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WHITE PAPER

Limitations of Small-Scale Methods for Testing the Durability of Reaction-to-Fire Performance

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Abstract

This white paper explores the limitations of small-scale methods, particularly the Cone Calorimeter, in evaluating the reaction-to-fire performance of fire-retardant-treated wood. While small-scale tests provide valuable data on material properties, they fall short in replicating real-world conditions, often underestimating fire risks. Facade systems, for instance, involve complex interactions between components such as insulation, cladding, and air gaps, which small-scale methods cannot capture.

To address these shortcomings, the paper emphasizes the importance of medium- and large-scale testing frameworks, such as the Single Burning Item (SBI) and SP Fire 105 tests. Medium-scale tests like SBI offer a more accurate representation of material performance by testing assemblies in three-dimensional configurations, while large-scale tests, exemplified by SP Fire 105, provide critical insights into the behaviour of complete facade systems under realistic fire conditions. These methods ensure a more comprehensive and reliable evaluation of fire safety.

The white paper also discusses the evolving standards, particularly the EN 16755, which is currently under revision. This reflects the industry's shift from small-scale methods like the Cone Calorimeter to medium-scale approaches like SBI. This progression aligns with modern fire safety needs, ensuring that testing methods better reflect real-world applications and enhance regulatory compliance.

Additionally, Woodsafe Timber Protection's newly initiated long-term study at its state-of-the-art lab highlights the company's commitment to advancing fire safety. Combining natural and artificial aging tests with robust fire evaluations, this research aims to provide essential data on the durability and effectiveness of fire-retardant-treated wood.

By advocating for medium- and large-scale testing, alignment with evolving standards, and investment in long-term research, this paper underscores the need for a comprehensive approach to fire safety in sustainable construction.

1

Introduction

The critical role of reaction-to-fire testing in ensuring fire safety. Reaction-to-fire testing is essential for assessing how materials and systems behave in the early stages of a fire. By evaluating parameters such as flame spread, heat release, and smoke production, these tests provide critical insights to ensure compliance with safety regulations, mitigate risks, and protect lives and property in real-world applications.

1.1 The critical role of reaction-to-fire testing in ensuring fire safety.

Reaction-to-fire testing is essential for assessing how materials and systems behave in the early stages of a fire. By evaluating parameters such as flame spread, heat release, and smoke production, these tests provide critical insights to ensure compliance with safety regulations, mitigate risks, and protect lives and property in real-world applications.

1.2 Overview of testing scales: Cone Calorimeter (small), SBI (medium), SP Fire 105 (large).

Fire performance testing is conducted at different scales to evaluate the behaviour of materials and systems under fire exposure. These scales range from small-scale laboratory tests to large-scale evaluations that mimic real-world conditions. Each scale serves a specific purpose, providing insights into various aspects of fire performance relevant to safety and compliance.

Small Scale – Cone Calorimeter

The Cone Calorimeter test, conducted according to ISO 5660-1, is a small-scale method for evaluating a material's reaction-to-fire performance. A sample, typically 100 x 100 mm, is exposed to a controlled radiant heat flux to simulate fire conditions. The test measures critical parameters such as heat release rate (HRR), time to ignition, smoke production, and mass loss. It provides data on how the material reacts under thermal exposure but is limited in predicting large-scale behaviour. Cone Calorimeter results are often used for research and product development.

Image 1: Cone Calorimeter

Medium Scale - SBI

The Single Burning Item (SBI) test is a medium-scale reaction-to-fire test used to evaluate the fire performance of building products. Conducted according to the EN 13823 standard, the test exposes a sample to a controlled heat source designed to simulate a single burning object, such as a trash bin or small furniture item. The sample, typically mounted in a corner configuration, is assessed for parameters such as heat release rate, smoke production, flame spread, and falling droplets. Results are used to assign European fire classifications (e.g., A1 to F) according to EN 13501-1.

Large Scale – SP Fire 105

The SP Fire 105 test is a large-scale fire test used to evaluate the fire performance of external cladding systems. Conducted according to Swedish standard SP Fire 105, it involves mounting the cladding system on a full-scale facade mock-up. A fire with 60 liters of Heptane is the source of the fire and creates a flash over ignition of the apartment that pushes flames out of the window opening and the flames expose the surface of the facade, simulating a realistic fire scenario. The test assesses flame spread and the risk of falling parts are observed.

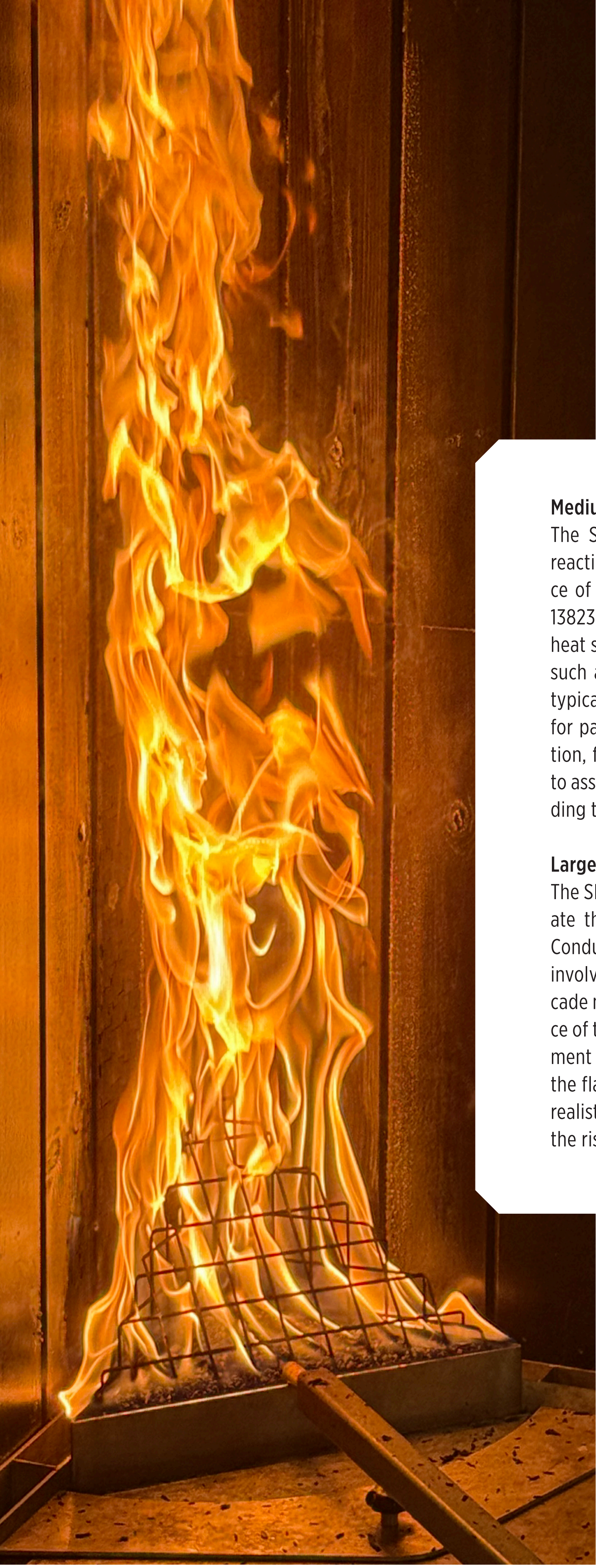
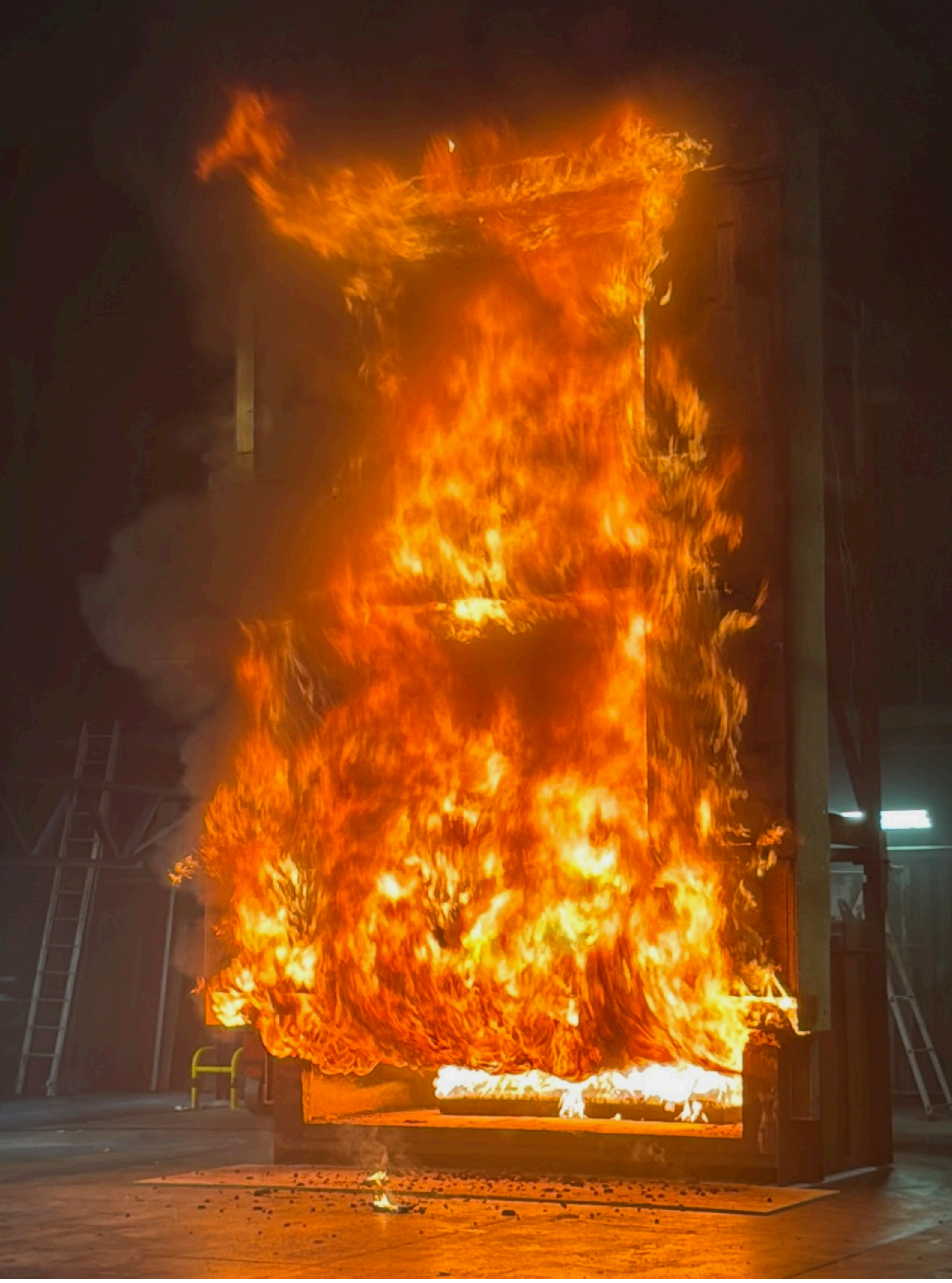


Image 2: SBI (medium scale)



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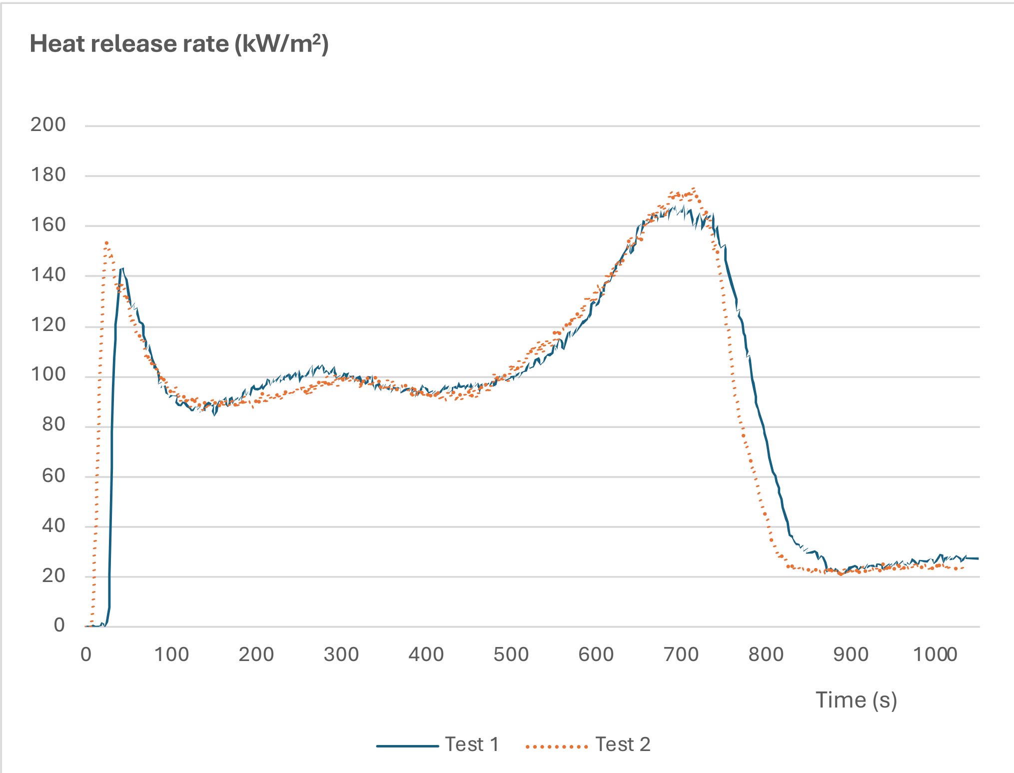
Limitations of Small and Medium-Scale Methods for Reaction-to-Fire Testing

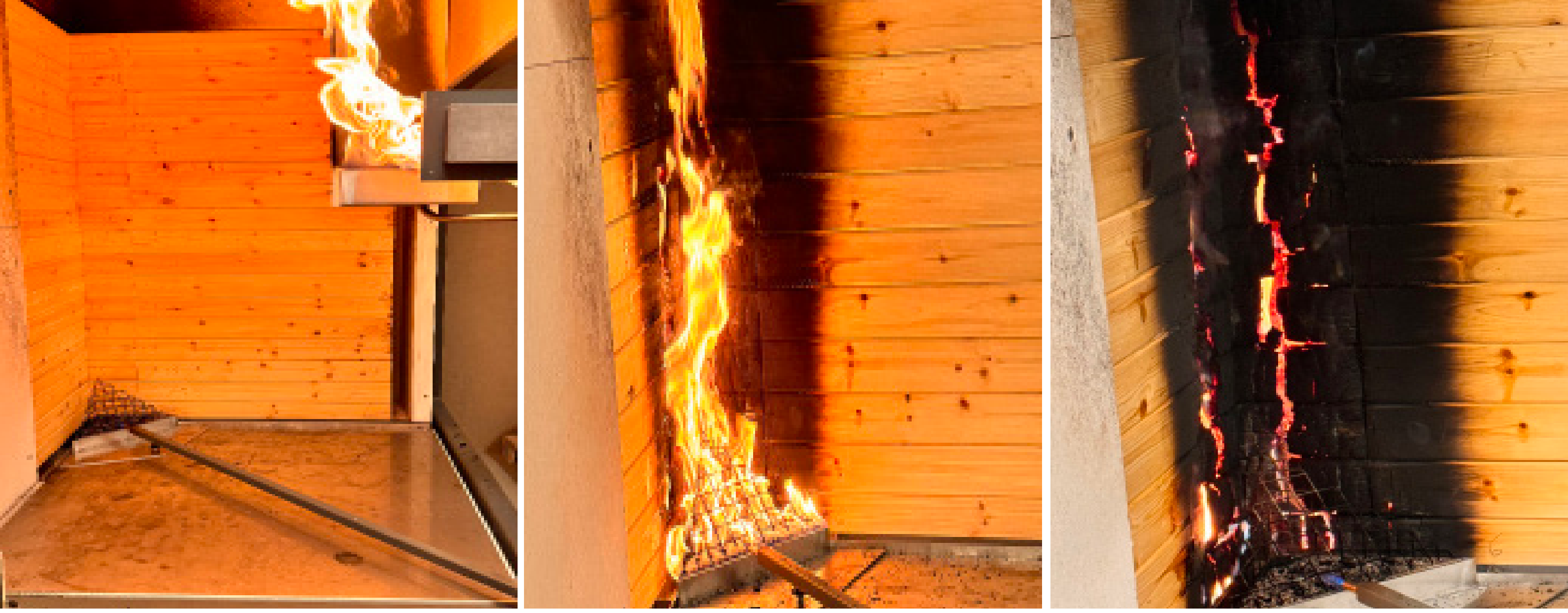
2.1 Comparison with small-scale (Cone Calorimeter) and medium-scale (SBI) results

It is well-documented among professionals conducting reaction-to-fire tests that the Cone Calorimeter gives test results useable for research but needs to be modulated to predict fire performance in the Single Burning Item (SBI) method. Such models are not available for fire-retardant treated wood products today. Only a "rule-of-thumb" is available for fire-retardant-treated wood products which have been tested in the SBI for fire class and then tested in the Cone Calorimeter (1).

Giving that products having peak HRR up to 100-120 kW/m2 indicates fire class B in SBI. This have been noted in several development projects (2).

Woodsafe Research & Development has performed extensive testing in the Cone Calorimeter. An example from our laboratory is a sample with peak heat release rate (HRR) of 169 and 176 kW/m^2 (double test), while the same sample achieved Euroclass B in the SBI test, complying with European fire safety standards. The accompanying figure shows the heat release curves.





The primary reason for this variation lies in the fundamental differences between the two test methods. The Cone Calorimeter evaluates a flat, small-scale sample under a uniform heat flux, which oversimplifies fire dynamics and fails to account for factors like flame spread or interaction between components. In contrast, the SBI test examines materials in a three-dimensional configuration, offering a more representative view of their performance in actual building applications.

These findings underscore the limitations of small-scale methods and the need for further research. A deeper understanding of the relationships between small, medium, and large-scale tests is essential to improve fire safety assessments and refine testing standards.

2.2 Comparison with medium-scale (SBI) and large-scale (SP Fire 105) results.

The comparison between medium-scale tests, such as the Single Burning Item (SBI) test, and large-scale tests, like SP Fire 105, reveals significant differences in their ability to assess facade fire performance. Results from the RISE report "The Facade of the City Swift, Stylish, Smart" (3) highlight these discrepancies with a specific case study.

The tested facade system consisted of a wall coated with Teknos fire-retardant paint, rather than being based on fire-impregnated wood. In the SBI test, this system achieved Euroclass C-s2, d0, which does not meet the Euroclass B requirement necessary for facade applications in many regulatory frameworks. However, when subjected to the SP Fire 105 test, the same wall system, using the Teknos fire-retardant base coat and the Teknos Nordica Eko topcoat, successfully passed. This large-scale test confirmed its ability to resist flame spread and secondary ignitions under realistic fire conditions.

The results highlight the limitations of the SBI test in predicting real-world fire behaviour for facade systems. While the SBI provides useful data on reaction-to-fire performance in controlled environments, it fails to fully capture critical factors like flame spread and system interactions. The SP Fire 105 test, by evaluating a complete wall system under realistic fire loads, provides a more reliable assessment of facade safety. These findings underline the importance of large-scale testing to validate medium-scale results and ensure compliance with fire safety requirements.

The divergence between these two testing scales highlights the need for further research https://media.woodsafe.com/en/woodsafe-launches-study-to-long-term-test-fire-retardant-treated-wood?hsLang=en
to bridge the gap, ensuring that medium-scale tests are enhanced or complemented to better predict large-scale fire behaviour.

2.3

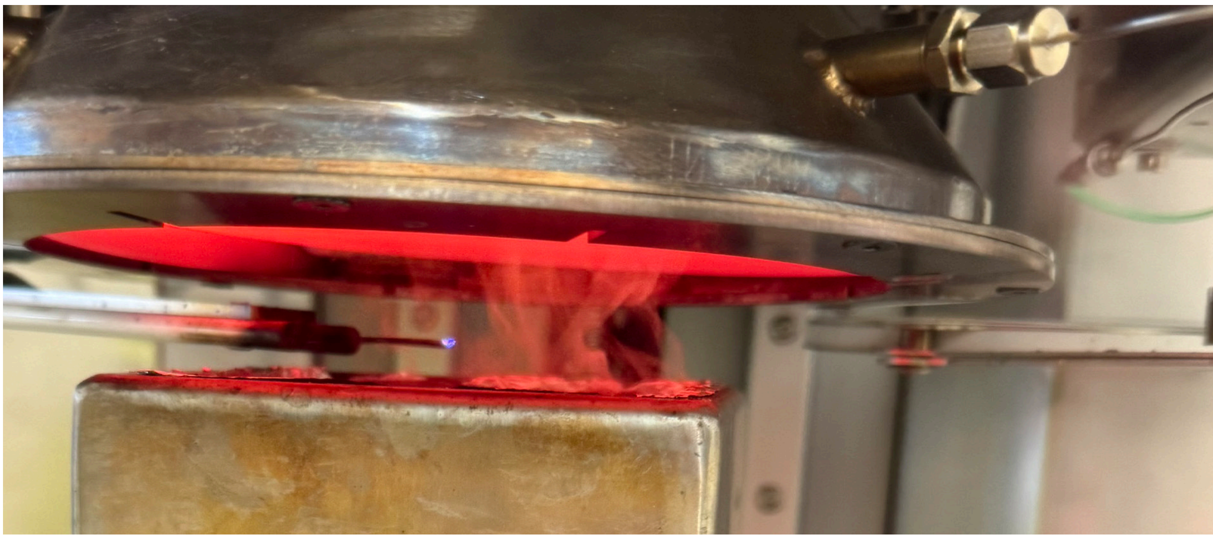
Why small-scale methods like Cone Calorimeter fail to predict large-scale facade performance.

Small-scale methods like the Cone Calorimeter, while valuable for certain controlled assessments, fail to accurately predict the performance of facades in large-scale fire scenarios. The Cone Calorimeter test focuses on measuring parameters such as heat release rate, time to ignition, and smoke production on small, flat samples under uniform heat exposure. While this data is useful for understanding material properties, it does not account for the complexities of real-world applications.

Facades involve multiple components—insulation, cladding, air gaps, and structural elements—that interact dynamically during a fire. The Cone Calorimeter cannot replicate these interactions, such as heat transfer across layers, vertical flame spread, or the influence of ventilation.

Moreover, the uniform heat flux in Cone testing is far removed from the uneven and escalating heat exposure typical in actual fires.

Large-scale methods like SP Fire 105 better represent these conditions by evaluating entire systems under realistic fire loads. These tests capture critical behaviours like flame spread, material integrity, and the risk of secondary ignition—factors essential for facade safety. Regulatory standards, such as the standard currently under revision EN 16755, are moving away from the Cone Calorimeter because it does not adequately reflect these real-world dynamics, emphasizing the need for medium- and large-scale testing to ensure effective fire safety.



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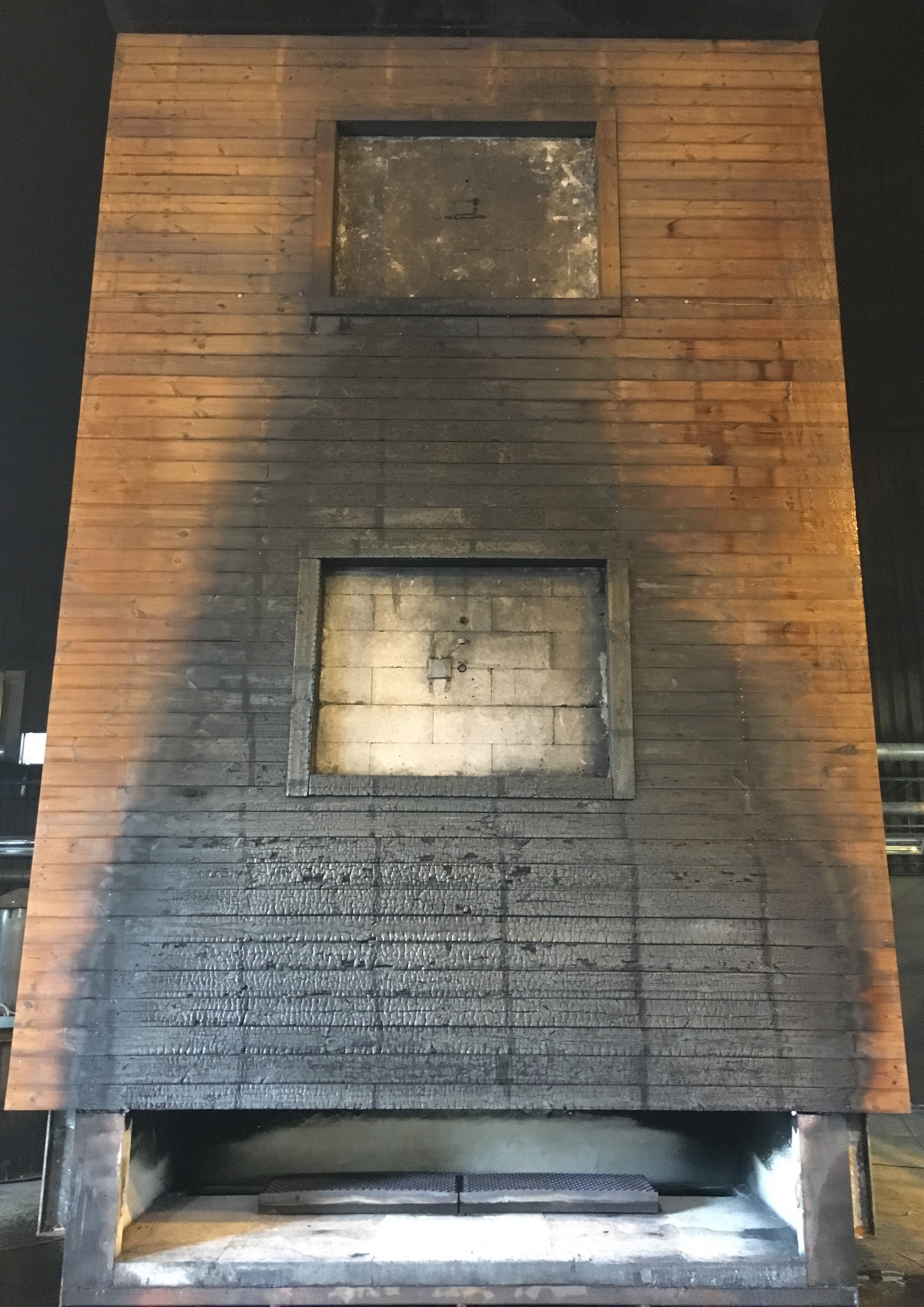
Evolving Standards: EN 16755 and the Shift from Cone Calorimeter Testing

The updated EN 16755 standard represents a significant evolution in the approach to testing and classifying fire-retardant-treated wood. One of the key updates in the standard under revision is the exclusion of the Cone Calorimeter (ISO 5660-1) and the exclusive use of the Single Burning Item (SBI, ISO 13823) test for evaluating reaction-to-fire performance. The SBI test provides a more robust and realistic assessment by testing material assemblies under conditions closer to real-world applications. Additionally, the standard under revision incorporates accelerated aging according to Method B, which includes exposure to UV light, ensuring a more comprehensive evaluation of a material's durability (4).

This shift reflects growing recognition of the Cone Calorimeter's limitations to predict SBI for these products. While useful for small-scale studies, it lacks the scalability and real-world relevance needed to predict the performance of facades in large-scale fire scenarios.

The uniform heat exposure in Cone tests oversimplifies fire dynamics and fails to replicate the complex interactions of facade systems.

By prioritizing the SBI test in the standard under revision, EN 16755 ensures a more reliable and scalable assessment of fire-retardant-treated wood. The focus on medium-scale tests highlights the importance of capturing more realistic fire behaviours while maintaining standardization across European markets. This development ensures improved alignment between test methods and the practical demands of fire safety in construction.



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Why Prioritizing Medium and Large-Scale Testing is Essential

4.1 Lessons from Other Engineering Disciplines on the Limits of Small-Scale Testing

Extrapolating small-scale results to predict real-life behaviour is fraught with challenges across various engineering fields. For instance, in structural engineering, testing a single steel beam under load does not account for the complex interactions and stress redistribution in a full building framework during seismic events. Similarly, in fluid dynamics, small-scale wind tunnel tests on aircraft models can fail to capture turbulence and airfoil behaviour at full scale due to differences in Reynolds numbers.

In automotive safety, crash tests using small-scale models often underestimate the forces and material deformations experienced in full-size vehicle collisions. Likewise, in chemical engineering, small-scale reactor tests may ignore critical heat transfer inefficiencies and reaction rates that emerge in industrial-scale setups.

These examples illustrate a common principle: scaling up introduces new variables and interactions that small-scale tests cannot replicate. In fire safety, small-scale tests like the Cone Calorimeter suffer from similar limitations, missing critical behaviours such as flame spread, and component interactions seen in full-scale facade systems. These lessons emphasize the necessity of medium and large-scale tests to capture real-world complexities accurately.

4.2 The Risk of Overestimating Risks

In the context of fire safety, the use of small-scale tests, such as the Cone Calorimeter, can sometimes lead to an exaggerated perception of risk. This is particularly relevant for the insurance industry, where decisions are often informed by test results to assess potential hazards and liabilities. While small-scale methods provide valuable data, they often fail to capture the complex dynamics of real-life fire scenarios. As a result, they may indicate lower performance than what would be observed in full-scale applications, leading to unnecessary restrictions and inflated risk assessments.

Large-scale tests, such as SP Fire 105, offer a more reliable and comprehensive evaluation of fire performance. By simulating real-world conditions, including flame spread, system interactions, and external environmental factors, these methods provide results that are directly relevant to actual building behaviour during a fire. This ensures a higher level of confidence in the safety of fire-retardant systems.

For the insurance industry, relying on large-scale test results reduces the likelihood of overestimating risks, allowing for more balanced and evidence-based risk assessments. Trusting these robust, real-world methods ensures safer building practices while avoiding the financial and operational drawbacks of overly cautious risk management policies based on incomplete small-scale data.

4.3 Overestimated Risks May Lead to Increased Climate Impact

Overestimating fire risks by relying solely on small-scale tests like the Cone Calorimeter can unintentionally lead to greater climate impacts in construction decisions. A calculation by Public Housing Sweden (5) highlights the environmental consequences: replacing timber with concrete in their standard building designs increases climate impact by 26-40% in kg CO_2 per m^2.

This significant increase is largely attributed to the carbon-intensive nature of concrete production compared to sustainable wood construction. Timber buildings, when treated and tested with large-scale methods such as SP Fire 105, can provide the same safety assurance as other materials, while maintaining their environmental advantages.

Misinterpretations of fire risks based on small-scale tests may push insurers, regulators, or developers to opt for materials with higher emissions, undermining global sustainability goals. By emphasizing medium- and large-scale testing, we can ensure both fire safety and environmentally sound material choices, reinforcing confidence in timber construction as a sustainable, safe, and viable solution.

5

Conclusion and Call to Action

5.1 Summary of limitations in small-scale methods like the Cone Calorimeter.

Small-scale methods, such as the Cone Calorimeter, have significant limitations in accurately predicting fire behaviour in real-world applications. These tests, focused on small, flat samples under uniform heat exposure, fail to capture critical factors like flame spread, material interactions, and dynamic fire conditions seen in large-scale scenarios. The inherent oversimplification in small-scale testing often leads to underestimating or misjudging the fire performance of materials and systems, highlighting their inadequacy for ensuring comprehensive fire safety.

That certain effects of configuration and design cannot be captured with small-scale tests is also emphasized in a recently published article by Hopkin et al. (6), where they state that in their case, the influence of panel orientation ”can only be captured with a system-scale test.”

5.2 Urging adoption of a medium and large-scale testing framework to align with modern fire safety needs.

Medium- and large-scale testing methods, such as the SBI (EN 13823) and SP Fire 105, offer more reliable and realistic assessments of fire performance.

By evaluating complete systems under conditions that mimic real-life scenarios, these frameworks address the limitations of small-scale tests. Adopting these methods is critical to align with modern fire safety demands, ensuring that materials and systems meet regulatory and practical safety requirements while instilling confidence in their performance.

5.3 Encouraging alignment with evolving standards like EN 16755 for better safety outcomes.

The EN16755 standard under revision exemplifies the progression toward more comprehensive testing practices. By transitioning from small-scale methods like the Cone Calorimeter to the medium-scale SBI test, the standard prioritizes methods that more accurately reflect real-world conditions. Stakeholders are encouraged to support this shift and align their practices with the updated requirements. Such alignment ensures improved fire safety, addresses durability concerns, and advances the industry's ability to respond to evolving safety challenges.

5.4 Initiated Long Term Study

Woodsafe Timber Protection has taken a proactive role in addressing the limitations of current testing methodologies by launching a long-term study at its Woodsafe Research & Development lab. This initiative involves testing fire-retardant-treated wood over extended periods, incorporating natural field aging, artificial aging in controlled environments, and fire testing with established methods, including SBI, Cone, and SP Fire 105.

Led by experienced researchers, the study aims to provide robust data on the durability and effectiveness of fire-retardant products over time. By prioritizing research and innovation, Woodsafe is setting a benchmark for advancing fire safety in both residential and commercial construction.

This multifaceted approach underscores the importance of embracing reliable testing frameworks, supporting evolving standards, and investing in forward-thinking research to ensure a safer, more sustainable future for fire protection.

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White Paper Limitations of small-scale method

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