-established approach used across safety-critical sectors to assess whether the overall level of harm associated with an activity is reduced when one method is substituted for another, even where new, lower-severity risks may be introduced.

At its core, net-risk analysis asks a simple but often overlooked question:
what risks are removed when a task is performed differently, and how do those avoided harms compare with the risks introduced by the alternative method?

This approach is already embedded, formally or informally, in areas such as aviation, offshore energy, construction, and major infrastructure projects, where decision-makers routinely balance residual technical risk against the reduction of human exposure to high-severity hazards. It reflects the practical reality that safety is not achieved by eliminating all risk, but by reducing exposure to the most severe and least controllable forms of harm.
The PwC Net Risk framework, developed in the context of future aviation and advanced mobility, articulated this principle clearly: regulatory assessments that focus solely on the risks introduced by a new technology, without accounting for the risks it displaces, produce distorted outcomes. In such cases, safer systems can be delayed or excluded not because they increase harm, but because existing harm has become normalised.

AutoSpray Systems' earlier paper, Applying Net Risk: The Safety Case for UK Drone Regulations, applied this framework to national injury and fatality data reported under RIDDOR. That analysis demonstrated that many drone-enabled operations substitute workers away from well-documented high-severity harm pathways, including work at height, hazardous terrain, and manual interaction with machinery and chemicals.
This paper applies the same logic to protected horticulture.

For greenhouse operations, the comparison is not abstract. It is between:

- routine human exposure at height, on fragile glass structures, often in wet or chemically treated conditions; and
- drone-enabled application, where the operator is physically separated from the hazard and the task is delivered through a bounded, auditable system.

The intent is not to suggest that drone operations are free from risk. They are not. Rather, the question is whether the risks they introduce are fundamentally different in nature and severity from those associated with incumbent methods.

In the case of greenhouse shading, shading removal and glasshouse cleaning, the dominant risks of conventional practice arise from falls from height, fragile surface failure, and loss of balance during maintenance activities. These risks are characterised by high consequence, limited recovery opportunity, and a direct pathway to serious injury or fatality.

By contrast, the residual risks associated with drone operations are geographically bounded, procedurally managed, and subject to engineering and organisational controls. Crucially, they do not require routine human presence within the highest-severity hazard zone.

This is an important distinction. Net-risk assessment does not require that an alternative method be risk-free. It requires that, when viewed as a whole system, the method reduces exposure to the most severe and least tolerable forms of harm.
By applying this framework consistently, this paper does not seek to redefine regulatory principles. It seeks to apply them coherently and proportionately to a sector where the hazards are already well understood, the tasks are routine, and safer substitutes are demonstrably available.

# 4. DRONE-ENABLED GREENHOUSE SHADING

## 4.1 CONVENTIONAL PRACTICE AND RISK PROFILE

Under conventional methods, greenhouse shading is typically applied through a combination of roof access, mobile elevated work platforms (MEWPs), and manual spraying or painting systems. These approaches require workers to operate at height for extended periods, often directly on or adjacent to fragile glass structures.

In practice, this involves repeated movement across roof sections, prolonged overhead spraying, and multiple passes to achieve adequate coverage. The dominant hazards associated with this work are well established: falls from height, fragile surface failure, slips on wet or treated glass, chemical exposure during application, and fatigue arising from physically demanding, repetitive tasks.

While control measures exist, these methods rely heavily on procedural compliance and sustained human performance within a high-severity hazard zone.

## 4.2 INTRODUCTION OF DRONE-ENABLED SHADING

AutoSpray Systems first deployed drone-enabled greenhouse shading in 2022, using XAG unmanned aircraft systems, now including the XAG P100 Pro platform.

In a typical configuration, the XAG P100 Pro is capable of applying shading material at a rate of approximately 1 hectare of glasshouse coverage per hour, with application volumes in the order of 600 litres per hectare, depending on formulation and site geometry. Application is delivered through automated flight paths within defined operating volumes, producing a consistent and repeatable coating across the glass surface.

The significance of this change is not simply productivity. It is the restructuring of exposure.

## 4.3 RISK SUBSTITUTION IN PRACTICE

Drone-enabled shading does not remove all work at height. What it does is change the nature, duration, and severity of that exposure.

Under drone-enabled methods:

- the primary application task is carried out remotely,
- operators are typically positioned on the ground, or
- where Visual Line of Sight (VLOS) is required, the Remote Pilot is elevated using a cherry picker or similar platform, without sustained movement across fragile surfaces.

This represents a material shift. Instead of workers spending extended periods traversing glass roofs while applying shading, any remaining work at height is limited in duration, static in nature, and focused on observation or verification rather than physical application.

From a net-risk perspective, the highest-severity hazard, prolonged human presence on fragile roof structures, is substantially reduced, even though it is not eliminated entirely.

## 4.4 CONTROL, CONSISTENCY AND ASSURANCE

Drone-enabled shading also introduces a level of operational control that is difficult to achieve through manual methods alone.

Flight paths, application rates, and operating parameters are pre-defined and recorded digitally. This enables:

- consistent application thickness,
- reduced over-application and material waste,
- fewer repeat passes, and
- a complete digital record of when, where, and how the task was carried out.

These records provide an auditable trail that supports both internal safety management systems and external regulatory assurance. In contrast, conventional shading methods rely largely on manual judgement and retrospective supervision.

## 4.5 SAFETY OUTCOMES AS THE PRIMARY DRIVER

While drone-enabled shading delivers secondary benefits in efficiency and material use, these are not the primary justification for its adoption. The primary driver is the reduction of routine exposure to high-severity occupational hazards.

By substituting remote application for prolonged roof access, drone-enabled shading aligns directly with the hierarchy of control. It does not depend on workers "being careful" in hazardous environments; it reduces the amount of time they need to be there at all.

This distinction is central to the net-risk argument advanced in this paper. The question is not whether drone-enabled shading introduces new risks — it does — but whether those risks are less severe, more controllable, and more recoverable than the risks they replace.

In the context of protected horticulture, and specifically greenhouse shading, the evidence suggests that they are.

## 4.6. DRONE-ENABLED SHADING REMOVAL

The same net-risk logic set out in Sections 4.1 to 4.5 applies directly to shading removal. Operationally, shading removal is delivered using the same drone-enabled method, the same operating volumes, and the same organisational controls and oversight arrangements as shading application. The substantive difference is simply the material being applied.

Rather than applying a shading compound, the drone applies a chemically keyed removal agent to the glass surface, typically during the autumn period, to break down and remove the shading layer.

Because the method of delivery and the system of work are the same, the benefits are identical: drone-enabled shading removal substitutes routine roof-access activity away from people and into a controlled, auditable process, reducing the need for human presence in the highest-exposure areas while maintaining consistent, repeatable application.

For the purposes of this paper, shading removal is therefore treated as a direct extension of the shading case, rather than a separate operational category.

# 5. GLASSHOUSE CLEANING AND BIOCIDAL APPLICATION

Glasshouse cleaning is a critical, recurring activity within protected horticulture. Maintaining light transmission through the glass structure is essential for crop performance, yield consistency, and disease control. Over time, algae, biofilms, and organic residues accumulate on glass surfaces, reducing transmission and increasing disease pressure if not actively managed.

Unlike shading, which is seasonal, glasshouse cleaning is a structural maintenance requirement. It must be undertaken repeatedly across the operational life of a glasshouse and cannot be deferred indefinitely without compromising productivity.

Under conventional practice, glasshouse cleaning requires direct human access to the roof structure, often combined with the application of cleaning agents or biocidal products. This places workers in prolonged proximity to fragile surfaces and necessitates repeated exposure during each cleaning cycle. From a safety perspective, this makes glasshouse cleaning one of the most persistent high-exposure maintenance activities within protected horticulture.

The relevance of this activity to net-risk assessment is therefore clear: it is routine, unavoidable, and repeatedly undertaken, meaning that any reduction in exposure has cumulative safety benefit over time.

## 5.1 DRONE-ENABLED GLASSHOUSE CLEANING

Drone-enabled glasshouse cleaning applies the same risk-substitution principles established earlier in this paper. Rather than requiring sustained roof access for application, the biocidal cleaning agent is delivered remotely using unmanned aircraft systems operating within defined and controlled volumes.

This approach restructures the task so that:

- the application itself is conducted without routine human presence on the roof structure, and
- any remaining oversight or verification activity can be limited in duration and scope.

As with shading and shading removal, the safety benefit does not arise from eliminating risk entirely, but from reducing the frequency, duration, and severity of exposure to the highest-risk elements of the task.

## 5.2 ACTIVE SUBSTANCE AND PRODUCT CONTEXT

The biocidal product proposed for drone-enabled glasshouse cleaning has been developed under an active substance which is nonanoic acid (pelargonic acid).

Nonanoic acid is a naturally occurring fatty acid with a long-established regulatory approval history and a well-characterised human health and environmental profile. Its mode of action is contact-based and non-systemic, acting on surface organisms rather than through systemic uptake or persistence.

This is a critical point for regulatory assessment. The proposal does not introduce a novel active substance, nor does it seek to reopen toxicological questions that have already been addressed elsewhere. The chemical hazard is known.

Accordingly, the regulatory question is not one of intrinsic chemistry. It is a question of how the product is applied, and how occupational exposure is managed during that application.

## 5.3 EVIDENCE-LED PROGRESSION TO COMMERCIAL APPLICATION

AutoSpray Systems adopted a staged, evidence-led approach to developing drone-enabled glasshouse cleaning approval with an already established product.

The first stage focused on application behaviour and exposure control. GLP-compliant drift studies were undertaken to quantify deposition and downwind drift when the product was applied using XAG unmanned aircraft systems. These studies were designed to assess whether aerial delivery altered exposure pathways compared to conventional methods.

Only once application behaviour had been characterised and shown to be controllable did AutoSpray proceed to efficacy assessment under a Trial Permit, issued but the HSE. This demonstrated that the biocidal product achieved the required cleaning performance when applied by drone.

This sequencing was deliberate. Worker protection and exposure management were addressed before commercial performance was considered. This mirrors the principles already applied in other regulated sectors and aligns with HSE expectations for proportionate risk assessment.

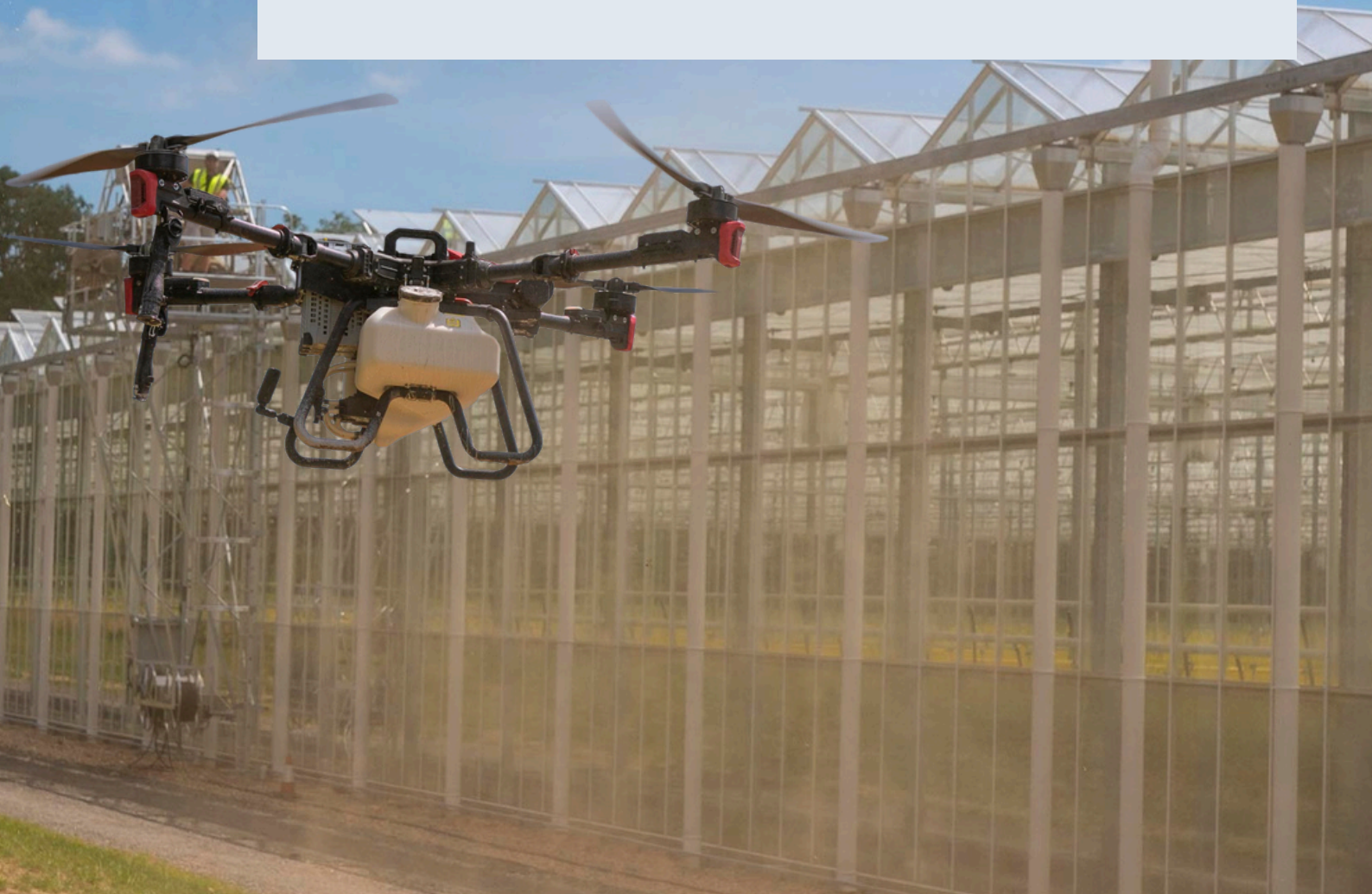
## 5.4 NET-RISK IMPLICATIONS OF DRONE-ENABLED CLEANING

From a net-risk perspective, drone-enabled glasshouse cleaning follows the same logic as shading and shading removal.

Conventional cleaning requires repeated human exposure at height across the life of a glasshouse. Drone-enabled delivery substitutes that exposure away from people and into a controlled, auditable system. Any residual human involvement is limited, task-specific, and does not require sustained movement across fragile surfaces.

Over time, this substitution has a compounding effect. Each cleaning cycle completed without routine roof access represents avoided exposure to a high-severity hazard. Across hundreds or thousands of hectares of protected horticulture, those avoided exposures accumulate into a meaningful reduction in occupational harm.

For the purposes of this paper, drone-enabled glasshouse cleaning should therefore be regarded as a natural extension of the shading case, differentiated by product but identical in safety logic.



# 6. QUANTIFYING AVOIDED HARM

This paper does not attempt to calculate precise injury or fatality avoidance figures. In sectors characterised by low-frequency, high-severity hazards, such precision is neither realistic nor necessary for sound regulatory decision-making.

Instead, the approach taken here aligns with how risk reduction is already assessed in other safety-critical domains: by measuring changes in exposure to known harm pathways, rather than attempting to predict individual outcomes.

Within protected horticulture, the dominant harm mechanisms associated with greenhouse shading, cleaning, and maintenance are well established. They relate primarily to work at height on fragile structures, often undertaken repeatedly across the life of a glasshouse. The safety benefit of drone-enabled methods therefore arises from reducing how often, how long, and how severely people are exposed to those hazards.

Accordingly, the paper focuses on a set of conservative, regulator-appropriate indicators of avoided harm, including:

- the number of hours of routine roof access removed from standard operations;
- the reduction in the number of personnel required to undertake work at height;[16]
- the reduction in duration and frequency of elevated exposure across repeated maintenance cycles; and
- the reduction in manual handling and application of chemical products during routine tasks.

These indicators do not rely on assumptions about individual behaviour or incident probability. They reflect structural changes to how work is carried out, and therefore provide a robust basis for assessing net-risk reduction.

Importantly, avoided harm in this context is cumulative. Each task completed without routine roof access represents one less exposure to a high-severity hazard. Across multiple cleaning and shading cycles, and across thousands of hectares of protected horticulture, those avoided exposures accumulate into a material improvement in occupational safety performance.

This approach is consistent with established regulatory practice where the objective is to reduce exposure to the most severe and least recoverable forms of harm, even when absolute incident numbers are low. It allows regulators to evaluate whether an alternative method improves safety outcomes without requiring speculative modelling or overstated claims.

# 7. RESIDUAL RISKS AND MITIGATION

Drone-enabled operations introduce residual risks, and this paper does not seek to minimise or disregard them. As with any operational system, these risks must be identified, assessed, and managed through proportionate controls.

In practice, the risks associated with drone-enabled greenhouse operations are bounded and predictable, and are managed through a combination of technical, procedural, and organisational measures. These include clearly defined operating volumes, exclusion zones around the area of operation, environmental operating limits, pilot competence requirements, and oversight through an established safety management system.

Crucially, these controls are designed into the system of work, rather than relying primarily on individual behaviour in hazardous environments. The resulting risk profile is therefore more structured and auditable than conventional methods that depend on sustained human performance at height.

From a severity perspective, there is a material distinction between the residual risks introduced by drone operations and those inherent in traditional greenhouse maintenance. Drone failure modes are geographically limited and do not require routine human presence within the hazard zone at the point of failure. By contrast, conventional methods place people directly on or adjacent to fragile roof structures, where loss of balance or surface failure can lead to immediate and severe consequences.

This distinction matters for regulatory assessment. While residual risk remains in both cases, drone-enabled methods avoid the combination of human presence and fragile surface exposure that amplifies severity in conventional greenhouse work. As a result, the residual risks associated with drone operations are generally lower in consequence, more controllable, and more recoverable.

In net-risk terms, the question is not whether risk is eliminated, but whether the overall exposure to the most severe and least tolerable harm pathways is reduced. The evidence presented in this paper indicates that, when properly controlled, drone-enabled greenhouse operations achieve that outcome.

## 8. POLICY IMPLICATIONS

The evidence presented in this paper indicates that the principal regulatory questions associated with drone-enabled greenhouse operations are no longer aviation-led. The Civil Aviation Authority has, for several years, operated proportionate, risk-based approval frameworks that allow unmanned aircraft to be deployed safely in complex environments where appropriate mitigations are in place. For the activities described in this paper, the aviation risk component is well understood and already subject to established oversight.

The remaining regulatory consideration relates to occupational exposure and chemical application, specifically how routine human presence at height can be substituted with safer delivery methods. That assessment sits primarily within the remit of the Health and Safety Executive[7].

This alignment is consistent with the intent of the Regulatory Innovation Office, which was established to accelerate regulatory decision-making [8] where new methods demonstrably improve safety outcomes but are delayed by fragmented or sequential processes.

In this context, enabling timely progression of biocidal applications for drone-enabled glasshouse cleaning represents an opportunity to deliver on RIO commitments, by prioritising applications that reduce foreseeable occupational harm rather than introducing novel risk.

7 https://www.kcl.ac.uk/policy-institute/assets/regulation-and-innovation.pdf

8 https://www.gov.uk/government/publications/regulatory-innovation-office-report-one-year-on/regulatory-innovation-office-one-year-on-html

# 9. CONCLUSION

Greenhouse shading, shading removal and glasshouse cleaning are not marginal or exceptional risks within protected horticulture. They are routine, repeatable activities that, under conventional methods, repeatedly place workers into well-understood, high-severity harm pathways, most notably work at height on fragile structures.

Real-world evidence confirms that these hazards are not theoretical. Serious falls through greenhouse roofs in the UK, and large-scale greenhouse structural failures in Europe, demonstrate the potential consequences when people are required to work on or beneath glasshouse structures. While such risks are managed today through procedural controls, those controls continue to rely on sustained human presence in the hazard zone.

The net-risk framework, articulated independently by PwC and applied previously through Applying Net Risk, provides a coherent and defensible basis for regulatory decision-making in these circumstances. Where an alternative method demonstrably reduces exposure to the most severe forms of harm, regulatory assessment should consider not only the risks introduced, but the risks that are avoided.

Drone-enabled greenhouse operations do not eliminate risk. They restructure it - moving the task away from people and into controlled, auditable systems. Where an established active substance is used, where application behaviour has been validated through GLP studies, and where efficacy has been demonstrated through staged progression, the safety case is no longer speculative.

At that point, regulatory delay is not neutral. It becomes an implicit decision to continue tolerating higher-severity occupational exposure in preference to a demonstrably safer alternative.

In this context, timely regulatory progression is not deregulation. It is the practical and proportionate application of existing occupational safety principles, aligned with the objective of preventing foreseeable harm within a sector of national importance.

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**Photos throughout this document:**
XAG P100 Pro on operation at Dyson Farming with QRS, members of the AutoSpray Pilot Network.