Protocols for Mitigating Cladding Risk

PMCR Foundation

C.01 – PMCR Design Concept

Version 2

Date: 13 March 2024

Aboriginal acknowledgement

Cladding Safety Victoria respectfully acknowledges the Traditional Owners and custodians of the land and water upon which we rely. We pay our respects to their Elders past, present and emerging. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life. We embrace the spirit of reconciliation, working towards equality of outcomes and an equal voice.

Application of Minister's Guideline 15

These documents contain information, advice and support issued by CSV pursuant to Minister's Guideline 15 - Remediation Work Proposals for Mitigating Cladding Risk for Buildings Containing Combustible External Cladding. Municipal building surveyors and private building surveyors must have regard to the information, advice and support contained in these documents when fulfilling their functions under the Act and the Regulations in connection with Combustible External Cladding on buildings:

a) which are classified as Class 2 or Class 3 by the National Construction Code or contain any component which is classified as Class 2 or Class 3;

b) for which the work for the construction of the building was completed or an occupancy permit or certificate of final inspection was issued before 1 February 2021; and

c) which have Combustible External Cladding.

For the purposes of MG-15, Combustible External Cladding means:

a) aluminium composite panels (ACP) with a polymer core which is installed as external cladding, lining or attachments as part of an external wall system; and

b) expanded polystyrene (EPS) products used in an external insulation and finish (rendered) wall system.

Disclaimer

These documents have been prepared by experts across fire engineering, fire safety, building surveying and architectural fields. These documents demonstrate CSV's methodology for developing Remediation Work Proposals which are intended to address risks associated with Combustible External Cladding on Class 2 and Class 3 buildings in Victoria. These technical documents are complex and should only be applied by persons who understand how the entire series might apply to any particular building. Apartment owners may wish to contact CSV or their Municipal Building Surveyor to discuss how these principles have been or will be applied to their building.

CSV reserves the right to modify the content of these documents as may be reasonably necessary. Please ensure that you are using the most up to date version of these documents.

Document Notes

The Protocols for Mitigating Cladding Risk (**PMCR**) is an approach developed by Cladding Safety Victoria (**CSV**) on behalf of the Victorian Government to consistently and systematically address the risk posed by the presence of combustible cladding on Class 2 and Class 3 buildings.

For many buildings, combustible cladding on the facade:

- does not present a high enough level of risk to warrant substantial or complete removal of the cladding; but
- presents enough risk to warrant a tailored package of risk mitigation interventions to be introduced that provide a proportionate response to the risk.

Some buildings may be of a construction type or size or may only comprise limited elements of combustible cladding such that no intervention or removal of cladding is required.

A set of documents has been assembled to describe the purpose, establishment, method and application of the PMCR. The full set of PMCR documents and their relationship to each other is illustrated in a diagram in Appendix A: PMCR document set and flow.

There are **seven** related streams of technical document in the PMCR document set:

A. Authorisation	Codifies the Victorian Government decisions that enable PMCR activation.
B. CRPM Methodology	Specifies the Cladding Risk Prioritisation Model (CRPM) method used for assessing cladding risk and assigning buildings to three risk levels.
C. PMCR Foundation	Defines the PMCR method, objectives and the key design tasks.
D. Support Packages	Captures the relevant risk knowledge and science-based findings necessary to systemise and calibrate PMCR application.
E. CSV Cladding Risk Policy	Establishes key CSV policy positions in relation to cladding risk.
F. PMCR Interventions	Identifies and describes the interventions that the PMCR method can employ to mitigate risk associated with combustible cladding.
G. Implementation	Specifies the standards and procedures that guide PMCR application.

The document set has been developed by CSV. Each document has a function in supporting the delivery of the PMCR and in communicating the PMCR risk rationale and method.

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Abbreviations

Acronym	Description / definition
ACP-PE	Aluminium composite panel with a polyethylene core
ARP	Advisory Reference Panel
CRPM	Cladding Risk Prioritisation Model
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSV	Cladding Safety Victoria
DELWP	Department of Environment, Land, Water and Planning
DTP	Department of Transport and Planning
EPS	Expanded Polystyrene
FRA	Fire Risk Assessment Tool (developed for the NFPA)
FRV	Fire Rescue Victoria, formerly the MFB
iAuditor Reports	A form of site inspection report, providing information relevant to a range of risk factors
IF-SCAN	Initial Fire Spread in Cladding Assessment Number
LRM	Logical Ranking Method
MFB	Melbourne Metropolitan Fire Brigade
NFPA	National Fire Protection Association
RAT	Risk Assessment Tool
SCA	State-wide Cladding Audit
SOU	Sole Occupancy Unit
VCT (Taskforce)	Victorian Cladding Taskforce
VBA	Victorian Building Authority

Overview

The Protocols for Mitigating Cladding Risk (**PMCR**) have been developed to provide a systematic mechanism for assessing and mitigating the risk posed by combustible external cladding on Victorian Class 2 and Class 3 buildings with lower levels of fire risk.

The development of the PMCR represents an extension of earlier work undertaken by Cladding Safety Victoria (**CSV**) to develop the Cladding Risk Prioritisation Model (**CRPM**). The CRPM provides a method for assigning buildings to a risk category based principally on two building features:

1. The extent to which cladding on a facade connects sole occupancy units (**SOU**) to provide the potential for external fires to carry fire from one dwelling to another; and
2. The extent of sprinkler protection in a building, as sprinklers can prevent:
    a. internal fires from breaking out of an SOU and reaching cladding; and
    b. external fires from breaking into an SOU and threatening life safety and compromising safe egress from a building.

Using the CRPM, buildings are placed in one of three risk categories (unacceptable, elevated and low).

The Victorian Government has adopted this system of risk categorisation, which is now published and underpins the design and delivery of the PMCR. The Victorian Governments' Cladding Risk Mitigation Framework defines the three cladding risk rating categories, as follows.

	Risk description	
Cladding risk rating category	**Sprinkler protected**	**Not sprinkler protected**
Unacceptable	Risk of fire spread across the Combustible External Cladding of **≥ 4 SOUs**	Risk of fire spread across the Combustible External Cladding of **≥ 3 SOUs**
Elevated	Risk of fire spread across the Combustible External Cladding of **3 SOUs**	Risk of fire spread across the Combustible External Cladding of **2 SOUs**
Low	Risk of fire spread across the Combustible External Cladding of **≤ 2 SOUs**	Risk of fire spread across the Combustible External Cladding of **≤ 1 SOU**

Source: Cladding Risk Mitigation Framework, Department of Transport and Planning, August 2023

For buildings with a cladding risk rating of unacceptable, the primary means of reducing cladding risk to an acceptable level is to undertake works that substantially remove and replace combustible external cladding.

For buildings with lesser risk, the removal and replacement of cladding is generally unnecessary.

The PMCR has been designed to address cladding risk without the need for cladding removal where the cladding risk rating is elevated or low.

The PMCR also provides a means of retaining cladding for buildings with an unacceptable risk rating where the risk of fire spread across the combustible external cladding is between 4 and 6 and the building has sprinklers installed inside SOUs.

This paper presents the design features of the PMCR, the main considerations that led to its development and the resources available to support its application.

1 PMCR design drivers

The Protocols for Mitigating Cladding Risk represent a unique Victorian endeavour to capture and operationalise fire engineering principles and apply them consistently to reduce cladding risk to an acceptable level.

The PMCR design has proceeded with a focus on a clear functional requirement and a single prime objective.

The **function** of the PMCR	is to provide evidence-based risk mitigation standards and procedures for designing and delivering cladding remediation works that are tailored for buildings of different risk levels.
The **objective** of the PMCR	is to ensure that the risk mitigation solutions applied utilise fire safety measures that are proven and available, and that the level of intervention is proportionate to the risk presented by cladding on each building.

This document explains how the PMCR design is underpinned by:

A clear scope for the design and application that responds to the problems created by cladding	(section 2)
An understanding of the cladding risk profile of Victorian Class 2 and 3 buildings	(section 3)
Awareness of the key stakeholders and their interests	(section 4)
A robust method for intervening to reduce cladding risk	(section 0)
PMCR rules driven by science and informed cladding risk policy	(section 0)
Guidance materials, procedures and standards to support PMCR application	(section 7)

Most importantly of all, the PMCR has been created for the benefit of people living with cladding on their buildings.

While the PMCR design is focused on the physical materials that have the potential to cause harm and those that can be used to mitigate risk (sprinklers, smoke detectors, etc), the human dimension of the cladding problem is a foundation concern of the Victorian Government.

It is important for Victorians to be safe in the spaces that they live, work and visit. It is also important that building owners are not burdened with a requirement to fund cladding remediation work that is disproportionate to the risk that cladding presents to them.

The PMCR will support Municipal Building Surveyors (**MBS**) to work with building owners to find a risk proportionate response to cladding that satisfies safety concerns.

2 The cladding 'problem' and the PMCR scope

The extensive use of combustible cladding on the buildings that people occupy, use and visit creates a fire risk for which a society wide response has been demanded.

The level of fire risk is such that governments around the world have decided that state directed or sponsored intervention is necessary.

The need that drove an interventionist approach is the imperative to prevent catastrophic cladding fuelled fires like the one that occurred at Grenfell Tower in London on 17 June 2017, which resulted in significant loss of life. Other prominent cladding fuelled fires, such as the Lacrosse (2014) and Neo200 (2019) that occurred in Melbourne have also led to facade fires of significant scale, albeit fortunately not resulting in any loss of life.

For buildings carrying substantial cladding fuel loads, an approach to remove the combustible cladding is often the best approach. Removing and replacing all or part of the 'outer skin' of a building is complex, time consuming and costly, but entirely justifiable where the risk posed by the cladding is unacceptably high.

The challenge remains, however, to specify what level of intervention is necessary in situations where the risk posed by cladding is not high. One of the main challenges for a risk-based intervention design approach, like the PMCR, is how to accommodate a risk-based approach within a compliance focused regulatory regime (see Appendix B: Imperative for a risk-based PMCR design for further discussion).

Risk management practice rarely sets as its objective the total elimination of risk, but rather the controlled management of risk using measures that are reasonable and practicable to apply.

The key consideration for the PMCR design is:

Is it justifiable (or necessary) to impose complex and costly risk mitigation obligations on building owners and works' funders that entail the wholesale removal of cladding where the risk posed by cladding is relatively low?

The PMCR seeks to find a risk proportionate response for buildings of all risk levels, with a primary focus on buildings with a cladding risk rating of elevated and low.

2.1 PMCR definition/description

The PMCR has been designed to provide guidance for MBSs about mitigating cladding risk. These protocols are an addition to the existing regulatory pathways available and do not, in any way, attempt to invalidate existing regulatory pathways to cladding risk mitigation.

Common to all remediation works under the PMCR is an expectation that some combustible cladding can be retained on these many buildings, where the risk of cladding ignition is contained and/or other safety measures are in place.

The PMCR consist of a set of interrelated components guiding both the design and application:

Protocols design	1. A **science-led method**, validated through a peer review process, that provides an evidence base for the standards underpinning the PMCR; 2. A **structure/model** for identifying hazards (threats) and adverse consequences and the ways in which targeted interventions function to mitigate cladding fire risk; 3. A **structure/approach for:** ▪ responding to hazards (threats) that have the potential to lead to cladding being ignited; and ▪ minimising adverse consequences, once cladding is ignited, giving primacy to the threat to people; 4. A risk-focussed **framework/method for classifying buildings** based on their exposure to cladding fire risk; 5. A **scope definition** that limits the application of the protocols to a finite set of buildings with a specific risk profile;
Protocols application	6. A **declaration/statement** that provides the necessary authority for the protocols to be applied, and noting any limitations to its application; and 7. A **written set of procedures and standards**, which specify how the risk mitigation interventions can be applied to eliminate hazards and reduce the consequences associated with cladding fire risk.

These constitute a package, all parts of which are needed in order for a viable and broadly accepted approach to the treatment of cladding risk to be applied.

2.2 Scope of protocols

The PMCR is intended for use on a specific set of buildings only.

There is an expectation that the PMCR can be applied to buildings:

- of 3 storeys or higher for which the predominant use is residential purposes (classes 2, 3 and 9c);
- with aluminium composite panels (**ACP**) or expanded polystyrene (**EPS**) as part of the external wall system; and
- with an elevated or low cladding risk rating, as determined by the Initial Fire Spread in Cladding Assessment Number (**IF-SCAN**) evaluation[1].

The PMCR is not intended to be a mechanism to impose a one-size fits all solution to address cladding risk on residential buildings, but will provide streamlined pathways for the application of structured and consistent risk mitigation interventions for as many elevated and low risk buildings as possible.

It is anticipated that the PMCR Standards may not be applicable for some buildings due to the unique properties of a building.

The PMCR implementation procedures provide for additional fire engineering assessment for those buildings where a PMCR Standards-based design is not considered an optimal fit.

1 The IF-SCAN evaluation is one part of a cladding risk assessment undertaken using the Cladding Risk Prioritisation Model (**CRPM**) developed by CSV in collaboration with the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**) Data61.

3 Cladding risk – a profile of Victorian Class 2 buildings

At the conclusion of 2023, there remained 845 Class 2 buildings[2] that have been found by CSV to have combustible external cladding and which are likely to require a risk mitigation solution using the PMCR.

These buildings are situated in 29 separate Local Government Areas (**LGA**), almost all of which are within the boundaries of greater metropolitan Melbourne.

For each of these buildings, the Initial Fire Spread in Cladding Assessment Number and sprinkler status is known. This allows each of the buildings to be triaged using the cladding risk ratings developed through the CRPM and defined in the Victorian Government's *Cladding Risk Mitigation Framework*.

The figure below shows the distribution of IF-SCAN values for PMCR target buildings at the end of 2023.

This distribution indicates that:

- **411** buildings (48.6%) have a **low** IF-SCAN risk rating;
- **354** buildings (41.9%) have an **elevated** IF-SCAN risk rating; and
- **80** buildings (9.5%) have an **unacceptable** IF-SCAN risk rating.

Less than one in ten of these buildings has an unacceptable rating and CSV will continue to manage the remediation of these buildings through its program of funded rectification works using the Victorian Government investment that targets the Class 2 buildings with the highest risk.

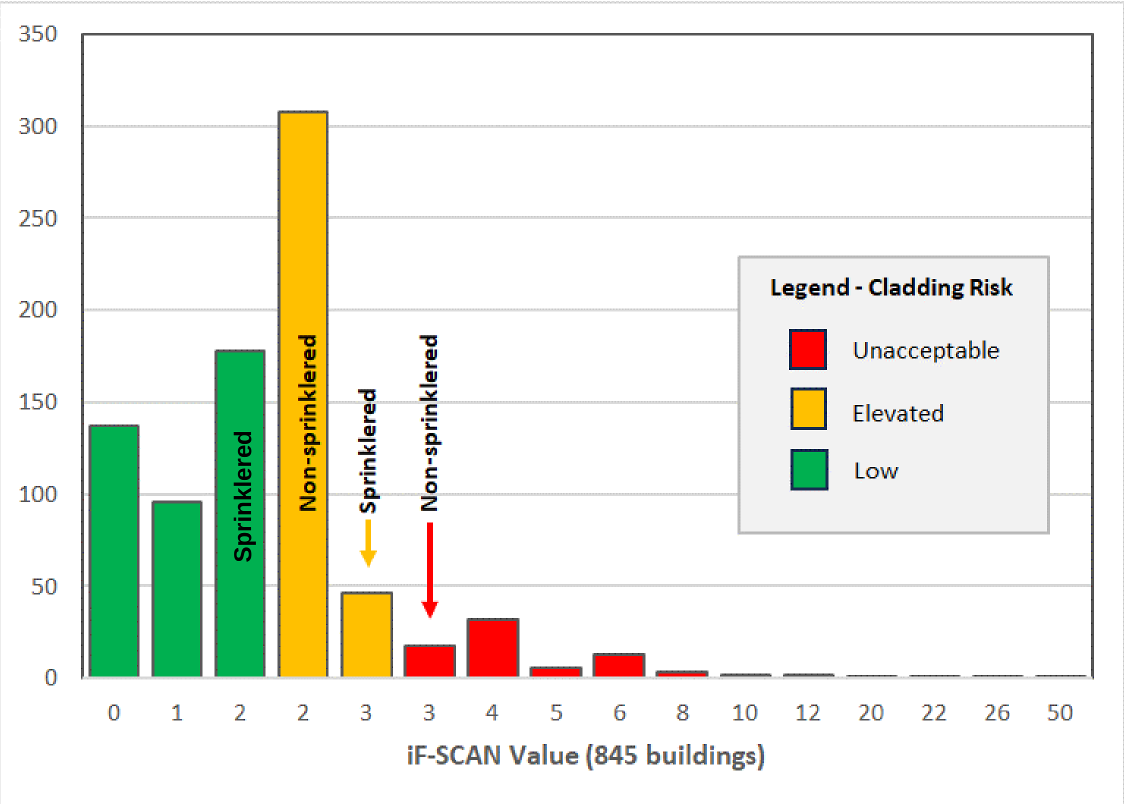

Figure 1: Distribution of CSV risk assessed buildings by IF-SCAN value

Source: Cladding Safety Victoria, 28 January 2024

[2] This count excludes buildings that have already been funded for cladding rectification work and buildings. CSV has also undertaken preliminary risk assessments for over 100 Class 3 buildings, of which 46 have been found to have combustible external cladding as part of their facade design.

The preponderance of PMCR effort will be focussed upon those buildings with a cladding risk rating of elevated. For the 354 buildings that share this rating the external cladding cannot spread fire between more than:

- 2 SOUs where the SOUs **are not** sprinkler protected; and
- 3 SOUs where the SOUs **are** sprinkler protected.

The figure below illustrates how the 354 CSV buildings with a rating of elevated compared to the iconic high-rise buildings at which cladding gave rise to large scale fires, horrific consequences (in some cases) and appropriately prompted a response from governments world-wide.

It shows that:

- 19 in 20 (94.6%) elevated risk buildings are low-rise buildings; and
- 7 in 10 (70.9%) elevated risk buildings are less than 11 metres in effective height, which are not in scope in almost every other jurisdiction world-wide with a focus on cladding.

The buildings that drew attention to the risk of combustible cladding are nothing like the elevated buildings for which solutions will be required using the PMCR.

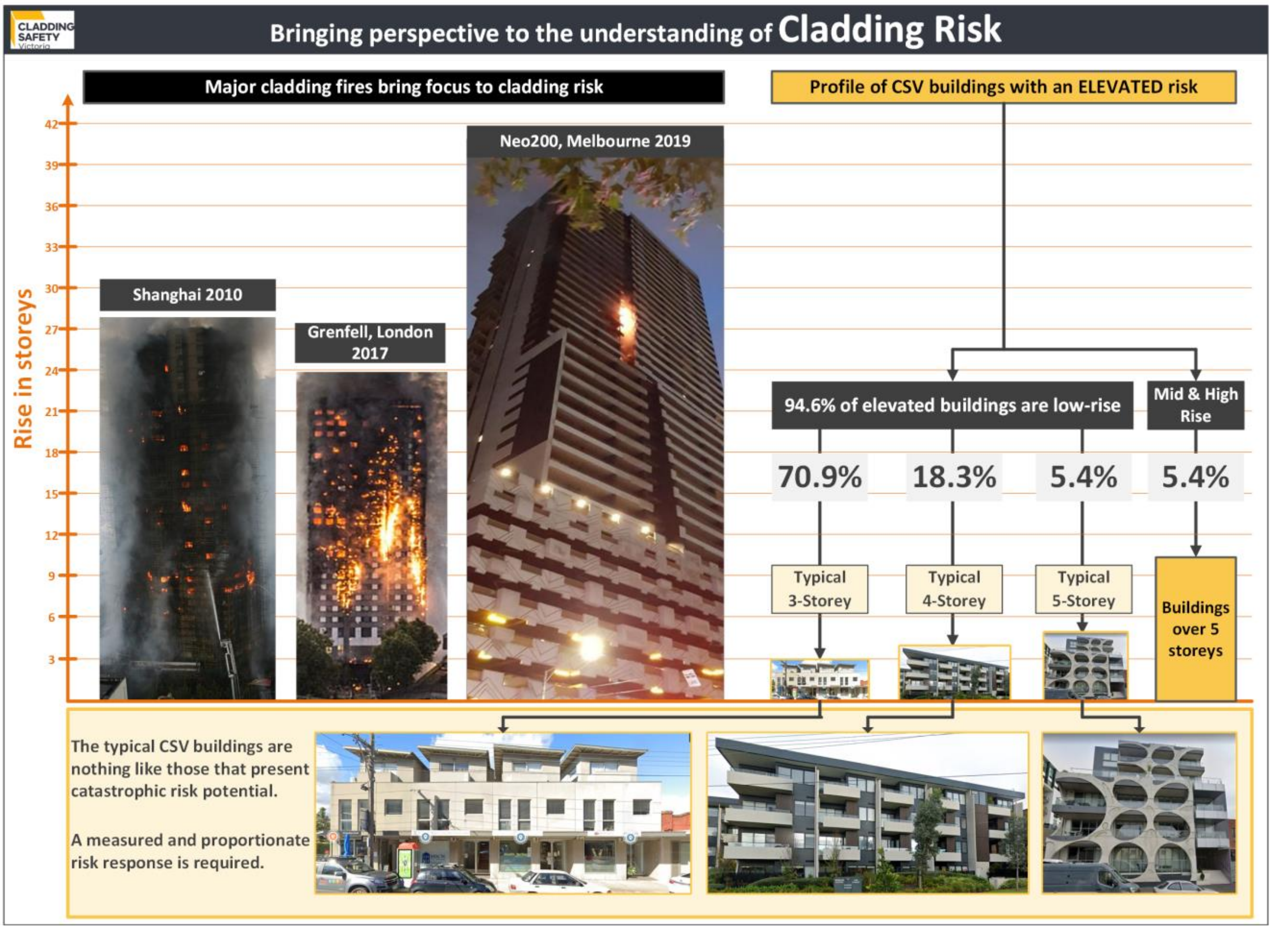

Figure 2: CSV Class 2 elevated risk buildings – a comparative cladding risk perspective

Source: Cladding Safety Victoria, 28 January 2024

The PMCR is designed to deliver a risk appropriate response to cladding, in which the effort in delivering a remedy (cost and complexity) is proportionate to the threat to life safety posed by the cladding.

Those buildings with a low cladding risk rating (constituting almost half of the CSV target buildings) have little capacity for cladding to spread fire between SOUs. However, they remain a focus of PMCR design planning, where action is required in instances where cladding compromises safe egress from a building.

4 PMCR audience and stakeholders

4.1 Primary audience

Municipal Building Surveyors are the primary audience for the PMCR. That is because it is this group that will be the primary users of the PMCR.

The PMCR is being designed to support MBSs in approving cladding Remediation Work Proposals (**RWP**) that will enable enforcement actions to be removed from buildings. This recognises that MBSs are the key decision maker in relation to the imposition (and removal) of obligations placed on building owners to address cladding related safety issues.

CSV has worked closely with MBSs over more than a year to communicate information about the purpose, design and proposed application of the PMCR. Through this process of engagement, the design of the PMCR has been continuously tested and adjustments have been made as necessary.

Also important, is the need for the PMCR to serve the interests of building owners and users, and accordingly the PMCR has been designed with a view to communicating with a non-technical audience.

4.2 Key stakeholders – protocols design

The design and implementation of the PMCR has relied on regular exchange between three key stakeholders within the Victorian Government:

- **Department of Transport and Planning (DTP)**

  DTP is the lead portfolio agency for planning activity associated with Victoria's built environment and has an important role to play in keeping the Minister for Planning informed about the PMCR design and application and the authorisation of its use under *Minister's Guideline 15* and the *Cladding Risk Mitigation Framework*.

- **Victorian Building Authority (VBA)**

  The VBA is the State's regulator overseeing compliance with building standards, including fire safety. The VBA has had a critical role to play in helping to accommodate a risk-centric approach to cladding risk within the compliance regime that applies generally. Supporting this endeavour is consistent with VBA's strategic priority to enhance its own risk-based regulatory approach[3].

- **Cladding Safety Victoria (CSV)**

  CSV is the state agency responsible for prioritising buildings on risk-based grounds to receive funding support to undertake cladding rectification work. CSV is also responsible for supporting the owners of lower risk buildings who will not receive funding to understand what options they have to address cladding risk. CSV's detailed building knowledge, information and expertise has been pivotal to the design of the PMCR and to their practical delivery.

This group has developed a shared understanding of the purpose and design of the PMCR and each party has worked to inform the design, development and delivery of the protocols as both critical reviewers and through leadership and activity in their respective domains.

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3 As set out in the Minister for Planning's Statement of Expectations (26 September 2021) for the VBA and identified as a priority in the VBA's Strategic Plan 2022-2027 (Vision 27).

4.3 Other stakeholders – interested parties

Other parties with a major interest in the PMCR and its intended use are:

- **Fire Rescued Victoria (FRV)**

  FRV provides the first response to all fires and so has a direct interest in any proposal to reduce a building's fire risk. FRV has been represented in risk assessment activity relating to the State-wide Cladding Audit (**SCA**) and brings a clear perspective on cladding risk and the need to address it. It has been important to demonstrate to FRV how the PMCR is designed to function to respond to cladding fire risk proportionately and to create a clear pathway for expediting cladding risk retirement in Victoria and in doing so, serve FRV operational concerns and priorities.

- **Insurance Council of Australia (ICA)**

  The premiums associated with property insurance are impacted significantly by the perception of cladding risk and the potential liabilities that creates for the insurance sector. Engagement with the ICA and insurance sector has been ongoing throughout the development of the PMCR. There is clear recognition that the PMCR approach can contribute to the reduction of cladding risk.

- **Society of Fire Safety (SFS), Engineers Australia**

  The design of safe and acceptable fire risk mitigation solutions for residential buildings relies substantially on the knowledge and technical capabilities of Fire Safety Engineers. Engagement with fire safety engineers is vital so that it can reasonably be concluded that:

  - the design of the PMCR aligns to fire safety good practice as it applies to cladding use on buildings of different risk ratings; and
  - the application of the PMCR incorporates the necessary fire safety checks to ensure that a protocols driven solution does not compromise the established existing Fire Safety Strategy for a building.

- **Victorian Managed Insurance Authority (VMIA)**

  The VMIA is the Victorian Government's insurer and risk adviser, insuring $201 billion of State assets including Victoria's road and rail systems, hospitals, schools, cultural institutions, cemeteries and national parks. The VMIA is an important stakeholder in the development and application of the protocols as it pertains to the State's risk appetite and exposure.

Through CSV's PMCR design team membership and CSV's formal engagement processes, regular communications have been maintained with all stakeholders about the design of the PMCR.

5 PMCR 'threat barrier' method

A threat barrier analysis approach has been used to provide a model for considering fire risk on buildings that are found to have combustible external cladding and the measures that can be adopted to mitigate cladding risk to a level deemed acceptable.

This method provides a recognised and convenient way of presenting all of the key risk elements that are the subject of the PMCR design and how they relate to one another.

The threat barrier (or bow-tie) diagram developed for the PMCR is depicted below.

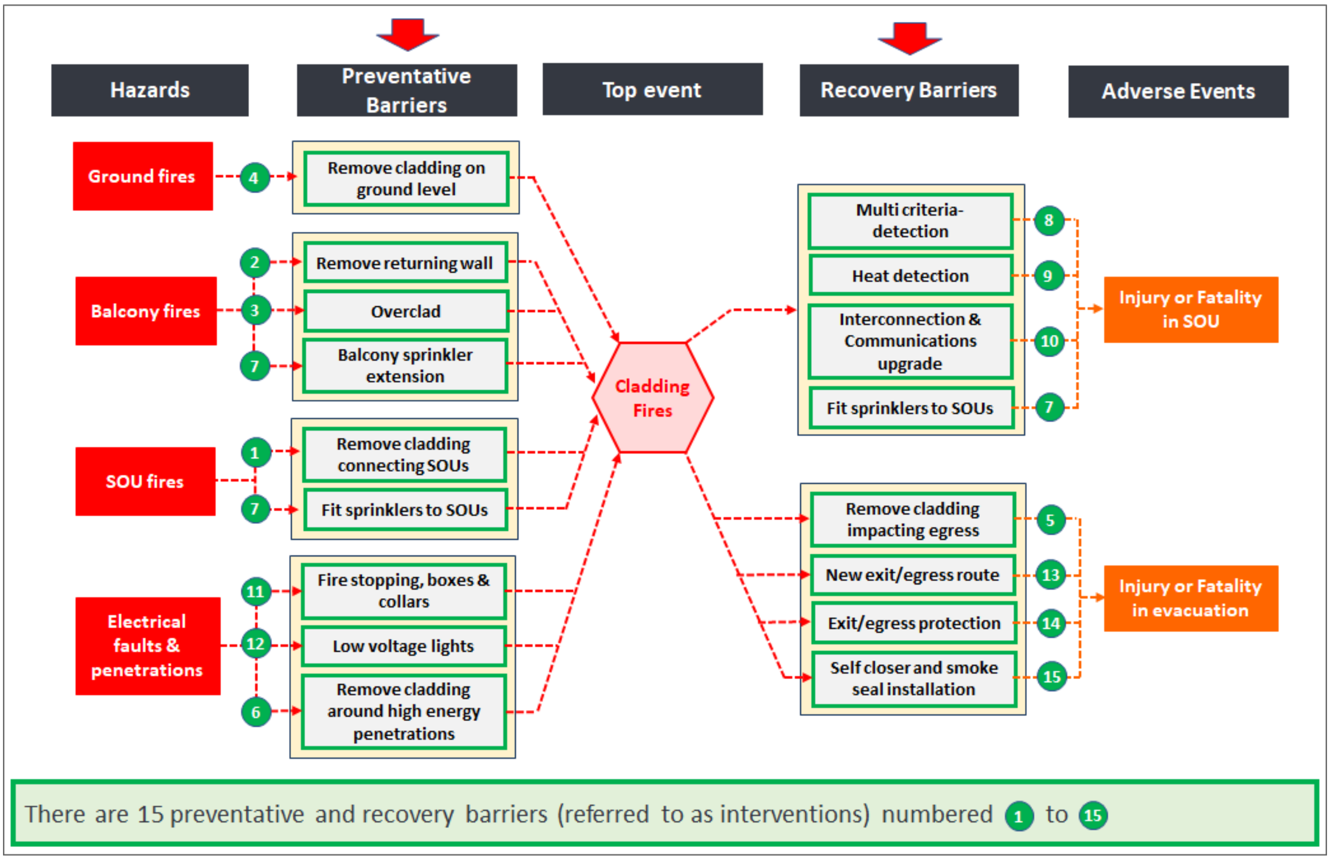


Figure 3: Threat barrier diagram – cladding risk on residential buildings

The threat barrier model approach is centred on a single risk element (the **top event**). For the PMCR, the top event is a fire that ignites the cladding, with risk mitigation efforts designed to either:

- Prevent fire from reaching cladding; and/or
- Reducing the adverse impacts of a fire that has reached cladding.

To mitigate risk to an acceptable level, the protocols aim to introduce controls that will reduce risk by preventing cladding ignition, limiting fire spread via cladding or reducing the impact on people (death or injury).

The threat barrier diagram incorporates five major components:

1	**Top event**	This is primary risk that the PMCR aims to avoid or mitigate risk in relation to. For the protocols, the top event is a cladding fire.
2	**Hazards**	These are the most **likely** sources of hazard capable of causing the top event (i.e. a fire reaching cladding).
3	**Preventative barriers**	This set of interventions respond directly to individual hazards and are designed to reduce (and prevent where possible) the **likelihood** of the top event from occurring.
4	**Adverse events**	These are the negative outcomes (**consequences**) that all measures should seek to reduce if the top event were to occur.
5	**Recovery barriers**	This set of interventions assumes that the top event has already occurred, and the risk mitigation focus should be on measures to mitigate adverse events (**consequences**).

The 15 interventions (barriers) proposed for use through the PMCR are designed to reduce risk by either:

- Reducing the **likelihood** of a fire from reaching cladding (**preventative barriers**); or
- Reducing the consequences of a fire (that is, threat to life) by assisting quick and safe escape from the building once cladding has been ignited (**recovery barriers**).

The work to develop the PMCR has built an evidence base for the objective application of this approach.

5.1 Acceptable Cladding Risk

In applying the PMCR method, the requirement is to ensure that each building has achieved an Acceptable Cladding Risk (a defined term in the Victorian Government's *Cladding Risk Mitigation Framework*).

In intervening to mitigate cladding risk under the Framework, the PMCR needs to bring each building to a state of Acceptable Cladding Risk: meaning that the Relevant Building:

- achieves a 'Low Cladding Risk' rating; or
- presents an overall level of risk to the life and safety of the occupants of the Relevant Building which is reasonably similar or less than the risk which would be presented by the same building, if that building had no Combustible External Cladding.

5.2 Baseline risk – what is safe enough?

Under the PMCR, there are 15 fire safety interventions that can be applied to a building to make that building safer.

The challenge is to establish a way of objectively determining that the safety measures that have been applied result in the building being made 'safe enough'.

The PMCR design adopts the following notion of '**safe enough'**.

Following the application of a set of risk mitigating safety interventions, a building is to be regarded as 'safe enough' if its risk profile (after intervention) is equal to or better than the risk profile for the same building (in its original state) without cladding.

Implicit in this statement is a trade-off: that trade-off being that the additional safety measures introduced through the PMCR will compensate for any residual risk that remains on the building due to the retention of cladding.

That is:

- A building with some cladding removed and a range of active and passive fire safety measures; will be similar to or better (in quantified risk terms) than;
- A similar building with all cladding removed but with none of the additional active and passive safety measures introduced.

This is considered a reasonable and proportionate risk approach to explore for buildings that have a relatively low level of cladding risk exposure.

5.3 Risk assessment focus and core assumptions

The assessment of cladding risk under the CRPM and the design of risk mitigation solutions via the PMCR are founded on the reasoned assumptions that:

1. Where a building fire occurs, there is an expectation that a fire fighting response to suppress and contain a fire will commence within a reasonable timeframe; and
2. While the 'behavioural/demographic' dimensions of fire risk must be recognised and addressed in broader strategies of fire safety planning and management, the function of the CRPM and PMCR is to respond to the 'structural' dimensions of fire risk only.

The influence of these considerations on the PMCR design are described in the following sub-sections.

Fire-fighting response times

The PMCR is designed to provide a proportionate response to the risk posed by Combustible External Cladding on Class 2 and Class 3 buildings.

The PMCR design is underpinned by a reasonable expectation that a fire fighting response will commence at a building fire within 20 minutes of fire fighters being alerted. For buildings where there may be added complexity in delivering a timely response, the PMCR introduces additional safety measures.

Another important aspect of a fire risk assessment is the delivery of a fire-fighting response. Any fire that is left unchecked has the potential to grow and spread beyond a manageable level and potentially produce significant adverse consequences, whether associated with a façade fire or otherwise. Where fire-fighters arrive quickly at the scene of a fire there is reasonable expectation that routine fire suppression actions will be effective and that building occupants will be safely evacuated.

Fire Rescue Victoria (**FRV**) is the agency responsible for providing the first response to fire on Victorian buildings, and has a strong record of responding to fires in a timely fashion. The target response time[4] for FRV is 7.7 minutes and the FRV record of response indicates that an acceptable response is achieved for the majority of emergency incidents[5].

The emphasis on the response time to a fire suggests that there is a veritable 'Golden Window' of time within which fire-fighting activity must be delivered to increase the probability that a fire will be suppressed and building occupants safely evacuated.

Evidence exists to show that delays in fire services arriving at an incident and setting up equipment to commence suppression/evacuation activity:

- Decreases the probability of the successful rescue of all occupants; and
- Increases the probability of death and injury.

Research of fire incident data in England shows the relationship between the fire-fighting response time and the probability of fatalities, casualties and rescues (FCR). It shows that where it takes more than 20 minutes to respond to a fire, the probability of a fire related death exceeds the probability of safe rescue.

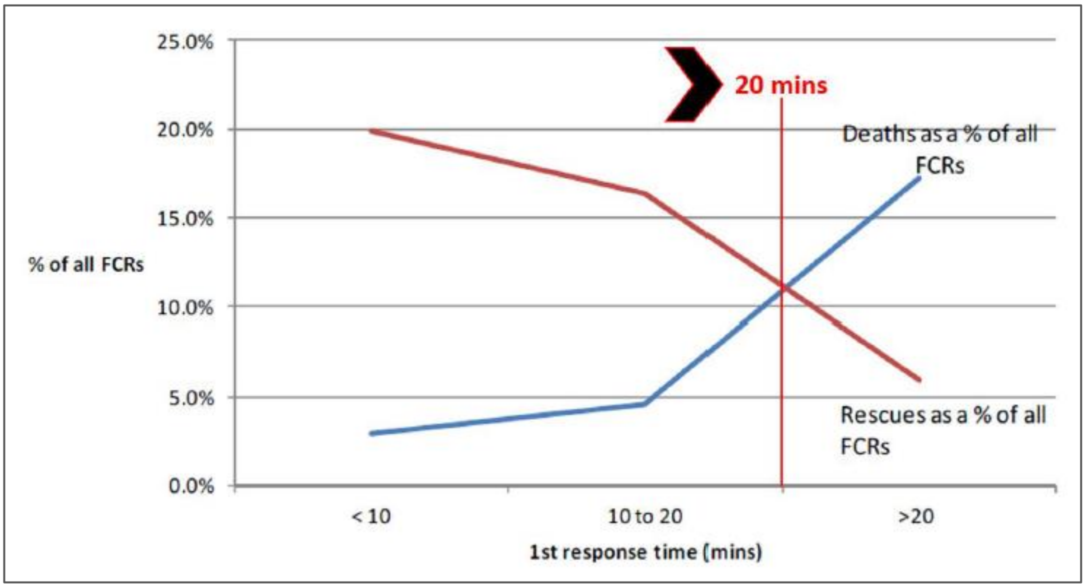


Figure 4: Percent of Fatalities, Casualties (all grades) and Rescues (FCRs) that die versus percent that are rescued, against response time

Source: The Fire Risks of Purpose-Built Blocks of Flats: an Exploration of Official Fire Incident Data in England, S.Hodkinson and P. Murphy, July 2021.

For the buildings that are the focus of the PMCR it should is noted that:

- 99% are located within greater metropolitan Melbourne, where fire fighting resources are generally in close proximity to buildings; and
- over 80% of buildings are under 18 metres in height (3 to 5 storeys), providing opportunity for a suppression response to be applied from the ground in the majority of cases.

[4] 'Response time is defined as the interval between appliance dispatched and the arrival of the first vehicle at the scene." (https://www.frv.vic.gov.au/response-times)
[5] For the most recent quarterly period for which response tome performance is published (1 April 2023 to 30 June 2023), FRV reported that 90% of fire incidents were responded to within 8.7 minutes.

These data suggest that it is reasonable to expect a timely fire fighting response in relation to the buildings that are the focus of PMCR assessment and risk mitigation planning.

The PMCR design applies a reasonable expectation that in all probability FRV will arrive at the scene of a fire in a timely fashion and that suppression and evacuation actions will be effective.

The importance of the effective delivery of a fire fighting response to combat a fire in a multi-rise building is not underestimated. Accordingly, the PMCR design provides for:

- added intervention measures to be taken where the cladding is located at height on the façade (above the fourth storey), where fighting a fire from ground level is less feasible and there are likely to be delays in commencing suppression activity (see E.02 – Cladding Risk Policy – Sprinkler Protection); and
- additional assessment of the risk posed by cladding to be undertaken where cladding is located on lower levels, but fire fighter access to the façade is impeded.

In this way, the PMCR both draws on the benefits of the fire fighting response in shaping interventions and also provides mechanism for varying the PMCR intervention approach in scenarios where the delivery of a timely fire fighting response may be problematic.

Behavioural and demographic features of fire risk

The level of threat to life safety from a building fire is certainly impacted by the profile of building occupants and users (demographic factors) and the fire safety practices of building occupants and managers (behavioural factors).

The other category of risk factors that impact the risk associated with building fires capture the fixed physical characteristics of a building (structural factors), which can inflate risk where not effectively controlled through regulatory safety controls.

In the 2020 design of CSV's risk assessment methodology, the CRPM, a clear scope focus for risk-based rectification action was placed on the structural dimension of risk only.

> A building's fire risk is influenced by both:
>
> - The way it has been constructed (structural risk); and
> - The way that fire risk is managed (behavioural risk).
>
> Construction planning and implementation requires long lead times and so, the risk modelling must produce priority rankings that are stable over time. Accordingly, the modelling will not consider fire safety practices (behavioural risk elements), which can change over time.
>
> These behavioural elements remain very important but must remain the preserve of regulatory compliance initiatives that can operate in parallel to CSV funded rectification work.

Source: B.01 - Cladding Risk Prioritisation Model Methodology: Overview/Approach.

The subsequent PMCR design is founded on this same CRPM principle, providing consistency and continuity in design principles from the 2020 CRPM to the 2024 PMCR.

The interventions applied through the PMCR constitute a response to the fixed physical properties of a building that directly create the cladding fire risk (i.e. the cladding itself) or accentuate the risk of cladding (through the configuration of particular architectural features and absence/presence of other safety features, like sprinklers and detection and alarm devices and systems).

The fire risk level of a building can change over time due to behavioural/demographic factors like:

- the maintenance of fire safety equipment;
- the management of rubbish/refuse;
- the storage restrictions (on balconies in particular);
- smoking policies and their enforcement; and
- the building user population, and the number and type of vulnerable 'at risk' people.

PMCR design solutions cannot be based on these considerations, potentially rendering the solutions of today as redundant tomorrow. Programs and initiatives tasked with improved building management practice are considered to be the best avenue for dealing with these risk factors.

The "attributes" and "capabilities" of any one particular individual will change over the lifetime of that individual. Furthermore, the "attributes" and "capabilities" of an individual living in a particular apartment today might be different to those of the individual living there tomorrow. The PMCR provides a "one time" for "all time" solution and must be agnostic to routine changes in occupancy.

This does not mean that the PMCR design is ambivalent to demographic and behavioural considerations associated with cladding fire risk:

- In CSV's funded rectification works program, the cladding remediation solutions applied for social housing took a conservative risk averse approach and placed emphasis on full/extensive cladding removal due to the predominance of vulnerable people in the population of each building; and
- The risk quantification that informs the PMCR design and application (see D.04 – Support Package – Risk Benefits) uses fire incident data within which vulnerable people are represented and risk assessment criteria and thresholds adopted by the PMCR are sensitive to occupant vulnerability in a generalised way.

These two points illustrate the ways in which the PMCR design and CSV implementation practice applies sensitivity to occupant vulnerability in both a case specific and general sense.

The Class 2 and Class 3 buildings that are the focus of PMCR assessment and remediation work planning generally have low or elevated risk profiles and do not have an occupancy profile disproportionately skewed by people with an added vulnerability fire the consequences of fire risk.

The types of building occupant that are most vulnerable to death or serious injury in a residential fire are a key focus of fire related research. In an Australian study of 900 residential fire fatalities over a 15 year period, the Bushfire and Natural Hazards Cooperative Research Centre provided the following summary of demographic groups at greatest risk of death in a fire.

Single variable analysis from the current research found that those most at risk of dying in a preventable residential fire included:

- Older people – people aged ≥65 represent 36.4% of total fatalities
- Young children aged 0-4 – 7.8% of all fatalities
- People who had a disability (61.8%)
- Aboriginal/ Torres Strait Islander people (over-represented by a factor of 2.5)
- People who smoked – 65.4% of known decedents were smokers
- Males – 64.3% of all fatalities (M:F death ratio 1.8), particularly those aged >45
- People who lived in the most socially and financially disadvantaged locations
- People who lived alone (44.5%)
- People who had medications (34.4%) or alcohol (32.7%) present in their blood.

Source: *Preventable Residential Fire Fatalities in Australia: July 2003 to June 2017*, Risk Frontiers/ Macquarie University, Metropolitan Fire Brigade and Bushfire and Natural Hazards CRC

Contemporary research and advocacy points to the importance of adopting measures to both:

- Address the risk posed by combustible materials in the context of the physical design features of each building and the fire safety devices available in that building; and
- Consider how risk exposure varies at a personal level for the people in place and how additional safety precautions may be necessary to identify vulnerable residents and manage the measures required to ensure that these people will be alerted to a fire and safely evacuated where necessary.

The PMCR design and the associated research that underpins it has been undertaken in parallel with other important international research work that furthers the interests of building occupant safety. The PMCR team has and will continue to collaborate with the leaders of parallel work in the area of building fire safety.

6 Science driven and policy defined

The PMCR has been designed to be an evidence-led method for assessing cladding risk and for defining proportionate risk mitigation responses, with a primary focus on buildings with an elevated cladding risk rating.

The science pertaining to structure fires is voluminous and is dispersed across a wide array of important and finite topics, yet gaps remain in those areas of most interest to the PMCR design. In particular, the behaviour of external fires (with research about internal fires predominant) and fire behaviour in relation to different facade materials.

Multiple jurisdictions (the United States, Canada and England in particular) have extensive fire incident databases covering hundreds of thousands of individual structural fire events. However, little incident data is available to allow exploration of fires involving combustible facade materials in particular.

Since CSV's inception, the growth in research activity relevant to combustible cladding is growing and CSV has commissioned its own research to expedite discovery in areas relevant to the PMCR design.

While the current science cannot always point definitively to threshold setting for the PMCR design, the current research based knowledge combined with fire engineering expertise can be used to prescribe threshold settings in the form of cladding risk policies.

In this sense, the PMCR design involves the prescription of risk threshold settings that are:

- Founded on contemporary international research;
- Supplemented by targeted CSV commissioned research;
- Interpreted from a fire engineering perspective for PMCR application; and
- Specified in CSV cladding risk policies that capture systematic fire engineering judgement and embed these in the PMCR design.

PMCR design and application has been informed by:

1. CSV research that comprises:
    a. A review of current literature;
    b. A review of regulatory requirements and standards; and
    c. New CSV sponsored research;
2. CSV policy positions developed in relation to cladding risk (that are informed by research); and
3. Expert judgement.

The purpose of this section is to identify:

- The fundamental research questions to support PMCR design and application;
- The high-level focus/intent of each area of research; and
- How the research findings inform PMCR design.

The choice of research questions is guided only by the need to develop the PMCR for use.

It is understood that the research questions pursued as part of the PMCR design are a small part of a broader science and academic endeavour to better understand building fire risk, which is well established and will continue beyond the life of PMCR based risk mitigation solution design in a Victorian context.

6.1 PMCR research focus

There are seven fundamental lines of research enquiry that have informed the design and application of the PMCR.

PMCR research focus	Intended application and use of research
1. **Cladding and materials**	Not all types of cladding present the same risk to occupant safety. Furthermore, the amount of cladding on a facade and how it connects SOUs and is configured will change the risk exposure of a building. Research that explores the combustibility of different products and how different scenarios change the risk exposure has informed the PMCR design in relation to judgements about: ▪ Cladding products that are in or out of PMCR scope. ▪ The extent of cladding removal necessary to break the connection between two SOUs to reduce the risk of fire-spread.
2. **External fire threats to cladding**	A major source of ignition threat to cladding is internal (i.e. fires originating in an apartment and spreading via a flashover to the outside or from a fire originating on a balcony). External ignition threats have the potential to spread fire to cladding, which are associated almost entirely with ground-based ignitions (cigarette smoking, bin fires and vehicle fires). Among these ignitions, vehicle and bin fires are considered to be of greater concern owing to the intensity of the fire that can not only ignite cladding but also facilitate rapid fire spread to adjacent areas of the building. An enhanced research based understanding of these external threats has been pursued to inform PMCR judgements about: ▪ When a ground-based ignition (i.e. vehicle and bin fires) threat justifies the removal of cladding. ▪ The extent of cladding removal that can be justified based upon the presence of a plausible ignition threat.
3. **Balcony fires**	Balconies are a common architectural feature of apartment buildings which are the focus of PMCR activity. Balconies are prominent dwelling social spaces and are used for a variety of purposes that can increase ignition risk. Where cladding is located on balconies or in proximity to balconies, there is a heightened likelihood of cladding being ignited and that fire spreading via cladding beyond the SOU of fire origin. Research was undertaken to inform PMCR judgements about: ▪ The extend of cladding removal necessary on balcony returns. ▪ The level of vertical separation between balcony edges that allows adjacent balconies to be considered not to be connected by cladding. ▪ The additional requirements/considerations when extending sprinkler to balconies to ensure their suppression efficacy.
4. **Exits and egress**	An important focus of the PMCR design is the capacity for occupants to safely egress the building in the event of a fire involving cladding. The presence of combustible cladding over and around a building exit has the potential to compromise: ▪ Safe egress of occupants from the building; and ▪ Entry to the building for fire brigade. Literature review and expert judgement considerations in relation to exits and egress has informed PMCR judgements about: ▪ Whether safe egress from individual SOU exits or building exits is compromised under different scenarios (considering extent and configuration of cladding). ▪ The duration during which the building must maintain its structural integrity after an ignition is detected and before fire services can start intervening. ▪ When a PMCR solution may require exit interventions where multiple exits are available on a single building.

PMCR research focus	Intended application and use of research
5. **Recovery barriers for risk mitigation**	The PMCR design incorporates a number of risk mitigation interventions that are referred to as recovery barriers. Collectively, the recovery barriers are intended to deal with situations where a fire has already reached cladding and the risk mitigation focus is on getting occupants out of the building safely. These interventions predominantly focus on enhancements in fire detection and alerting associated with Essential Safety Measures (**ESM**). Literature review of ESM interventions and their effectiveness informed PMCR judgments about: ▪ The scenarios in which ESM based intervention can be employed in combination with targeted cladding removal (or in place of cladding removal) to mitigate risk on PMCR buildings.
6. **Risk quantification**	The approach to risk mitigation under the PMCR model provides for the adoption of solutions which can demonstrably reduce risk to an acceptable cladding risk level. A Bayesian Network analysis method was sought to model the spread of fire across a facade between adjacent building features from SOU to SOU and quantify the reduction in risk that results for a variety of PMCR intervention scenarios. This analysis is fundamental to demonstrating that a Remediation Work Proposal has reduced risk to an acceptable cladding risk level, relative to a benchmark comparison building (see section 5.2). Research undertaken in this stream of enquiry can inform PMCR judgements about: ▪ How to select an acceptable risk reduction solution.
7. **Accessories and penetrations**	One potential ignition threat to cladding is associated with the use of electrical and gas fuelled devices where the supply of power penetrates the cladding. The type of appliance/device (e.g. lighting, air conditioning) and the level of insulation protection provided for the power supply will inform an assessment of the ignition risk. Research assembled about the typical installation and the ignition threat posed will inform PMCR judgements about: ▪ When a device may need to be replaced/upgraded. ▪ When an intervention around a device (cladding removal, over cladding or fire box) may need to be required.
8. **Sprinkler protection**	At the time of developing the CRPM in late 2020, a conservative view was taken about the protective value of sprinklers for the purpose of rating buildings with sprinklers. It was postulated that sprinkler protection has been undervalued in the CRPM methodology and research to gather information about sprinkler protection was needed to test the risk status of buildings with sprinklers. With the shift in CSV operational focus to lower risk buildings, it is important to review how the CRPM based rating method should appropriately reflect the protective value of sprinklers in a building fire. Research was undertaken to enable: ▪ The risk benefits of sprinklers on buildings with cladding to be better understood. ▪ Risk mitigation solutions to be designed under the PMCR that represent a proportionate response to cladding, where sprinkler protection is available.

The research findings that inform the PMCR design are found in the five Support Packages that form part of the overall PMCR document set (see Appendix A: PMCR document set and flow).

The PMCR design work has been ongoing since 2021. The earliest research. assembly of data and PMCR methodological development was prepared in 2022, which is presented in Appendix C: A review of relevant literature and software (2022) to reflect the roots and continuity of PMCR development.

6.2 PMCR policy focus

Using the international research and CSV initiated research together with the expert judgement of CSV's inhouse panel of building surveyors and fire safety engineers and facade material specialists, cladding risk policies have been developed that prescribe clear parameters for PMCR based risk intervention.

CSV has prepared two policy statements to inform the design parameters of the PMCR and support its implementation.

PMCR policy focus	Focus and application of policies
1. **Trivial and tolerable risk**	The approach to cladding remediation has evolved quickly over a short period of time. While initially guided by a compliance driven mindset dictating that certain facade products should be removed, the move towards a risk-based approach has led to the inevitable question about why cladding needs to be removed in all instances to promote life safety. The question as to whether to retain or remove cladding ultimately comes down to the issue of risk tolerance. In determining what risks can be tolerated under the PMCR, CSV has considered both the: ▪ **likelihood** of a fire igniting cladding and spreading in cladding under different scenarios; and ▪ **consequence** (harm to people) that would most likely result due to a cladding fire in each scenario. For each scenario, consideration has been given to the risk posed by cladding and a CSV cladding risk policy determination specified about the conditions under which cladding risk in each scenario is considered tolerable. Any risk deemed tolerable requires no action in a Remediation Work Proposal (RWP) developed for the purposes of the PMCR. The issue of risk tolerability covered in the policy has focussed on: ▪ cladding materials with lower levels of combustibility, heat release and fire spread rates than that observed for ACP-PE and EPS; and ▪ the cladding connectivity between adjacent SOUs (both vertically and horizontally) and how different breaks (gaps) in the cladding and different architectural features serve to reduce the degree of SOU connectivity to a tolerable level where cladding removal becomes unnecessary.
2. **Cladding remediation and sprinkler protection**	Cladding Safety Victoria has reviewed international research and fire incident data to answer two specific questions about fire safety in sprinkler protected buildings: 1. To what extent does sprinkler protection in a building improve safety?; and 2. Under what cladding scenarios is a sprinkler protected building sufficiently safe to allow for cladding to be substantially retained? It was found that a sprinkler protected building with cladding on a facade that connects 13 SOUs is as safe for occupants as a non-sprinklered building with no cladding (when considering rates of death and injury). Although not the primary focus of PMCR risk considerations, the PMCR analysis also assessed levels of property loss from fire. It found that a sprinkler protected building with cladding on a facade that connects 6 SOUs is likely to experience a lower rate of property loss than a comparable building with no cladding and no sprinklers. These findings support a policy position that cladding removal is generally unnecessary on any building with an IF-SCAN of 6 or less when that building has sprinkler protection in SOUs.

A detailed description can be found about the development of these policy positions in the two Cladding Risk Policy papers that form part of the overall PMCR document set (see Appendix A: PMCR document set and flow).

7 PMCR assessment processes, procedures and standards

The value of the PMCR is in its capacity for remediation standards to be applied with consistency to real buildings.

This requires clearly articulated pathways for bringing a building to an acceptable cladding risk rating and documented processes, procedures and standards to guide implementation.

The PMCR provides more than one pathway via which a building can achieve an acceptable cladding risk rating (as illustrated in the diagram below).

There are some concepts in the remediation workflow on the following page that require some explanation.

- **Acceptable Cladding Risk**

  The term Acceptable Cladding Risk is a defined term in the Victorian Government's *Cladding Risk Mitigation Framework*.

  There are two pathways that can be used to bring a building to an Acceptable Cladding Risk level:

  1. Intervene in a way that achieves a Low Risk Rating (this can only be achieved by the targeted removal of cladding to break the connection between SOUs created by cladding); and

  2. Retain cladding, but employ interventions that are sufficient to make the building safer than the benchmark building without the proposed interventions and without cladding (the CSV assessments captured in RWPs will demonstrate this).

- **Primary and secondary standards**

  After assessment, all buildings and all cladding clusters (this is the subject of the section that follows) on the building can be assigned to a risk category in a cluster typology.

  The category that each cluster is assigned to will determine the primary standards of intervention that apply. This provides for consistency in the intervention approach to cladding clusters with a similar risk profile (reflected in the cluster typology).

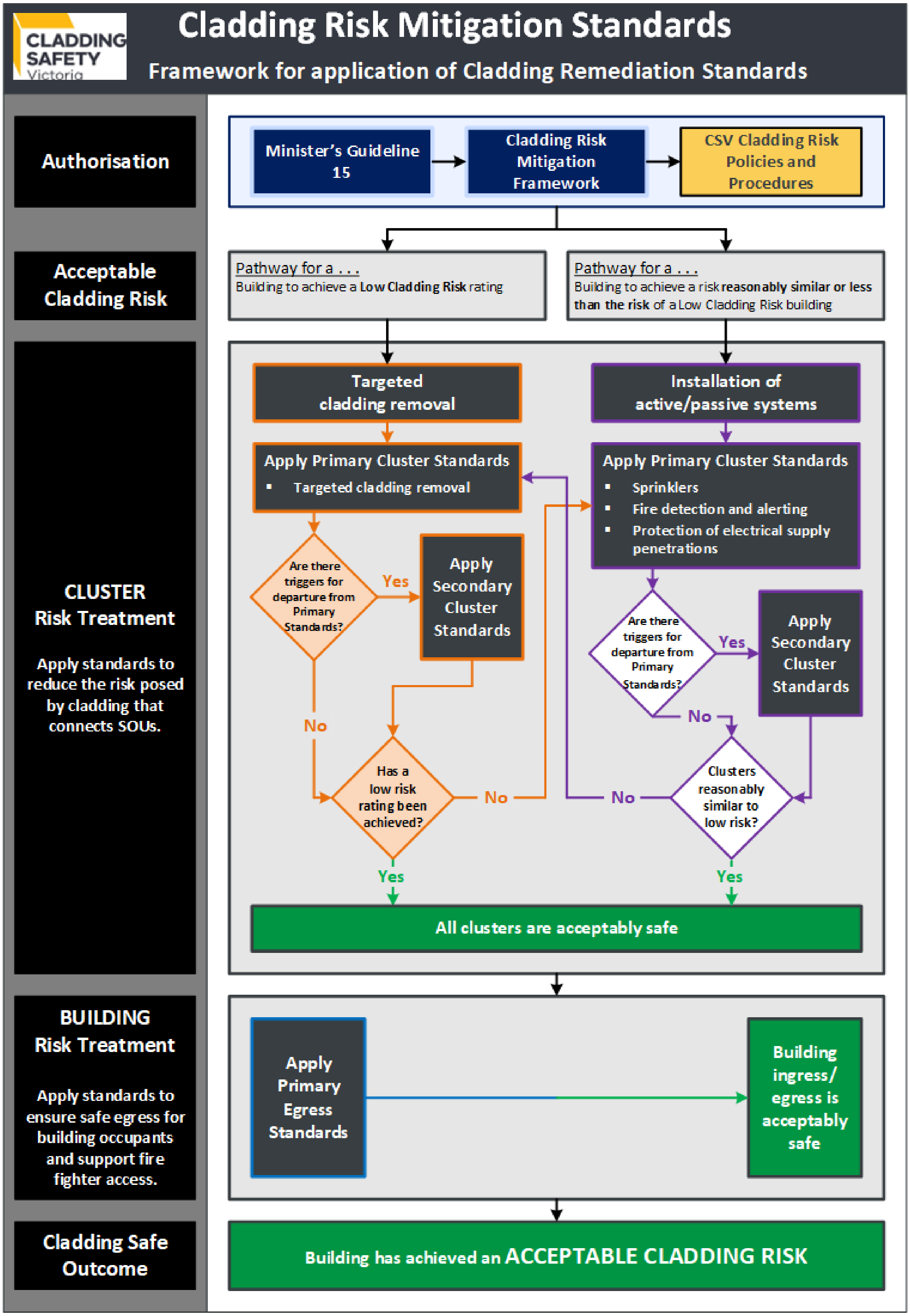
  To ensure the intervention specified in a PMCR primary standard is not ill-fitted to a cluster, the assessment process requires the assessor to consider a number of trigger questions that will help to identify unique aspects of the cluster that may warrant a different intervention response.

  Where a trigger question indicates the presence of a unique attribute of the cluster, variations to the primary standards will be required. These variations are pre-defined and represent a sub-typology of the primary standards. These are identified as secondary standards.

- **Building and cluster risk treatments**

  The PMCR assessment process requires risk to be assessed for the building overall (with a focus on safe egress for occupants) and also for each individual area of cladding on a facade – a cladding cluster. This two-level risk assessment is the subject of section 7.1).

CSV has prepared *Standard Operating Procedures* and *Cladding Remediation Standards* that form part of the PMCR document set (see Appendix A: PMCR document set and flow).


CLADDING SAFETY Victoria
Cladding Risk Mitigation Standards
Framework for application of Cladding Remediation Standards
Authorisation
Minister's Guideline 15
Cladding Risk Mitigation Framework
CSV Cladding Risk Policies and Procedures
Acceptable Cladding Risk
Pathway for a . . .
Building to achieve a Low Cladding Risk rating
Pathway for a . . .
Building to achieve a risk reasonably similar or less than the risk of a Low Cladding Risk building
CLUSTER Risk Treatment
Apply standards to reduce the risk posed by cladding that connects SOUs.
Targeted cladding removal
Apply Primary Cluster Standards
Targeted cladding removal
Are there triggers for departure from Primary Standards?
Yes
Apply Secondary Cluster Standards
No
Has a low risk rating been achieved?
No
Yes
Installation of active/passive systems
Apply Primary Cluster Standards
Sprinklers
Fire detection and alerting
Protection of electrical supply penetrations
Are there triggers for departure from Primary Standards?
Yes
Apply Secondary Cluster Standards
No
Clusters reasonably similar to low risk?
No
Yes
All clusters are acceptably safe
BUILDING Risk Treatment
Apply standards to ensure safe egress for building occupants and support fire fighter access.
Apply Primary Egress Standards
Building ingress/ egress is acceptably safe
Cladding Safe Outcome
Building has achieved an ACCEPTABLE CLADDING RISK

7.1 Assessment of cladding risk

The PMCR design requires the assessment of cladding risk to be undertaken on two levels:

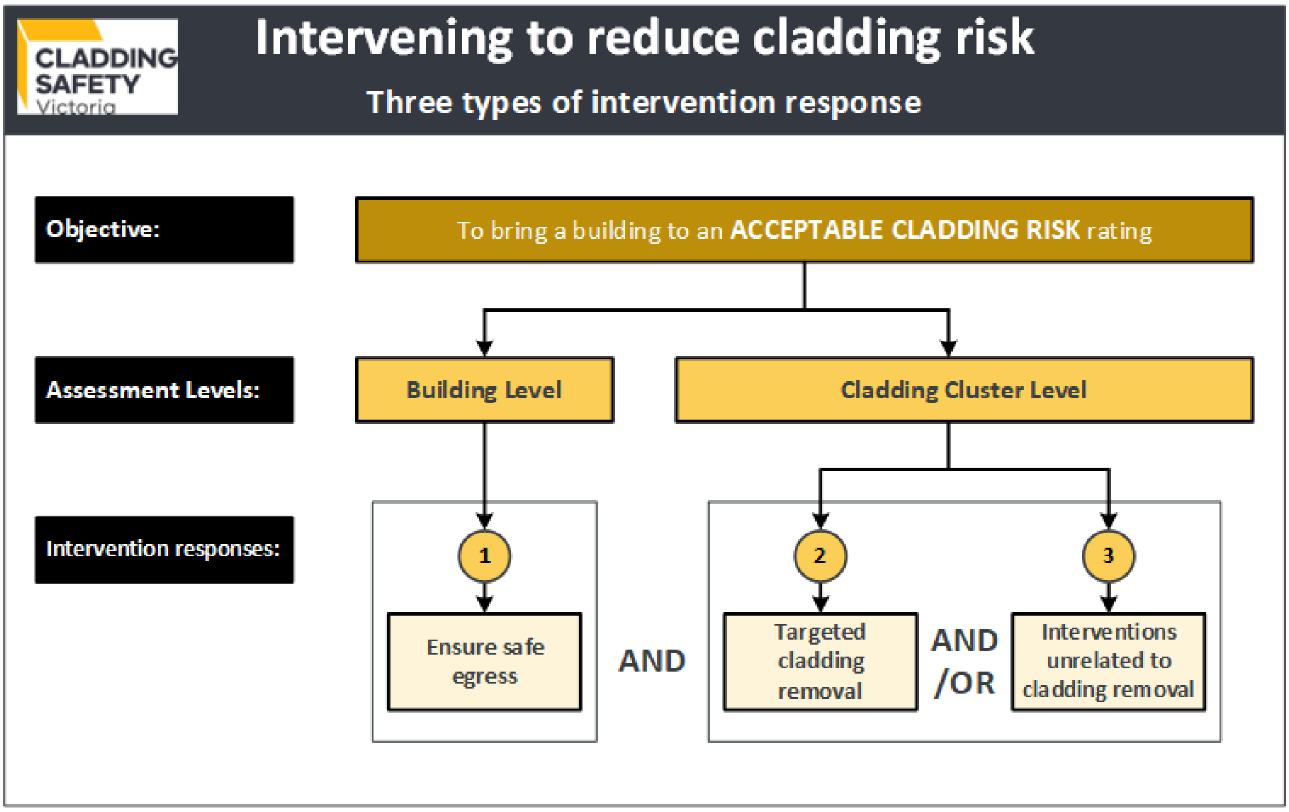
1. Building Level

   This level of assessment is focussed on evaluating the safety of egress options for building occupants. It involves consideration of all available paths of egress from a building as a single assessment exercise. That is, there may be no need for intervention in relation to one egress path compromised by cladding where other 'cladding safe' egress paths are available for each occupant.

2. Cladding Cluster Level

   A building may have one or more areas on the facade with combustible cladding. Each of these areas is referred to as a separate cladding cluster. Each cladding cluster must be assessed independently. The optimal way to apply interventions may vary from cluster to cluster.

The method for bringing a Class 2 or Class 3 building with External Combustible Cladding to a state of Acceptable Cladding Risk requires three types of intervention response to be considered. These types of intervention response are represented diagrammatically below.



To declare a building to have achieved an acceptable cladding risk it is necessary to ensure that:

- Every building occupant has a safe path of egress from the building where there is a cladding fire; and
- Each cladding cluster is acceptably safe after intervention, either by:
  - The targeted removal of cladding to break the connection between SOUs; and/or
  - Retaining cladding and applying other interventions.

7.2 Cladding Clusters

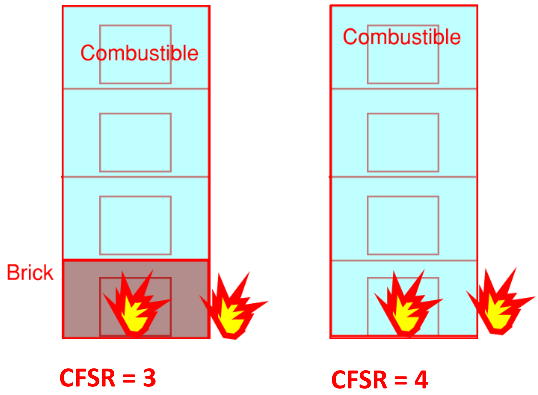
As the key focus is on facade fire spread via cladding, it is imperative that the location and configuration of cladding across an entire building is first understood.

Any assessment of a building to which the PMCR may apply, therefore, commences with an assessment of all cladding.

What is a Cladding Cluster?

A Cladding Cluster is an area on a building facade that has a designated External Combustible Cladding product that runs continuously and overlays some part of the floor plan of one or more SOUs. Each Cladding Cluster is given a number (the Cluster Fire Spread Risk - **CFSR**), which represents the number of SOUs connected by the continuous run of cladding.

The images below depict the representation of cladding clusters and the count of the impacted SOUs.



Different cladding configurations lead to CFSR differences

Cladding connects 4 SOUs (CFSR = 4)

The process of identifying Cladding Clusters

The process for assessing cladding risk and preparing a proportionate response to the cladding risk encompasses five sequential steps that are used to:

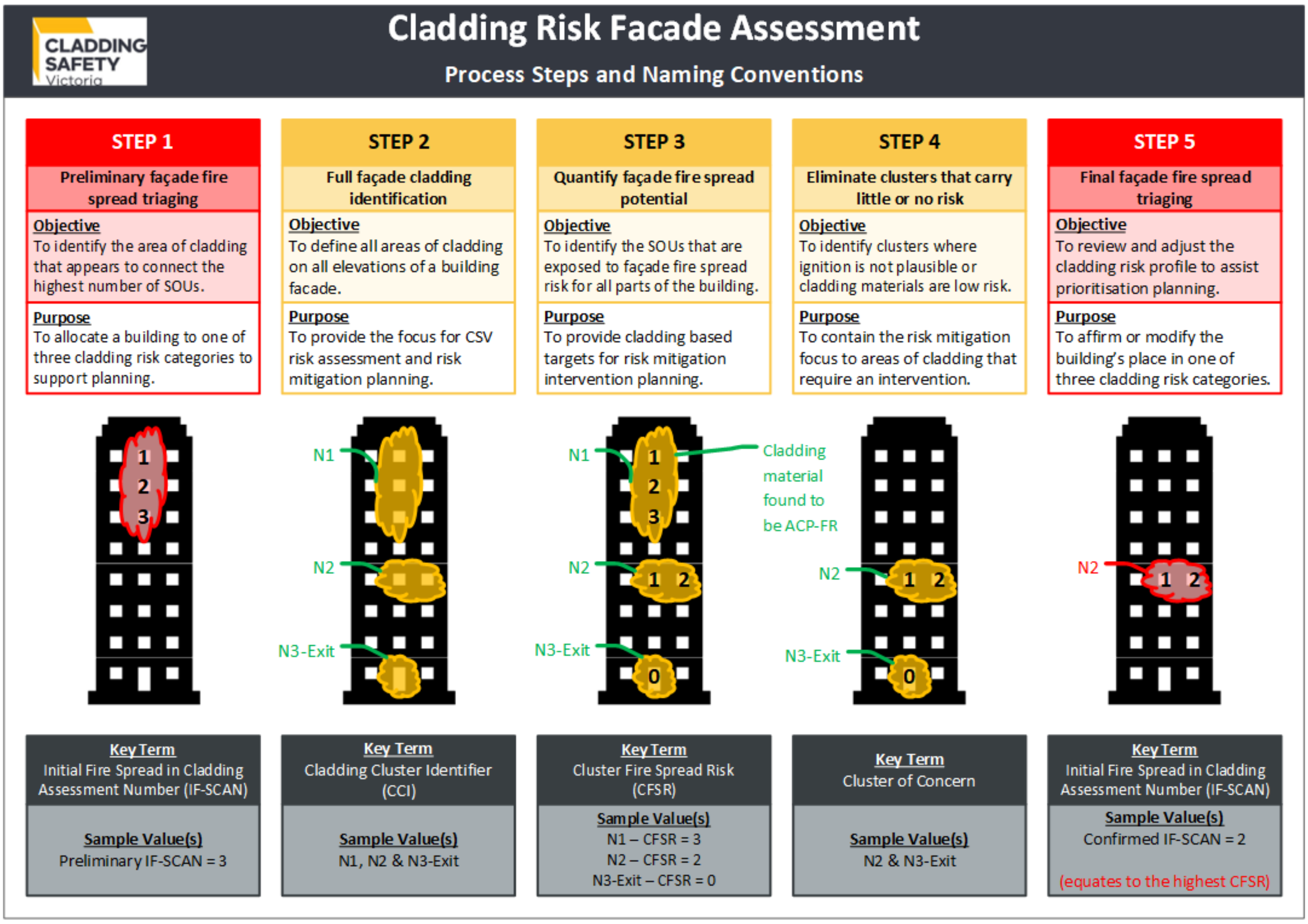
a) Determine the risk profile of a building (informed by the IF-SCAN);

b) Identify and assess each individual cladding cluster (using the CSFR);

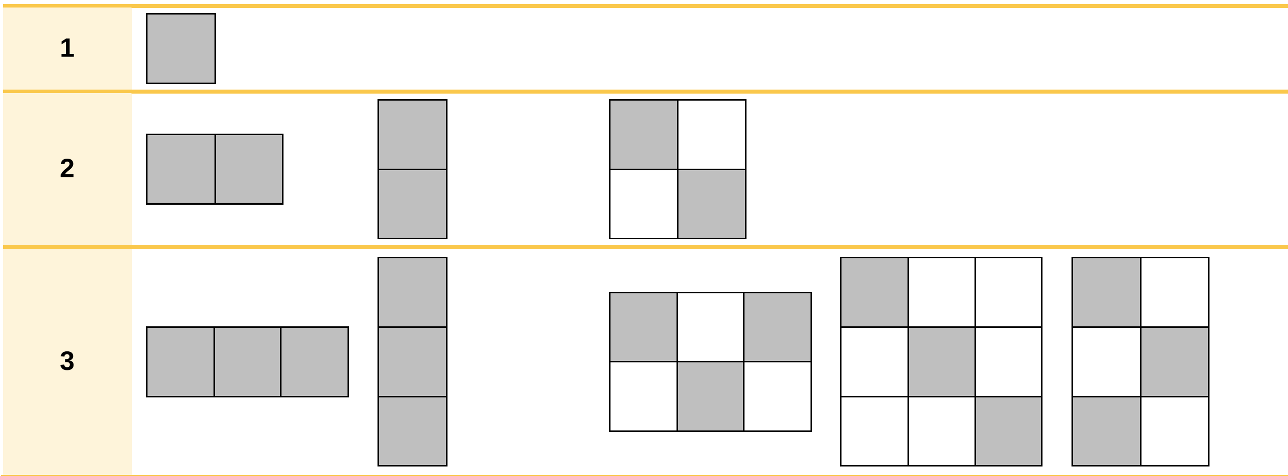
c) Identify and eliminate any cladding clusters that do not represent a plausible risk to occupants; and

d) Set the scope for the application of interventions under the Framework.

This five-step process is illustrated on the next page.



For an elevated risk rated building (for example), all cladding clusters are assessed and a cladding profile developed for the building. This profile identifies all configurations associated with CFSR values of:



In the image above:

- each SOU is represented by a square (☐); and
- each SOU that is connected by cladding is shaded grey (☐).

It is important to identify variations in cladding connectivity for each cladding cluster on a building as the fire spread properties and the effectiveness of risk mitigation interventions may be influenced differently.

Applying interventions to Cladding Clusters

When applying interventions to a cladding cluster as part of an overarching design solution to bring a building to an Acceptable Cladding Risk rating, the interventions only need to be applied to the SOUs that are associated with the cladding cluster.

Building owners may choose, of their own volition, to apply interventions to other SOUs that are not associated with a cladding cluster. In doing so, there is no recognised additional benefit to the assessment of cladding risk under the PMCR Standards.

7.3 Cladding Remediation Standards for risk mitigation interventions

PMCR Standards have been developed for the remediation of cladding risk.

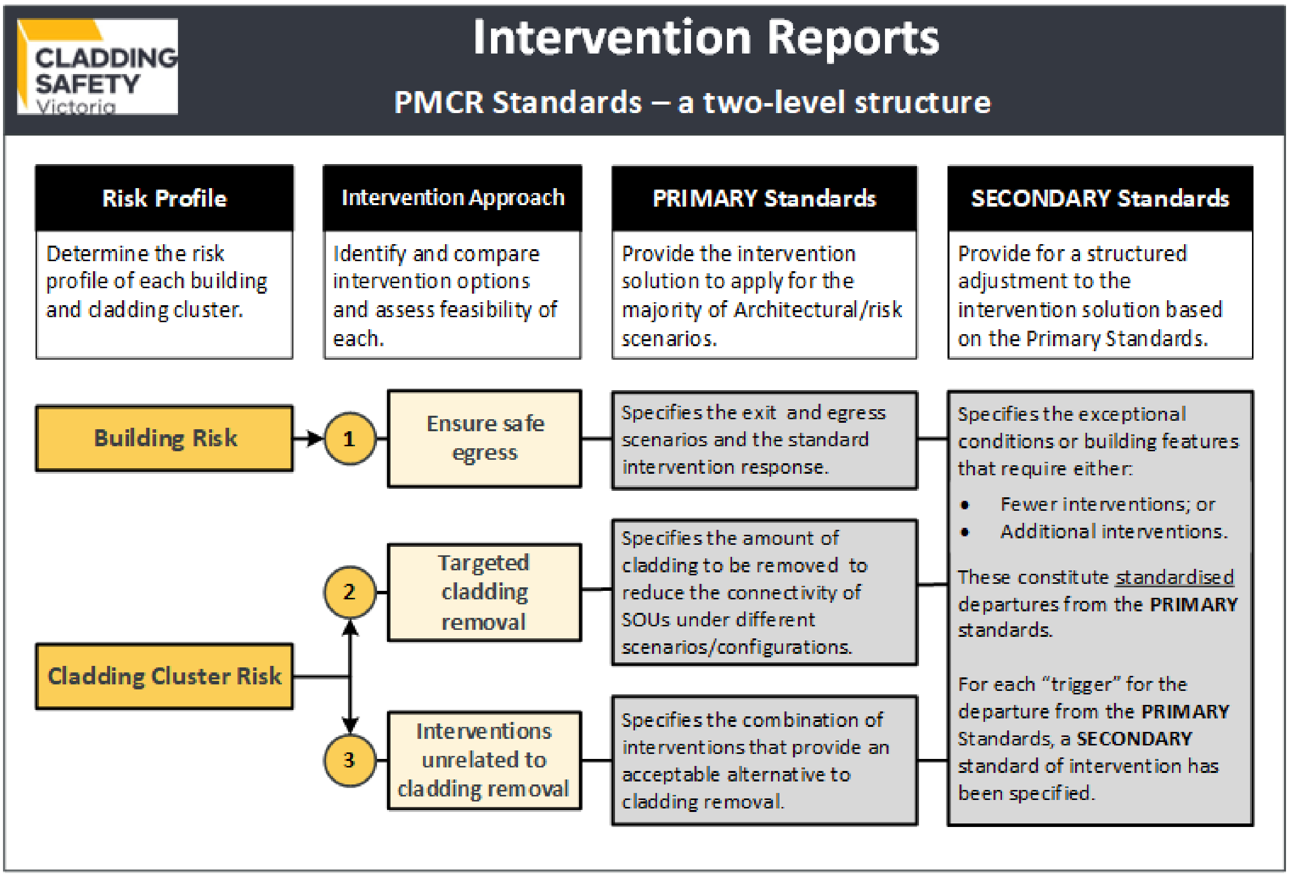
These standards provide a structured way to:

1. Identify the risk profile of each building (and the risk profile of each cladding cluster); and
2. Specify a 'standard' set of interventions that can be applied to bring each cluster and the building to an Acceptable Cladding Risk.

The PMCR Standards comprise two hierarchical levels of standards. This structure is predicated on a risk perspective that:

- A risk profile can be defined for each building and cladding cluster based on a core set of architectural and risk attributes (focussed on exposure to ignition hazards);
- All buildings and cladding clusters that have the same risk profile can generally be brought to an Acceptable Cladding Risk by applying a common set of interventions (**Primary Standards**); and
- Some buildings and cladding clusters will have unique architectural and risk features that warrant a departure from the Primary Standards, and a structured means of departure can be formulated (**Secondary Standards**).

This two-level approach to the design of PMCR Standards is illustrated below.



Before determining whether an intervention is required in response to cladding, a building must first have progressed to the stage where all relevant information has been gathered, all combustible cladding clusters have been defined and rated, and IF-SCAN and CFSR ratings have been assigned. Once this has been achieved, the building is ready for solution design and communication to the relevant MBS and building owners.

Applying interventions involving sprinkler protection should be understood in the context of the structured method for risk profiling that applies to cladding clusters (as described in section 7.4).

7.4 Cladding cluster risk typology

The key determinant of the risk profile of cladding clusters is the availability of sprinklers.

The **four criteria** used to identify the risk profile of a cladding cluster are:

1. The availability of sprinklers in SOUs;
2. Cluster Fire Spread Risk – the CFSR;
3. Building floor level associated with the highest point of the cladding cluster; and
4. Type of Combustible External Cladding.[6]

The application of these criteria creates a **cladding cluster risk typology** with 11 profiles.

The two tables below illustrate how the four criteria intersect to determine the cladding cluster risk typology that are the focus of the PMCR Standards.

<table>
<tr><th rowspan="2">CFSR</th><th colspan="5">Building Rise in Storeys</th></tr>
<tr><th>3</th><th>4</th><th>5</th><th>6 to 8</th><th>9 +</th></tr>
<tr><td>0</td><td colspan="5" rowspan="3">Type A</td></tr>
<tr><td>1</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td colspan="2">Type B1</td><td colspan="3">Type B2</td></tr>
<tr><td>4</td><td colspan="2" rowspan="3">Type C1</td><td colspan="3" rowspan="3">Type C2</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
<tr><td>7 +</td><td colspan="5">Type D</td></tr>
</table>

<table>
<tr><th rowspan="2">CFSR</th><th colspan="5">Building Rise in Storeys</th></tr>
<tr><th>3</th><th>4</th><th>5</th><th>6 to 8</th><th>9 +</th></tr>
<tr><td>0</td><td colspan="5" rowspan="2">Type E</td></tr>
<tr><td>1</td></tr>
<tr><td>2</td><td colspan="5">Type F</td></tr>
<tr><td>3</td><td colspan="2" rowspan="2">Type G</td><td colspan="3" rowspan="2">Type H</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td colspan="5" rowspan="3">Type I</td></tr>
<tr><td>6</td></tr>
<tr><td>7 +</td></tr>
</table>

In total there are:

- 6 cladding cluster types for sprinkler protected buildings (types A to D); and
- 5 cladding cluster types for non-sprinklered buildings (types E to I).

7.5 Exit risk typology

A typology has also been developed for the assessment of exit risk scenarios involving different architectural features and variations in the use of cladding in proximity to the exit and the associated egress paths.

.

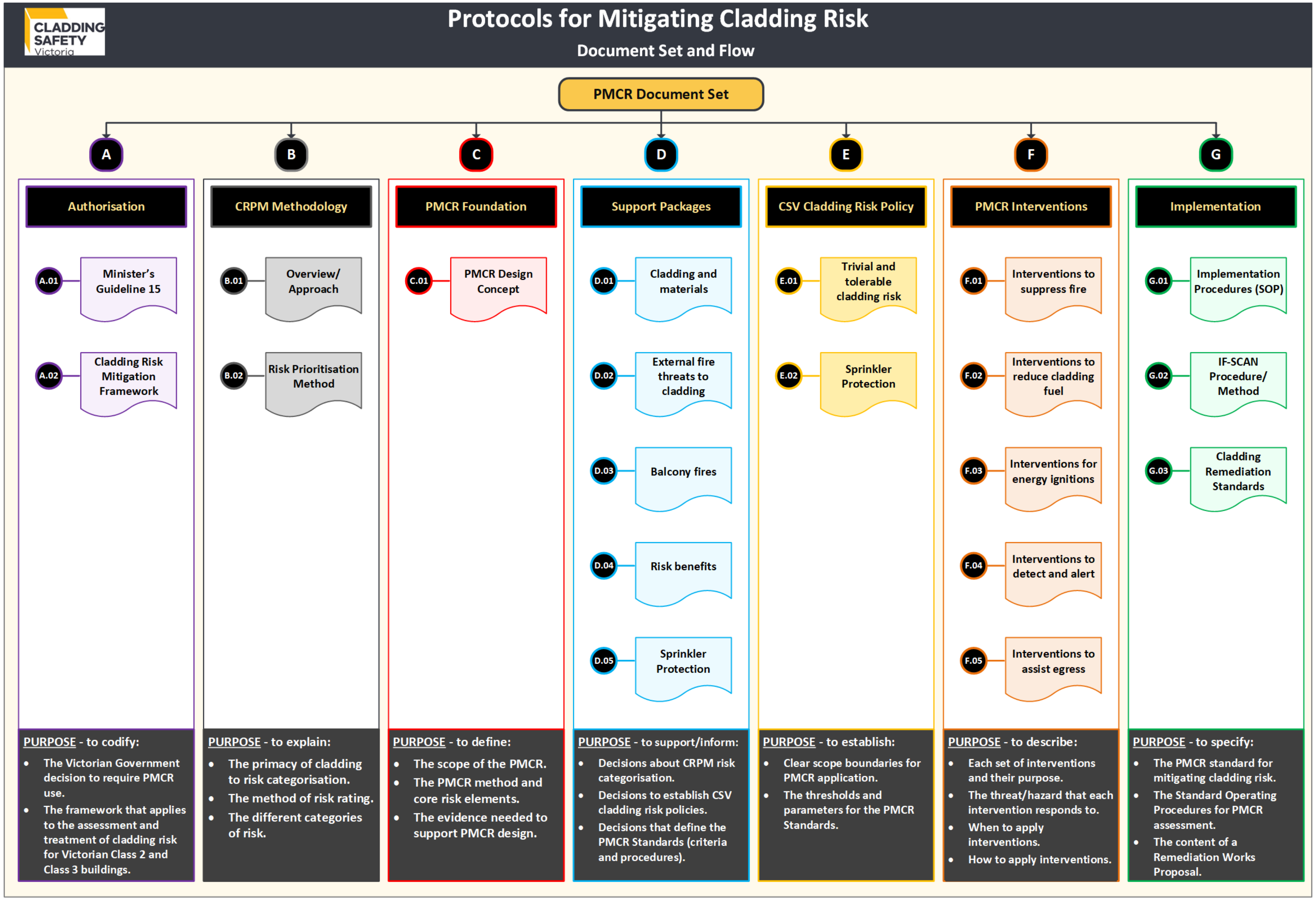
[6] Under the Framework, '**Combustible External Cladding'** means:

i. aluminium composite panels (ACP) with a polymer core which is installed as external cladding, lining or attachments as part of an external wall system; and

ii. expanded polystyrene (EPS) products used in an external insulation and finish (rendered) wall system.

Appendices

Appendix A: PMCR document set and flow



Appendix B: Imperative for a risk-based PMCR design

A structured, systematic, repeatable and proportionate method for addressing cladding risk on lower risk buildings is not available. This leaves thousands of apartment owners and occupants facing cladding risk that they are uncertain about how to address. This problem is not unique to Victoria[7].

In multiple jurisdictions, action is being taken to ensure that **cladding products** with high levels of combustibility are excluded from future construction works.

> On 13 January 2021, the Victorian Government issued the *Prohibition of High-Risk Cladding Products Declaration* (the **Declaration**). The Declaration took effect from 1 February 2021, and provides that:
>
> for buildings of Type A and Type B construction that are the subject of applications for building permits made after 1 February 2021, the use of the following products is prohibited:
>
> - ✓ aluminium composite panels (**ACPs**) with a core of less than 93% inert mineral filler (inert content) by mass in external cladding as part of a wall system; and
> - ✓ all expanded polystyrene (**EPS**) products used in an external insulation and finish (rendered) wall system (together, the Prohibited Products); and
>
> Minister's Guideline 14: Issue of Building Permits Where Building Work Involves the Use of Certain Cladding Products dated 13 March 2018 (**MG-14**) is revoked.

Actions such as this serve to ensure that the scale of the problem will not be extended.

This leaves governments with a potentially large but contained 'problem set' of existing buildings with cladding that require a response. Determining the appropriate level of response for each building is the challenge for planners.

Cladding risk is an area in which governments everywhere have intervened, driven primarily by a need to avert catastrophic risk consequences. Finding a way to calibrate the response so that each building's residents and users are safe is the key to successfully managing this problem across the building population.

Two countervailing approaches to cladding risk are in play that need to be reconciled:

1. the <u>cladding product is the primary problem</u>, its use is generally non-compliant and risk mitigation actions need to be driven to achieve compliance; and
2. the <u>cladding product is not the primary problem</u> - it is the amount, location and configuration of the cladding that constitutes the primary problem, and risk mitigation actions are needed that bring cladding risk to an acceptable level.

A focus on cladding products as **the** problem raises the prospect of an overreaction to cladding risk.

Risk-based and compliance-based approaches are well aligned when cladding risk is rated high and both approaches converge on a solution of full or substantial cladding removal.

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7 A major finding of the New South Wales (**NSW**) Auditor General's Report: *Building regulation: combustible external cladding* (13 April 2022), is "There is no process by the Cladding Taskforce for clearing buildings other than those in the high-risk category". The report further states: ". . . any level of combustible external cladding poses a residual risk to buildings, and some further action may be warranted, subject to appropriate risk assessment and taking into account a proper balance of cost versus risk and benefit. There is no forward plan for any action by DCS and DPE on these buildings."

A key recommendation of the NSW Auditor-General was that by October 2022 the Department of Customer Service and the Department of Planning and Environment should "ensure that the NSW Government Cladding Taskforce develops an action plan, taking into account an assessment of cost versus benefit and risk, to address buildings with combustible external cladding assessed by Fire and Rescue NSW as low-risk."

In contrast, where the cladding risk rating is relatively low, the solutions offered by risk-based and compliance-based approaches tend to diverge.

A compliance-centric response to cladding has the potential to compel building owners to apply substantial cladding removal solutions that are often excessive from a risk-reduction perspective. Risk mitigation solutions that allow the retention of cladding are difficult to justify when the overarching aim is compliance.

A risk-reduction approach can provide a basis for cladding risk to be deemed acceptable (and a level of non-compliance tolerated) where combinations of the following situational elements apply:

- the amount of cladding is small;
- the cladding in use benefits from having fire retardant materials within it;
- cladding is clustered in a way that does not provide for a large-scale fire to be spread via cladding;
- cladding is maintained at a safe distance from ignition sources;
- the location of cladding limits the ability of cladding fires to enter residential spaces; and
- other protections are in place to suppress fires and/or to support residents in being alerted to a fire and to safely evacuate the building.

The adoption of a risk-centric mechanism will enable solutions to be designed, approved and applied for buildings with a lower level of cladding risk. Such a mechanism is not currently available to MBSs.

Rationale for a risk-centric response to cladding

Victoria has developed a consistent and efficient method for removing cladding from high-risk buildings.

A comprehensive framework for addressing **all levels** of cladding risk was considered essential for Victoria.

The extent of cladding use in Victoria is so extensive and the variation in risk exposure so broad across the building population that a tailored risk-centric approach to cladding risk is necessary.

The need for a risk-centric approach is driven substantially by an imperative/opportunity to:

- **address uncertainty** about what types of solution (beyond full cladding removal) will be acceptable for addressing cladding risk on lower risk buildings;
- **satisfy a community need** for timely, clear and consistent information about the risk status of buildings and the options available to building owners to mitigate cladding risk;
- **build on the foundation structure** for risk-centric solution design articulated by the Victorian Cladding Taskforce;
- **leverage and utilise the knowledge and capability** accumulated in Victoria about cladding and the viable responses to cladding risk;
- **apply solutions that are proportionate** to the risk posed by cladding on each building; and
- **address inconsistency and inefficiencies** in engineered performance solutions.

The benefits of a risk-centric approach must be extended to lower risk buildings, for which a structured, tailored and proportionate approach to addressing cladding risk has not previously been clearly articulated.

Addressing uncertainty

The design of a risk-centric approach to the cladding risk must serve to reduce uncertainty and be founded on statements of fact that are underpinned by clear evidence.

With respect to combustible cladding use on multi-dwelling residential properties:

- It is **accepted** that the presence of combustible cladding on buildings increases the fire risk for building residents, users and first responders to a fire.
- It is also **accepted** that the risk posed by combustible cladding varies from building to building.

These two immutable facts have made it necessary for:

1. action to be taken quickly to mitigate risks associated with combustible cladding, and
2. risk mitigation requirements to be scaled in a way that ensures that the burden of taking action to deal with cladding is in proportion with the risk posed by the cladding on each building.

In Victoria, the government acted decisively to respond to the community threat posed by combustible cladding, providing $600 million of direct public investment to reduce cladding risk on the highest risk residential buildings. This investment has already allowed cladding removal work to be initiated on over 300 Class 2 buildings.

The objective to quickly mitigate cladding fire risk in the Victorian built environment is well supported by this action (point **1**, above).

Uncertainty about what could reasonably constitute a viable and practicable solution for buildings with lower cladding risk, leads to a default remedy that involves the removal of cladding.

This uncertainty creates and magnifies problems for the owners of these lower risk buildings:

- the costs of treating risk are high;
- public funding is not available for these lower risk buildings;
- many building owners are either unable or unwilling to self-fund cladding removal works at high cost;
- the residual cladding risk on these buildings remains untreated;
- enforcement actions requiring owners to deal with cladding remain in force;
- there is variability and inconsistency in practitioner views about cladding risk and how to treat it;
- insurance premiums are driven higher due to the presence of cladding; and
- routine property transacting around apartment sales and rental are disrupted.

These are the **dis-benefits** that have accrued for the population of Victorian apartments owners and residents, which a risk-centric approach to responding to cladding risk seeks to remedy (point **2**, above).

Through the design and introduction of the PMCR, Cladding Safety Victoria is seeking to provide a structured approach (and a heightened degree of certainty) to the delivery of acceptable risk mitigation solutions for buildings of all levels of cladding risk.

Responding to community need

CSV manages a pool of approximately 1,600 buildings with varying degrees of cladding risk for which clarity about a pathway to a 'cladding safe' status is sought.

In managing these buildings, CSV is in regular communication with building owners and their representatives. In each of the past three years to 2022-23, CSV has recorded in excess of 10,000 communications between CSV personnel and building owners, providing CSV with clear insights into the expectations and concerns of building owners[8].

For those buildings with an unacceptable cladding risk rating, CSV accords the building a high priority and assesses each building for its eligibility to have cladding rectification works funded. For these buildings, there is a high level of certainty about risk mitigation solutions that is not yet available for buildings with an elevated or low risk rating.

There is a clear imperative to extend the risk response framework so that solutions can be designed and approved for lower risk buildings and importantly clear expectations about the pathway to a 'cladding safe' status can be communicated to building owners.

The development and application of the PMCR will contribute significantly to meeting this community need for clarity about the options available to building owners.

Building on the foundation risk structure

On 3 July 2017, the Victorian Government established the Victorian Cladding Taskforce (the **Taskforce**) to:

"investigate the extent of non-compliant external wall cladding on buildings Statewide, and make recommendations for improvements to protect the public and restore confidence that building and fire safety issues are being addressed appropriately."[9]

Following a two-year period of broad-based review and consultation, the Taskforce laid the foundation for a risk-centric approach to be used for addressing cladding risk in the Victorian context. Their conclusion was that the level of intervention used to mitigate cladding risk should be tailored according to the level of risk associated with each building. This sentiment is captured in the Taskforce's final report (see textbox below).

Rectification should be prioritised on the basis of risk

The new authority should prioritise intervention on the basis of risk, dealing first with **higher risk buildings**. This is necessary in order to reduce the risk of catastrophic incidents. The VBA will be the MBS for most of the higher risk buildings while council MBSs will be responsible for lower risk buildings.

The VBA, acting as MBS for the higher risk buildings should prioritise the issuing of building notices and orders on the basis of risk. Council MBSs will be responsible for buildings classified as moderate or low risk through the audit process. **Low risk buildings** do not generally require cladding removal and an educational approach on fire safety will be appropriate for these buildings. Owners of low risk buildings with some cladding may seek a declaration from the Building Appeals Board under Section 160A of the Building Act 1993 that their building complies with the Building Act.

Buildings identified as **moderate risk** in the audit will need to be further assessed to determine if they require replacement of combustible cladding or whether other steps can be taken to enable them to be categorised as low risk and compliant with the Act.

Source: Victorian Cladding Taskforce: Report from the Co-Chairs, July 2019

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8 Cladding Safety Victoria Annual Reports for 2020-21, 2021-22 and 2022-23.

9 Victorian Cladding Taskforce, Interim report, November 2017.

Implicit in this risk oriented view of cladding is that the large-scale removal of cladding is likely to be unnecessary for many buildings with a lower level of cladding risk.

The Taskforce recommendations provided the impetus for CSV's establishment and the Victorian Government to adopt the risk-centric approach to prioritising cladding rectification works that is now enshrined in CSV's legislative purpose and functions.

The design of the PMCR is predicated on this principle of risk categorisation and the need to specify risk mitigation response options that are both proportionate to the underlying cladding risk and that will be accepted by those deciding whether a cladding risk solution is sufficient to bring that building to an acceptable level of cladding risk.

Leveraging knowledge and capability base

In over four years of operation, over 1,600 buildings with combustible cladding have been referred to CSV, or triaged by CSV for risk assessment, targeted funding support and general advice to building owners. This has allowed CSV to develop a great depth of knowledge and expertise about combustible cladding and the risk it poses to building occupants and users.

CSV has access to detailed information about hundreds of Victorian Class 2 and Class 3 with combustible cladding and has accumulated tens of thousands of hours of knowledge through:

- Building inspections;
- Document reviews;
- Engagement with building owners, practitioners and Municipal Building Surveyors;
- Cladding risk assessments;
- Solution design, costing and review processes; and
- Construction works, now underway or completed on over 350 buildings.

The building data, knowledge and capability that has been generated places CSV uniquely to help to respond to the challenge of dealing, in a proportionate way, with the risk posed by combustible cladding.

CSV is combining this knowledge with science-led innovation to:

1. Assess buildings for cladding risk and assign each building to one of three risk rated categories; and
2. Develop Cladding Remediation Standards and guidance that can be applied to make buildings in each risk category cladding safe.

The **overall aim** is to provide an evidence-based mechanism for cladding risk mitigation solutions to be designed that will support Municipal Building Surveyors (**MBS**) in removing any enforcement action related to cladding.

This recognises that it is MBSs that must be satisfied that sufficient safety measures have been taken in order for an enforcement action[10] imposed on building owners to be removed.

10 An enforcement action includes a building notice, building order, building order for minor work or emergency order issued by the Municipal Building Surveyor under Part 8 of the *Building Act 1993*.

Bringing proportionality to the cladding risk response

In designing a risk-centric approach to cladding risk, one of the primary judgements that needs to be made is what buildings should be included in the set of buildings for which risk mitigation action is required. This is the first level of risk-based judgment that needs to be made.

In particular, does the 'problem set' include:

- Buildings of all types (including free-standing houses, townhouses and other single owner dwellings);
- Buildings of all heights; and
- Buildings in which the cladding products that are in use have flame retardant properties.

In working to address cladding risk, different jurisdictions have defined their respective 'problem sets' in different ways. This type of scope judgement has led to all jurisdictions excluding single owner private dwellings and a number of jurisdictions excluding low-to-medium rise buildings that are under 18 metres tall (typically under 6 storeys). Victoria, in contrast to most other jurisdictions, includes residential buildings under 18 metres (3 to 5 storeys) in the problem set. Moreover, Victoria is the only jurisdiction in the world to focus on buildings under 11 metres in height.

The exclusion of low-rise buildings from scope in many jurisdictions recognises that these buildings have shorter egress paths for escape (relative to mid- and high-rise buildings) and there is an increased capacity for fire fighters to fight fires from ground level on low-rise buildings compared to taller buildings. These types of scope inclusion decisions demonstrate the way in which risk-centric thinking features even before an individual building has been assessed in detail (while recognising that the detailed knowledge of individual buildings amongst experts is what provides the basis for such judgements to be made).

The threat posed by cladding on lower risk buildings, and low-to-medium rise buildings as a subset of these, should be understood in the context of fire risk overall.

Another risk scope factor that differentiates the Victorian response from that of other jurisdictions, is the Victorian focus on expanded polystyrene (**EPS**) as a product of concern. Other Australian states and territories have focussed risk mitigation activity on ACP, as has Victoria. However, many Australian states and territories have not singled out EPS as a high risk product requiring a regulatory response.

United Kingdom experience

In mid 2021, the Ministry of Housing, Communities and Local Government (MHCLG) in the United Kingdom commissioned a panel of independent experts[11] to:

" . . . consider issues of proportionality in relation to building safety in medium and lower-rise blocks of flats, the impact on the housing market, and what more government could do to ensure approaches that are proportionate to the level of risk."

In preparing its statement for the MHCLG, the independent experts noted:

"MHCLG Advice Notes and expert opinions provided to government have consistently supported a proportionate risk-based approach to fire safety in buildings. Unfortunately, since the Grenfell Tower tragedy, not everyone involved has adopted such an attitude towards building safety."

Excerpts from the statement of the independent experts to the MHCLG are presented in the textbox below.

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11 *Independent expert statement in building safety in medium and lower-rise blocks of flats*, presented to the Ministry of Housing, Communities and Local Government, United Kingdom, 21 July 2021

Independent expert statement in building safety in medium and lower-rise blocks of flats

…

6. Fires in homes in England are rare, including high rise. Fire data provided to the Home Office by Fire and Rescue Services shows that:

   a. Dwelling fires attended by fire and rescue services in England have reduced by more than a quarter over the last decade and are at an all-time low since comparable statistics started to be collected in 1981/82. This is despite the fact that, in 2020, people spent very much greater amounts of time in their homes as a result of Covid restrictions. In the year ending December 2020, there were 27,482 primary dwelling fires attended by Fire and Rescue Services in England. That is 75 a day, spread across 24 million dwellings in England.

   b. The vast majority of fires (91%) were in houses, bungalows, converted or low rise (three storeys or lower) flats or other properties, while 9% were in blocks of flats of four storeys or more.

   c. While any death in a fire is tragic, only a small proportion of fires resulted in a fire-related fatality in 2020: 176 people in total lost their lives in dwelling fires (down from 257 in 2009/10), of which just 10 fatalities were in blocks of flats of four or more storeys. This is the lowest number of fatalities from fire since comparable statistics began to be collected forty years ago.

   d. Very few fires spread from the room where they start, and incidences of fire spread are rarer in blocks of flats over four storeys than in lower rise dwellings. In 2019/20, 7% of fires spread beyond the room of origin in blocks of flats over four storeys, compared with 9% in blocks below four storeys and 14% in houses, bungalows, converted flats and other dwellings.

…

11. The evidence is clear that the risk of fire related fatalities is very low in buildings of any height. Government's decision to focus its attention on greater risks from fire spread in high rise buildings of 18m and over is a proportional response to the level of risk. Furthermore, the evidence on medium rise blocks of flats over four storeys shows that incidences where fires spread are rare.

. . .

12. While we know that there have been systemic failures in assuring quality and oversight of the way in which some blocks of flats were built in the past this cannot be taken to mean that there is a systemic risk of fire in blocks of flats.

13. Furthermore, in most cases in blocks of flats below 18m where fire safety risks are identified (such as the presence of combustible cladding), adequate levels of safety can be achieved for residents by implementing cost effective risk mitigations (such as smoke and fire detectors and alarms, adequate means of escape, sprinklers and smoke control systems). Where these risk mitigations are not present their introduction, or other cost-effective measures or enhancements, can mitigate risks identified without unnecessarily financially burdening those involved. Where EWS1 forms and assessments have already been completed for buildings below 18m and have identified costly remediation work we strongly recommend that these assessments are reviewed to ensure that the proposed solution is cost effective and proportionate.

. . .

15. However, based upon the evidence available, it is clear that in blocks of flats below 18m the risk aversion that we have seen in the mortgage and insurance markets - in the identification of significant and costly construction works to completely replace external wall systems or in the additional scrutiny being applied through encouraging or even mandating EWS1 assessments - is unjustified and unnecessary. There should not be an assumption that there is significant risk to life unless there is clear evidence to support this.

. . .

Source: Independent expert statement in building safety in medium and lower-rise blocks of flats, presented to the Ministry of Housing, Communities and Local Government, United Kingdom, 21 July 2021.

The key data presented for the United Kingdom amplify the call for a proportionate risk-centric response to cladding on lower risk buildings. This is based on the fact that:

- Building fires are very rare events;
- Fire history in the UK indicates that the incidence of fires (and fire related fatalities) is lower than it has been for 40 years, contrasting with a false perception of reduced fire safety in modern built environments;
- The majority of fires and fatalities occur in buildings under three storeys; and
- Very few fires spread beyond the room of origin, reducing the likelihood of internal fires reaching cladding.

Of particular interest is the assertion in the independent expert statement that a significant risk to residents should not be assumed without clear evidence to support this view being provided. In contrast, the burden of proof in Victoria is placed on building owners, who need to show cause for why cladding should not be removed (once an enforcement action is in place).

In other international developments that pertain to the response to cladding risk, the Scottish Government has introduced legislative safety reforms from 1 June 2022:

". . . requiring any cladding on domestic or other high risk buildings above 11m to be strictly non-combustible."[12]

Of interest is the different treatment of buildings under 11 metres in height (equating to buildings under 4 storey), illustrating again the way in which building height is seen as a factor in considering the level of risk exposure associated with combustible cladding.

In developing a proportionate response to cladding in the built environment, it is vital to contemplate the genuine risk to building occupants and users based on fire history and evidence.

Addressing inconsistency/inefficiency in fire engineered solutions

Solutions entailing the retention of cladding are already able to be accommodated within the existing regulatory framework applying to building safety in Victoria.

The development of performance solutions (that provide for some cladding to be retained), rely on fire engineered solutions that in CSV's experience have resulted in remedies that sometimes prove to be more costly than solutions involving the removal of all cladding.

Furthermore, the development and assessment of fire engineered performance solutions involve lengthy processes that do not necessarily yield consistent and repeatable outcomes.

Practitioner actions have not always supported owners in developing low-cost options to mitigate cladding risk.

One function of a risk-centric approach must be to bring greater efficiency, consistency and proportionality to solution design, particularly for buildings with a relatively low risk profile.

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12 Statement from Scottish Building Standards Minister Patrick Harvie in relation to proposed reforms on 22 April 2022 (https://www.gov.scot/news/ban-on-combustible-cladding/).

Conclusion

Combustible cladding is a unique and far-reaching fire safety problem that warrants attention in its own right. Governments around the world have called for cladding risk to be treated as a unique element that demands a priority focus for building planners, practitioners and regulators.

When assessing a building, solution designers require a degree of freedom to separate issues of cladding risk from other sources of risk in order to effectively prioritise the treatment of cladding risk. This is a necessary response to a short-term problem that, once remedied, will not return[13].

Other sources of building risk will and must continue to be the focus of existing practices designed to address issues of safety beyond cladding.

In determining the treatments necessary to reduce cladding risk, it is necessary to consider the true risk posed to building occupants by cladding so that solutions can be designed that provide a proportionate response to the risk and do not unnecessarily burden the residents and owners of buildings with cladding.

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13 Regulatory instruments banning the future use of combustible cladding products are instituted to ensure that the scale of the cladding problem does not grow. In Victoria, *Prohibition of High-Risk External Wall Cladding Products Declaration* was published in the Victorian Government Gazette on 13 January 2021.

Appendix C: A review of relevant literature and software (2022)

The PMCR has been developed over a period of more than two years. This appendix contains the results of a literature review and PMCR design considerations and planning that were assembled in 2022.

These are included here to reflect the continuity in the CSV research endeavour and the history of PMCR evidence-led planning.

CSV has continued to develop its scientific approaches and understanding of external facade material fire-spread dynamics based upon the early works and considerations provided below.

This appendix contains the review of most relevant literature found at the time of report. This includes technical/practice guides or other activities relating to cladding rectification, risk tolerance, fire testing with different cladding type and fire simulators. These areas have been selectively reviewed with a focus on their relevance to the target building group (i.e. those with elevated cladding risk).

Separate sections within this appendix have been provided for:

- Standards and practices regarding assessment and rectification of combustible cladding;
- The ALARP risk principle;
- Fire testing;
- Software; and
- Cellular Automata and Bayesian Network approaches.

A summation of the main findings from the literature review are also presented.

Standards and practices regarding assessment and rectification of combustible cladding

The development of the protocols is informed by existing standards and practices that pertain to the assessment of cladding risk and the design of mitigation requirements and pathways to mitigate cladding risk.

The following practice guides are the focus of this section:

1. Engineers Australia's Society of Fire Safety Practice Guide for Façade/External Wall Fire Safety Design [4].
2. High Rise Buildings with Combustible Exterior Wall Assemblies - Fire Risk Assessment Tool by the National Fire Protection Association [5], and
3. PAS 9980 – Fire risk appraisal and assessment of external wall construction and cladding of existing blocks of flats – Code of practice [6]

AUSTRALIA: Society of Fire Safety Practice Guide for Façade/External Wall Fire Safety Design (by Engineers Australia)

The practice guide for facade/external wall fire safety design [4] (by the Society of Fire Safety, Engineers Australia - referred to as SFS Practice Guide hereafter) proposed an instructional methodology to conduct fire risk assessment of external fire spread hazard of buildings with combustible claddings.

The SFS Practice Guide discussed about the risk assessment approach based on "As Low As Reasonably Practicable" (ALARP) and "So Far As Is Reasonably Practicable" (SFAIRP) with the recommendation on the SFAIRP approach over issues relating to insurability and professional liability of the buildings and building practitioners.

The methodology includes a three-phase assessment (as illustrated in Figure 1) which includes sequential investigations on hazards, consequences, fire scenario, risk goals as well as remedial measures. The SFS Practice Guide does not include a newly developed risk rating methodology but recognises the use of the Department of Environment, Land, Water & Planning and Victorian Cladding Taskforce risk assessment tool (DELWP/VCT Tool) and the National Fire Protection Association (NFPA) EFFECT Tool for phase 1 and AS/NZS 31000 for both phase 1 and phase 2. A comprehensive list of fire safety design aspects, possible fire scenarios and rectifications was also proposed in this SFS Practice Guide. Examples of fire scenarios and rectification measures proposed in the SFS Practice Guide are illustrated in Table 2 and Table 3. The full list of recommended rectification can be found in Appendix 3 of the SFS Practice Guide.

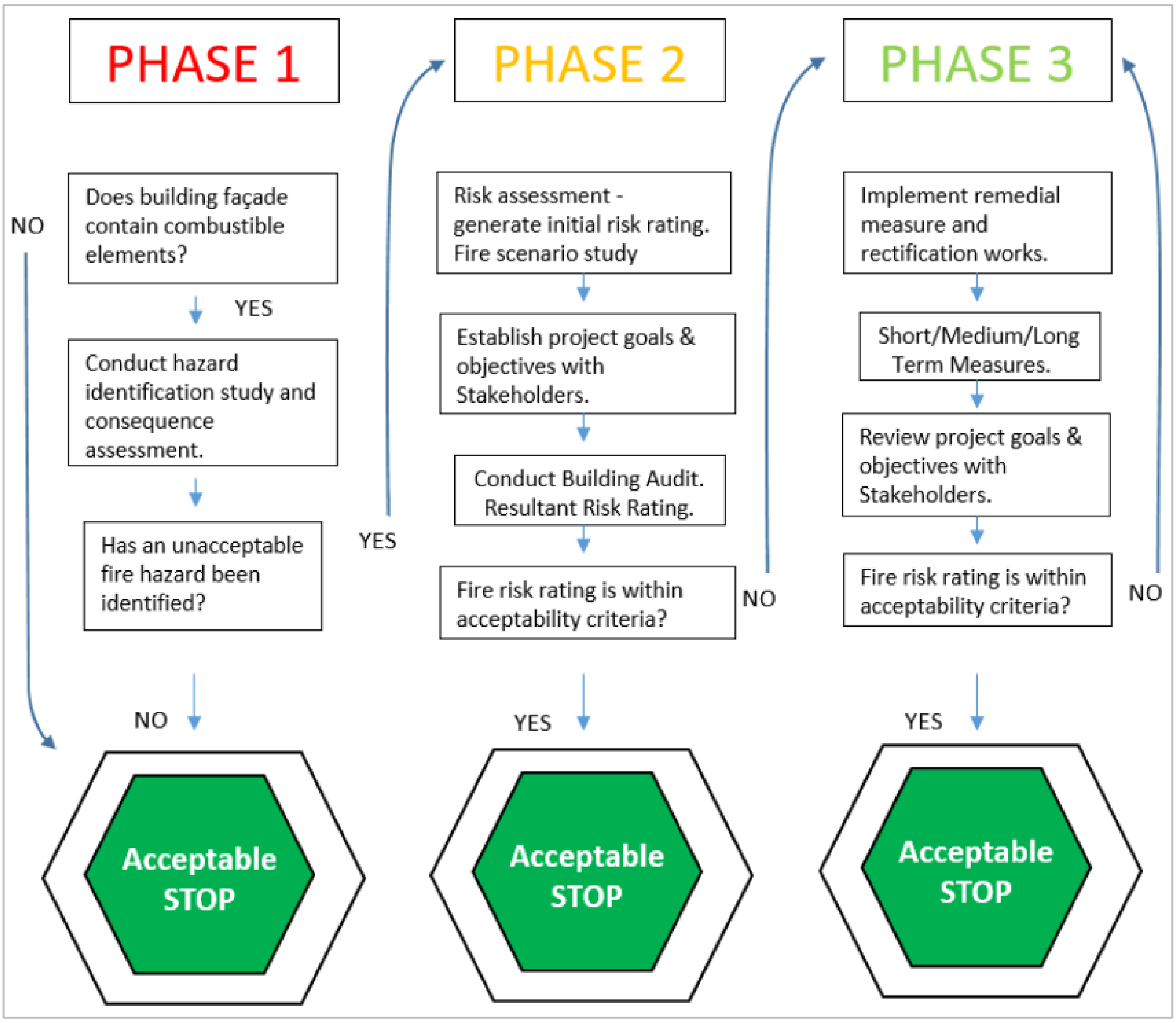


Figure 1: Flow chart of three-phase methodology for fire risk assessment as proposed by Society of Fire Safety, Engineers Australia [4]

Table 1: Examples of fire scenarios relating to cladding fires as mentioned in the SFS Practice Guide [4]

Fire scenario	Description
Internal fire	Fire on the floor plate Fire in the kitchen Fire on the balcony
External fire	Fire in car underneath building façade/awning Fire in waste bin and skips Fire in the external seating area
Fire across the boundary	Fire in building across the title boundary Bushfire event

Table 2: Examples of rectification measures as mentioned in the SFS Practice Guide [4]

System	Elements
Active systems	Upgrade of automatic suppression (sprinkler) – to enhance coverage where not already provided, upgrade to fire brigade facilities (hydrants) – to extend coverage, enhance detection and alarm systems to provide warning of a façade fire.
Passive Protection	Removal or replacement of panels – partial or complete depending on the results of the risk assessment, introduction of separation – barriers within cavities and/or creating fire breaks to arrest spread via the façade, enhanced internal separation – to the building compartmentation strategy, or the isolation of fire escape routes.
Operational	Eliminate, or if not possible isolate, all combustibles that can create a fire exposure to the façade, both external and internal. Manage the use of balconies and external spaces. Staff training and increased warden to occupant ratio.
Means of escape	Afford people greater choice of escape routes along with effective training, demonstrate that the total building evacuation time can be decreased.
Fire Fighting	Enhance access routes to and within the building to reflect façade fire hazard, increase information – building info packs, signage, staff interface – for attending crews.

The SFS Practice Guide provides details on the identification of hazards based on building fire safety design, fire scenarios and possible rectification measures that can be inputs for the development of PMCR. There is a lack of a specific risk rating tool for claddings especially those associated with elevated risk as the Victorian Cladding Taskforce Risk Assessment Tool is only recommended for phase 1 while the AS/NZS 31000 is a general method on any fire risk assessment process.

INTERNATIONAL GUIDE: High rise buildings with combustible exterior wall assemblies: Fire Risk Assessment Tool (by NFPA)

NFPA published a report of their EFFECT Tool (referred to as NFPA FRAT Report hereafter) which documented the development of EFFECT. EFFECT is a qualitative tool being used to prioritise buildings with combustible cladding based on their fire risk as well as to measure the success of the mitigation measures proposed by revisiting the risk assessment. The process was proposed with three tiers: Tier 1 – Prioritisation of buildings, Tier 2 – Fire risk assessment by enforcers or authority having jurisdiction and proposing initial mitigation measure and Tier 3 – Further fire risk assessment and mitigation by fire and façade engineers. EFFECT Tool covers Tier 1 and Tier 2 of the above-mentioned process.

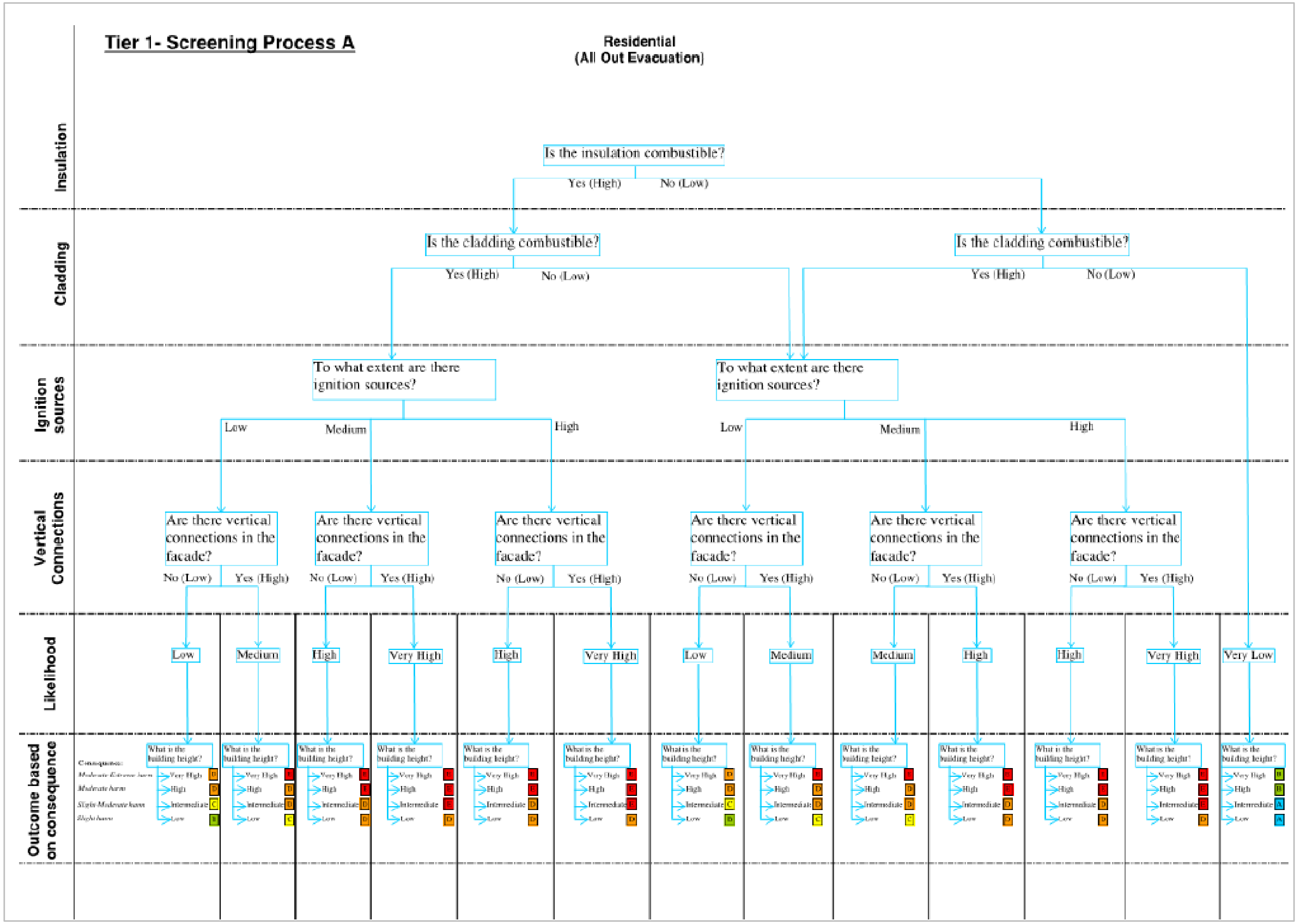
The outcome of EFFECT Tool is a ranking scale that identifies the response for a particular building with combustible cladding. This ranking scale has been extracted from PAS 79:2007 [7] which has been supressed by PAS 79-1:2020 [8] and PAS 79-2:2020 [9].

Outcome Ranking	PAS 79	Action & Timescale
A	Trivial	No action is required.
B	Tolerable	No immediate action is required. No major additional fire precautions are required. However, there might be a need for reasonably practicable improvements that involve minor or limited cost which can be considered in the longer term.
C	Moderate	Action is required in the medium term. It is essential that efforts are made to reduce the risk. Risk mitigation measures, which should take cost into account, should be implemented within a defined time period.
D	Substantial	Action is required. The risk could be substantial. Considerable resources might have to be allocated to reduce the risk. If the premises are unoccupied, it should not be occupied until the risk has been reduced. If the premises are occupied, urgent action should be taken.
E	Intolerable	Urgent action is required. It may be that premises (or relevant area) should not be occupied until the risk is reduced.

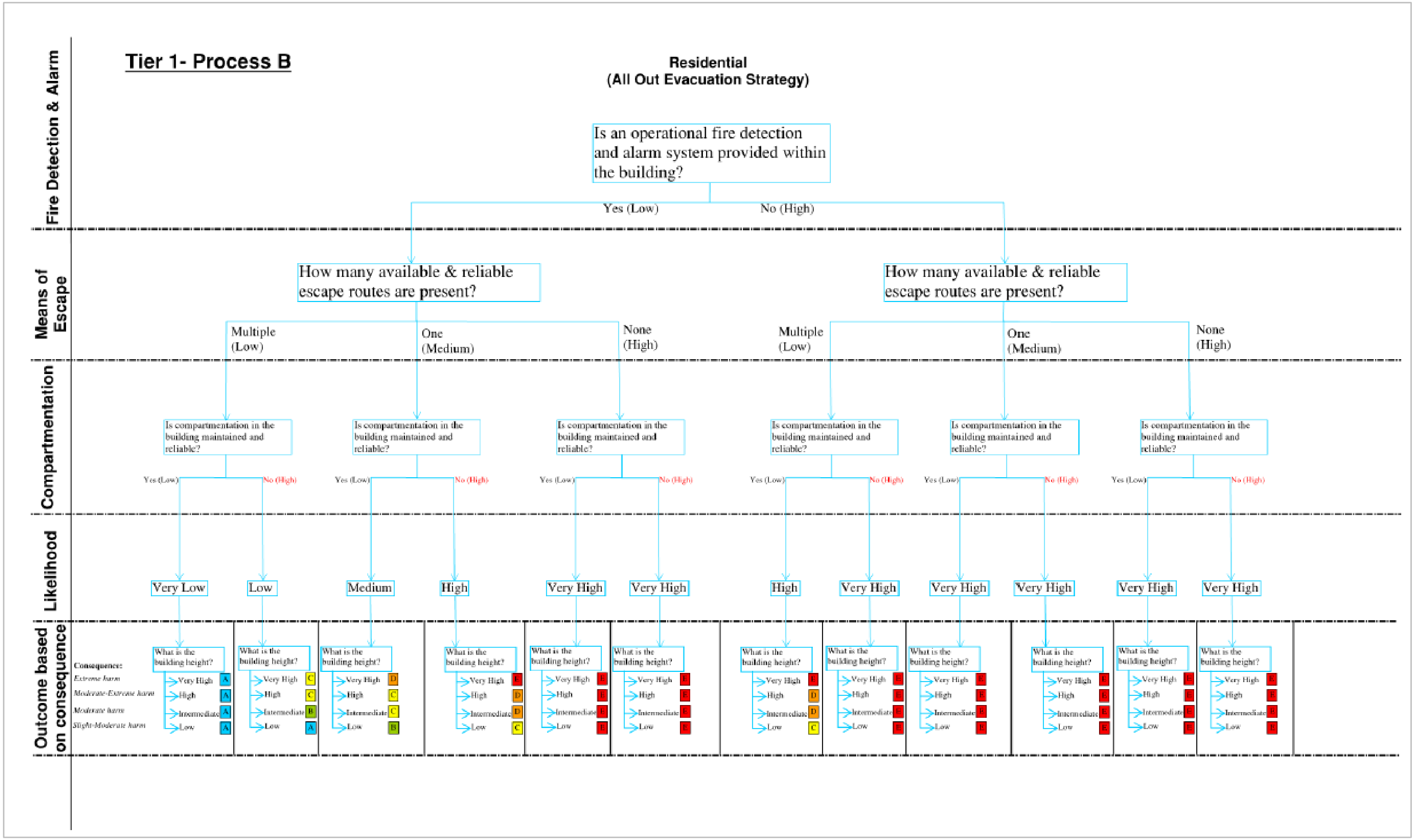
Figure 2: Ranking outcome of EFFECT Tool [5]

NFPA FRAT Report considers buildings with different occupancy use (office and residential) and evacuation strategies (all out vs. stay put). This review only covers residential buildings with all out evacuation as this is the likely strategy being used in Australia. Figure 3 contains flow diagrams for the two parallel processes conducted in Tier 1. It is noticed from Figure 3 that there is no risk differentiation given to buildings with various height of vertical connections. When the combustible cladding is vertically connected over the height of the facade, it is clear that the likelihood of a fire spread over multiple floors is higher; however, the extent of these vertical connections trigger different fire spreads and thus a differentiation to the risk should be considered. In addition, the building height is considered in NFPA EFFECT as a factor affecting the consequence of a fire on multiple stories. Considerations were not given whether combustible claddings exists partially or fully over the building height.

NFPA FRAT Report also provides four mitigation measures, namely (1) management solutions, (2) repair and regular testing/maintenance of existing fire safety provisions, (3) installation of additional fire safety provisions (active or passive), and (4) facade system remediation with an increase in the effectiveness to reduce fire risk in that order.


Tier 1- Screening Process A
Residential
(All Out Evacuation)
Insulation
Cladding
Ignition sources
Vertical Connections
Likelihood
Outcome based on consequence
Is the insulation combustible?
Yes (High)
No (Low)
Is the cladding combustible?
Yes (High)
No (Low)
Is the cladding combustible?
Yes (High)
No (Low)
To what extent are there ignition sources?
Low
Medium
High
To what extent are there ignition sources?
Low
Medium
High
Are there vertical connections in the facade?
No (Low)
Yes (High)
Low
Medium
High
Very High
High
Very High
Low
Medium
Medium
High
High
Very High
Very Low
What is the building height?
Very High
High
Intermediate
Low

(a)



(b)

Figure 3: Tier 1 process A (upper) and process B (lower) as proposed by NFPE EFFECT [5]

To sum up, the NFPA EFFECT Tool was developed to qualitatively prioritise cladding risk based on likelihood and consequence as well as to validate the efficacy of mitigation measures. This is a general tool that was designed for all buildings with combustible claddings. Therefore, there was limited consideration on the extent of the vertical connection of claddings as well as the partial or full coverage of the combustible claddings over the height of the facade.

The NFPA EFFECT TOOL appears to operate at too high a level of aggregation for it to be applied to reduce the cladding risk premium on elevated risk buildings in Victoria.

INTERNATIONAL GUIDE: PAS 9980:2022 Fire risk appraisal and assessment of external wall construction and cladding of existing blocks of flats – Code of Practice

PAS 9980:2022 Fire risk appraisal and assessment of external wall construction and cladding of existing blocks of flats – Code of practice [6] (development facilitated by the British Standards Institution, referred to as the PAS 9980 hereafter) provides guidance and recommendations directly applicable to the risk associated with the spread of fire across external walls.
PAS 9980:2022 informs consultants and building industry professionals by forwarding an appropriate method for structuring Fire Risk Appraisals and Assessments (now defined as the Fire Risk Assessment of External Walls) that relate specifically to the external wall fire spread in UK apartment buildings.

PAS 9980:2022 acknowledges that fire spread between levels of an apartment building is possible in all cases unless the fire is extinguished before this occurs. PAS 9980:2022 is a tool that discusses the external wall systems of an apartment building in their entirety – PAS 9980:2022 does not discuss the risk of combustible cladding specifically.

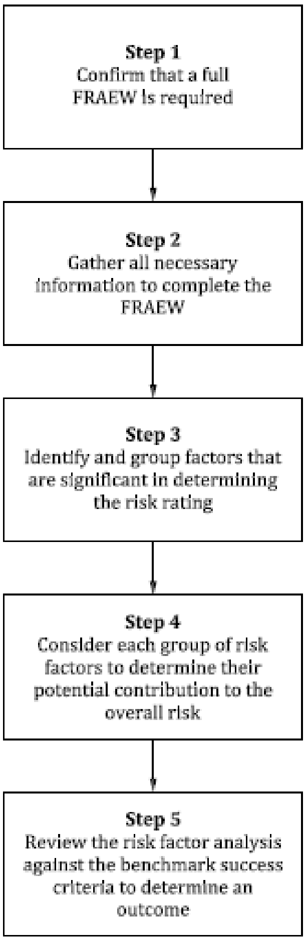


Figure 4: The five step approach as identified in PAS 9980:2022 [6]. FRAEW stands for Fire Risk Assessment of External Walls

PAS 9980:2022 proposed a five-step approach defined in the FRAEW (Fire Risk Assessment of External Walls) as shown in Figure 4; however, it does not provide a clear benchmark for tolerable risk. The fundamental concepts proposed in PAS 9980:2022 can be applicable to the protocols which are:

- Fire spread is likely to result in ‘limited’ secondary fires.
- Increased early warning should alert occupants to evacuate before the adverse impacts of a resulting secondary fire are experienced.
- Secondary fires resulting from a cladding fire should not compromise common area egress paths.
- Fire and rescue service intervention is likely to be effective due to increased occupant warning and earlier brigade notification.
- PAS considers a method for identifying risks that are associated with external fire spread that informs the high-level selection of risk mitigating measures (interventions) appropriate to various external wall fire spread scenarios.
- Similarly, PAS 9980:2022 recognises the need for a pragmatic approach, less about compliance benchmarks and more about appropriate levels of risk mitigation. For the purposes of the PMCR, appropriate level of risk mitigation attributable to a very specific building set (IF-SCAN 2-3).
- Additionally, the PAS acknowledges the differing levels of fire engineering experience may be required depending on a problems complexity. The PMCR accepts that for this specific building set, an MBS should have the required level of competency to implement the protocols. Where buildings are outside of the PMCRs scope, the services of a registered and experienced fire safety engineer is required.
- Regarding balcony fires, PAS 9980:2022 qualitatively assesses a balconies potential or the likelihood of storage. Resolving a building’s IF-SCAN similarly requires that the MBS turn their mind to the extent to which a balcony is enclosed and the likelihood of a balcony being used for significant storage.

The ALARP risk principle

The ALARP principle is often used in risk management aiming at reducing the risk to a level deemed tolerable without over-investment [10]. The ALARP principle is widely accepted, including in informing judgements and formal decisions made by regulators and for government policy development [11]. The application of the ALARP principle relates to finding solutions in a tolerable region between high-risk and the low-risk thresholds (see Figure 5). The high-risk area of the graph is considered intolerable whilst the low-risk area is considered negligible.

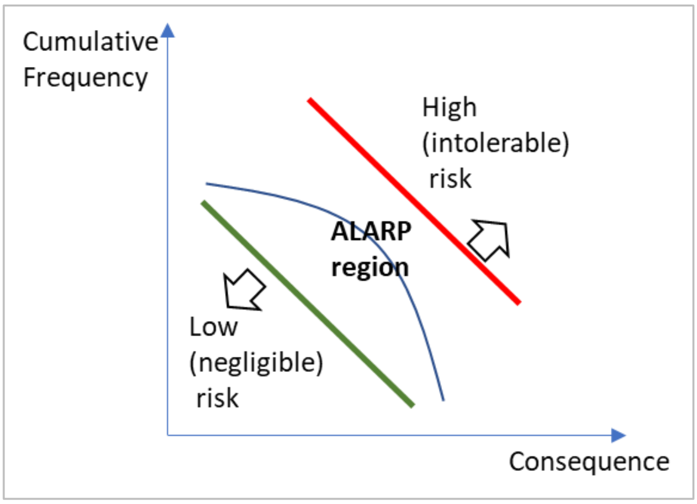


Figure 5: Graphical representation of the ALARP principle [12]

In Figure 6, the axes relate to event frequency per unit time (e.g., number of fatal building fires) and to event consequence per time (e.g., number of fatalities). Expected loss, i.e., risk, is the product of these axis values. Thus, it is suggested that the risk-neutral societal risk thresholds are linear on a log-log plot with these axes [13], meaning that an event with ten times more severity in outcome is tolerated only if it has at most one tenth of the frequency of a comparative event that is just below the intolerable risk threshold.

For many practical problems, there will be a range of feasible solutions contained within the tolerable risk region. An efficient frontier of these solutions can be formed on a plot of residual risk (RR) versus input resource intensity[14] (IC). The solutions on this frontier are non-dominated with respect to input resource intensity and residual risk: for a given RR the non-dominated solution has the least value of IC, and moreover there is no lower RR available without increasing the IC. Hence the ALARP principle is satisfied by each of these efficient-frontier solutions because they are drawn from the ALARP region and RR is minimised for a reasonably practical risk-reducing resource expenditure IC. We have maximised the benefits out of the available resources which can be deployed for risk mitigation.

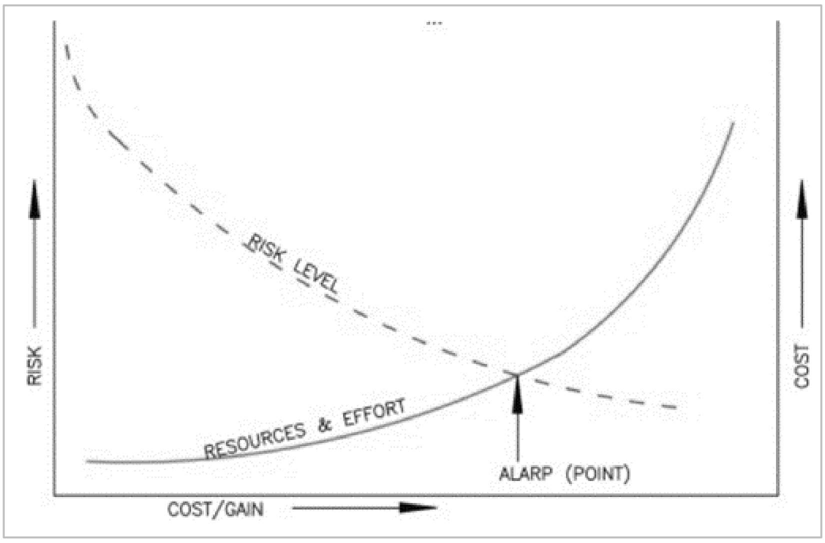


Figure 6: ALARP point for the special case where risk and cost are able to be expressed in the same scalar units

In the special case where RR and IC can be expressed in the same scalar units (e.g. financial cost) then there exists an optimal trade-off point on the efficient frontier. This may be termed the "ALARP point" and is a cost benefit ratio minima (Figure 6). Otherwise, when RR and IC do not share units and/or are multi-dimensional, the decision maker(s) must consider the merits of alternative efficient-frontier solutions and justify selection(s) accordingly.

Although the ALARP principle can be used interchangeably with "So Far As Is Reasonably Practical" (SFAIRP) [14], SFAIRP approach has been recommended for facade fire safety issue owing to possible complications around insurability and professional liability [4]. Ale et al. [15] discussed the difference between these two qualifications as ALARP is applied to the level of risk and to control the risk while the requirement of safe SFAIRP is applied in reducing the hazard. The study acknowledges the difference in law of these two terms but refers to them as "representing the same health and safety legal test". It was concluded that using ALARP in policy making can maximise the quantitative aspect and strengthen the implication of certain measures onto human life. The suitable approach to use ALARP as part of the regulatory system is to translate ALARP into industry standard rather than a guidance as a matter of opinion [15].

[14] For input resource intensity, cost is one potential measure but is far from the sole option.

Fire testing

Following the tragic Grenfell Tower fire and other cladding fires across the globe, significant effort has been spent to understand the fire dynamics and processes involved in cladding fires as well as effective solutions to address this problem. Following the test series conducted by BRE UK on different facade configurations, i.e. various combinations of cladding and insulation materials with different combustibility, there are a lot of work focusing on the current testing standards [16], and the need for a new method of testing [17-20]. Guillaume et al. [17] conducted a series of ISO 13785-1 tests and concluded that cladding played the governing role of the fire behaviour while other materials such as insulations contributed to a much lesser extent to the system fire reaction (Table 3). The team has conducted further analysis using the two-way ANOVA without replication on different parameters including the maximum heat release rate (HRRmax), total heat release (THR), maximum smoke production rate (RSP max), total smoke production (TSP), maximum carbon dioxide emission rate (CO_2max), carbon dioxide total mass released (CO_2 total), maximum carbon monoxide emission rate (COmax) and carbon monoxide total mass released (CO total) with results presented in Table 4. Compared to the Fcrit (with the probability of 0.05) of 6.944, it means that if F is more than Fcrit and p is less than 0.05, it can be concluded with 95% confidence interval that the factor (either cladding or insulation) influences the corresponding fire parameter. It can be seen from Table 4 that cladding type has an influence on all fire parameters being investigated except the maximum carbon monoxide emission rate. On the other hand, the insulation material only statistically significant to the total heat release and the carbon monoxide total mass released. While it is noted that other combustible insulations with a lower thermal degradation temperature was not included in this work, the governing role of cladding materials in the fire behaviour of the facade system is recognised.

Table 3: Fire reaction of different cladding and insulation combinations (study of fire behaviour of facade mock-ups equipped with aluminium composite material-based claddings, using intermediate-scale test method), processed data from [17]

Cladding	Insulation	HRR max	THR	RSP max	TSP	CO_2 max	CO_2 total	CO max	CO total
PE	Phenolic	5059	641	23	3604	259.9	60.2	3.089	0.386
PE	PIR	5000	668	21.8	3110	260.3	52.9	2.952	0.317
PE	Mineral wool	4783	456	18.5	2614	275.2	48.7	0.648	0.079
FR	Phenolic	180	232	1.8	1114	31	37	0.956	1.006
FR	PIR	297	258	4.6	2290	39	38.5	0.808	0.859
FR	Mineral wool	198	180	2.6	1270	22.8	25.2	0.832	0.538
A2	Phenolic	144	207	3.3	1850	67.3	41.9	0.871	1.036
A3	PIR	206	241	7.4	2923	70.2	53.9	1.008	0.891
A4	Mineral wool	94	138	0.9	1225	38.8	31.1	0.34	0.341

Table 4: Two-way ANOVA to investigate the significance of cladding type and insulation material, processed data from [17]

Fire parameter	Factor	F	p
HRRmax	Cladding	3780.1502	2.79629E-07
	Insulation	2.70915626	0.180373938
THR	Cladding	83.7323657	0.000544215
	Insulation	8.24557329	0.038105482
RSPmax	Cladding	93.2583264	0.000440813
	Insulation	3.46213753	0.134070963
TSP	Cladding	7.27071479	0.046540769
	Insulation	3.27451604	0.143778768
CO2max	Cladding	279.949395	5.03173E-05
	Insulation	0.52415143	0.627811375
CO2 total	Cladding	10.4325765	0.025878417
	Insulation	5.22833509	0.076556741
COmax	Cladding	4.11705852	0.106899265
	Insulation	2.04289701	0.244722914
CO total	Cladding	24.4825739	0.005703476
	Insulation	17.7594847	0.010244924

It has further been observed that most research has been heavily focused on the materials or the extreme of cladding. For example, the study presented above only discriminates different types of Aluminium Composite Material (ACM) in relation to its polyethylene content. However, the fire behaviour of facade which is not fully covered with ACM and the influence of factors such as geometry, relative locations and the interaction of claddings with internal building features have not been fully understood. This fact may lead to inadequate understandings on the level of risk associated with claddings which could vary significantly even though they are constructed with the same materials. In addition, despite the challenge of different testing regimes and requirements with different synergies to the actual fire performance of facades, it is acknowledged that the cost and time involved in fire testing is quite significant owing to the unique construction and design of facades in different buildings. There is a strong need for numerical simulation to complement facade fire testing to optimise the resources for projects involving a large number of different buildings.

Software

Fire Dynamics Simulator

There are different simulation tools which have been used for analytic fire safety design. Among those, the Fire Dynamics Simulator (FDS) developed by NIST is the most widely used software to estimate the temperature and smoke development in buildings. The tool includes different modules which considers material properties, different gas species, chemical reactions and dynamic flows. It is evident from numerous studies that FDS can be deployed for facade fire prediction.

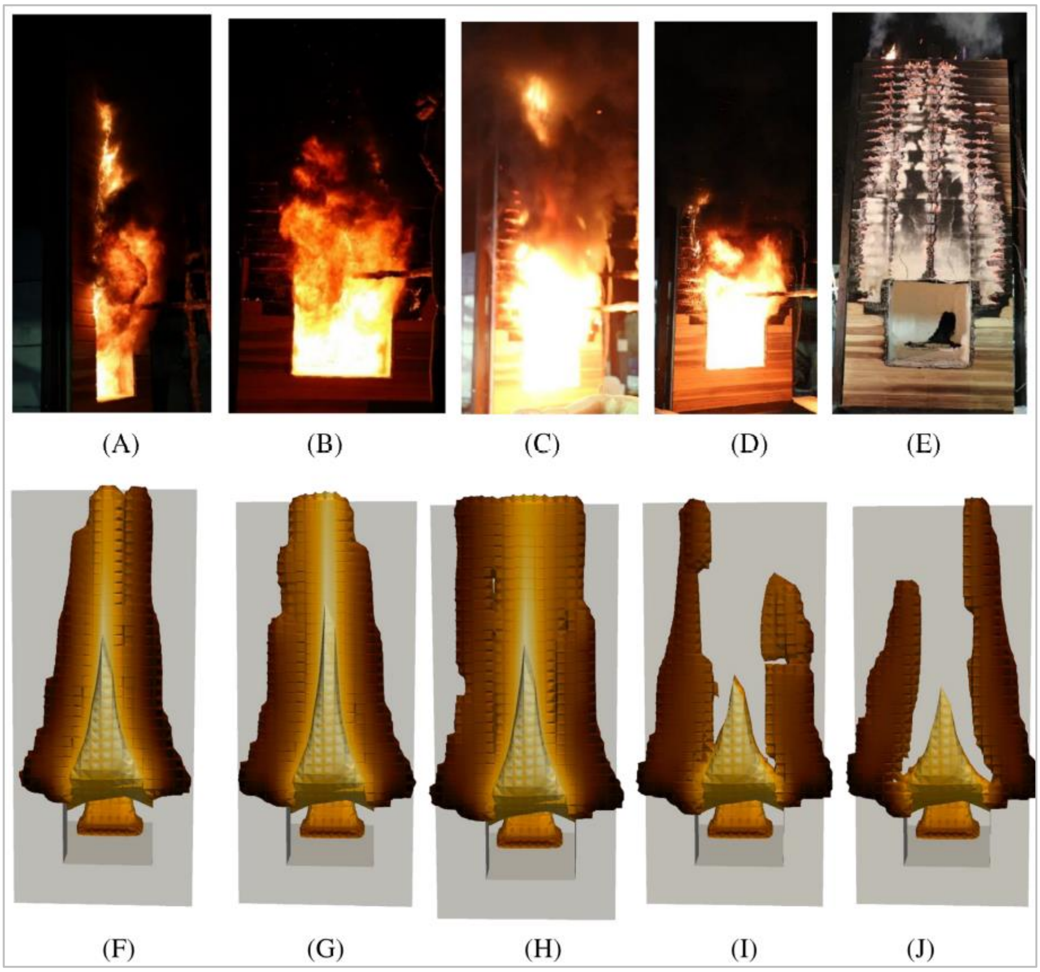


Figure 7: Study one – FDS and experiment: Numerical and experimental study of cedar façade fire [21]

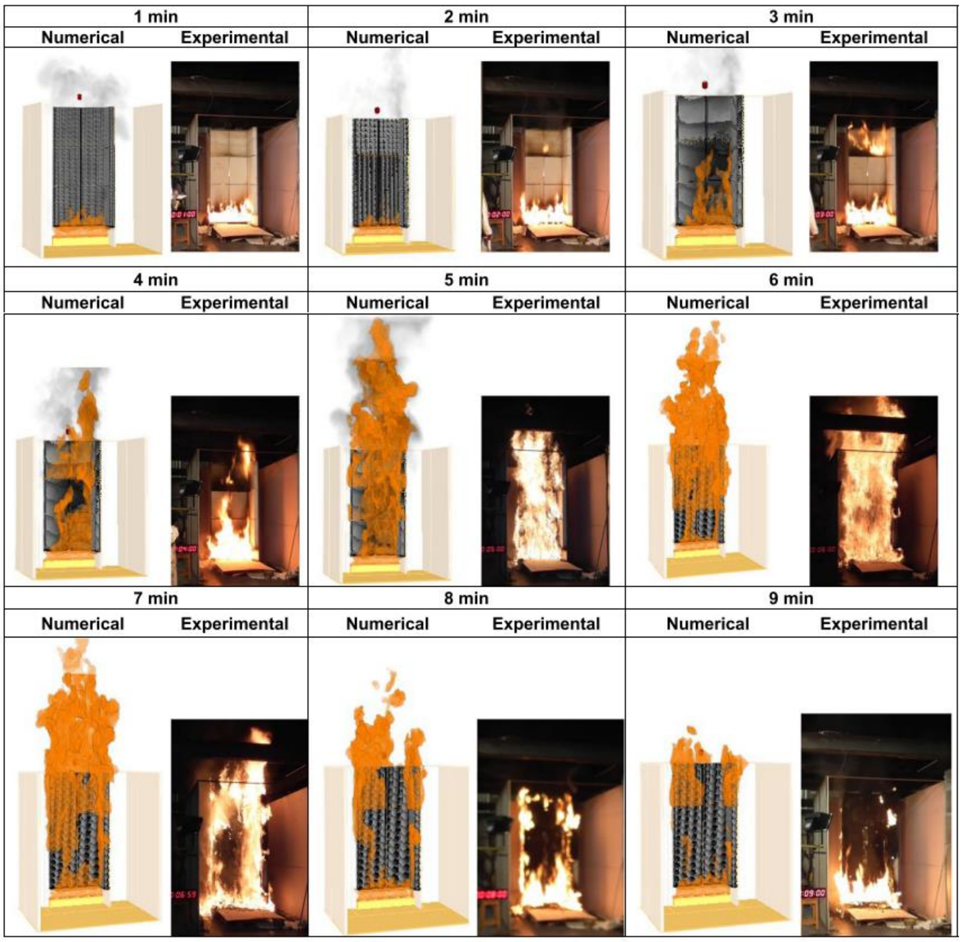


Figure 8: Study two – FDS and experiment: Numerical simulation of the fire behaviour of façade equipped with aluminium composite material-based claddings – Model validation at intermediate scale [2+2]

Nilsson et al. [23] successfully modelled SP Fire 105 fire tests using FDS with reasonable agreement with experimental results. The study investigated numerically the set-back distance and effect of spandrel. It was found that a spandrel height of at least 1.2m can provide a similar impact to mitigate fire spread as a 60cm horizontal projection. It is evident from this work that FDS can be used to comparatively study the impact of geometry on external fire spread. In addition, FDS can also be used to study the external fire interacting with wind (speed and direction) on facade fire spread on an isolated rectangular building. FDS was found to reasonably capture the reserve flow near wall effect on rectangular buildings (Figure 10).

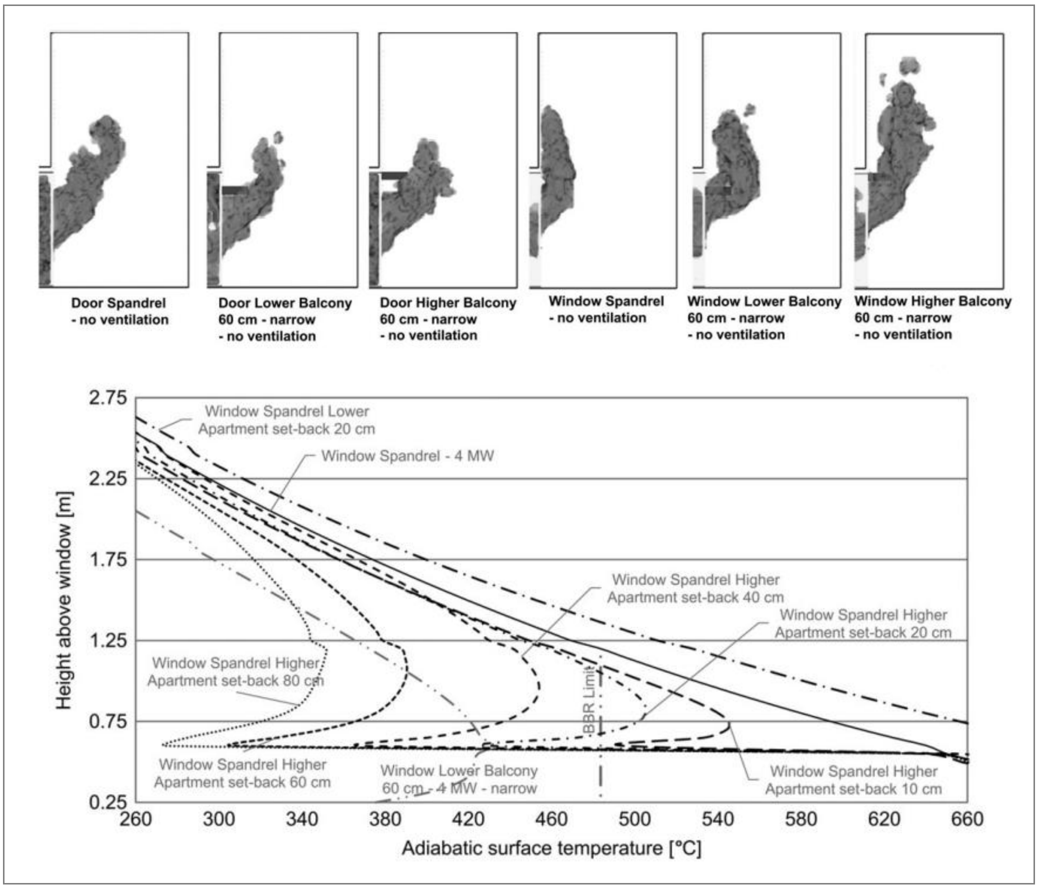


Figure 9: Use of FDS for modelling geometry [24]

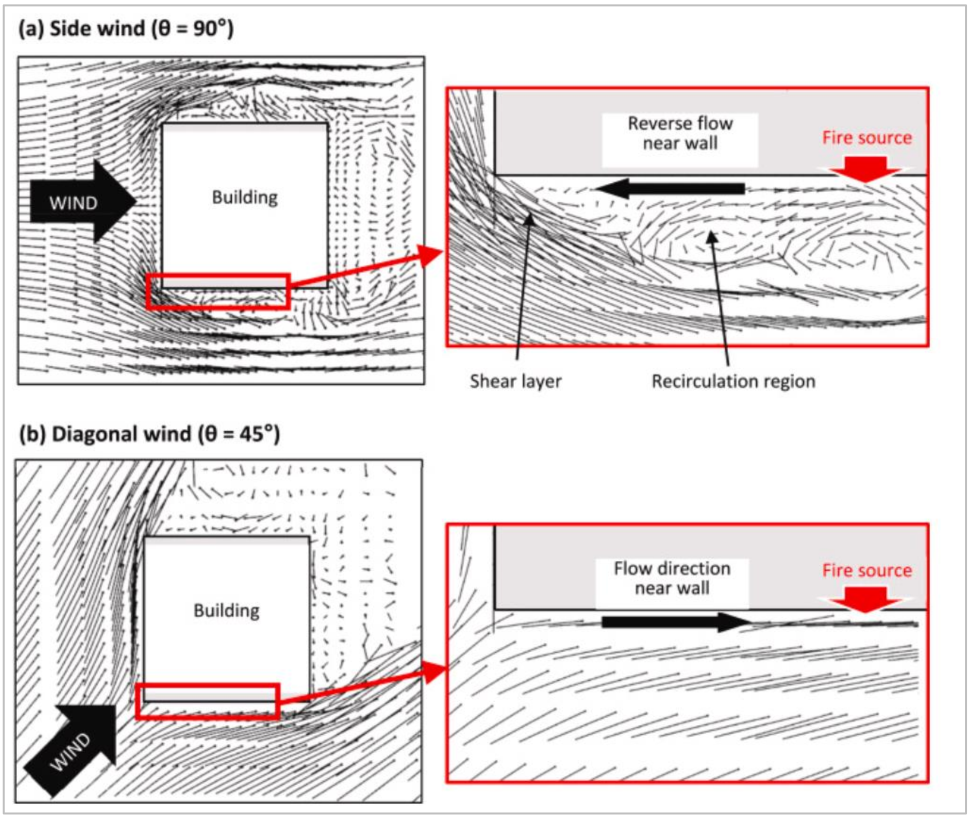


Figure 10: FDS for wind-facade fire interactions [25]

However, working with complex simulation tools as such often requires in-depth engineering knowledge in order to generate meaningful and accurate data. Johansson et al. [26] conducted research in which the same fire problem was given to fire engineers with substantial experience working with FDS. A significant variation in simulation results were found and the study emphasised the need for further improvement in applying FDS for fire safety design and that great care must be taken. A recent trend in fire simulation is the integration of artificial intelligence or machine learning to improve the accuracy of numerical models like FDS. Nguyen et al. [27] proposed the use of machine learning in calibrating fire source models for FDS's facade fire tests in accordance with JIS A 1310 and BS 8414.

Thermal Radiation Analysis

Thermal radiation analysis (TRA) software can assist with complex radiation calculations that are common in fundamental fire engineering analysis.

Where flame temperature, facing area and emissivity are calculated prior, the program can be used to calculate radiation from flames incident on surrounding, adjacent and opposite surfaces.

TRA is beneficial for external radiation analysis as the program employs radiation calculations only and has no convective and material characteristic scope.

The accuracy of the modelling is proportionate to the accuracy of the scenario constructed within the software and the resolution applied to the emitting and receiving surfaces (divided into sub panels – the greater the number the better). Surface inputs employ cartesian geometry in 3-dimensional space (as indicated in Figure 11 below) and can resolve configuration factors and the radiative heat flux between emitter and receiver through the Stefan-Boltzmann equation where:

$$E = \sigma T^4$$

to

$$Q_{rad=\sigma \varepsilon F_{d1-2}} (T_1^4 - T_2^4)$$

where

q_{rad}	=	Radiation heat transfer
σ	=	Stefan – Boltzman constant ($5.670374419 \times 10^{-8}$)
ε	=	Emissivity factor
F_{d1-2}	=	Configuration factor
T_2	=	Temperature of emitter (K)
T_1	=	Temperature of receiver (K)

Where flame produced from a potential cladding fire or from an external source (vehicle, adjacent building openings) can be calculated in terms of flame height, temperature and distance, TRA software may be able to inform, and dimension limiting relationships for egressing occupants (receivers) and retained cladding (emitter).

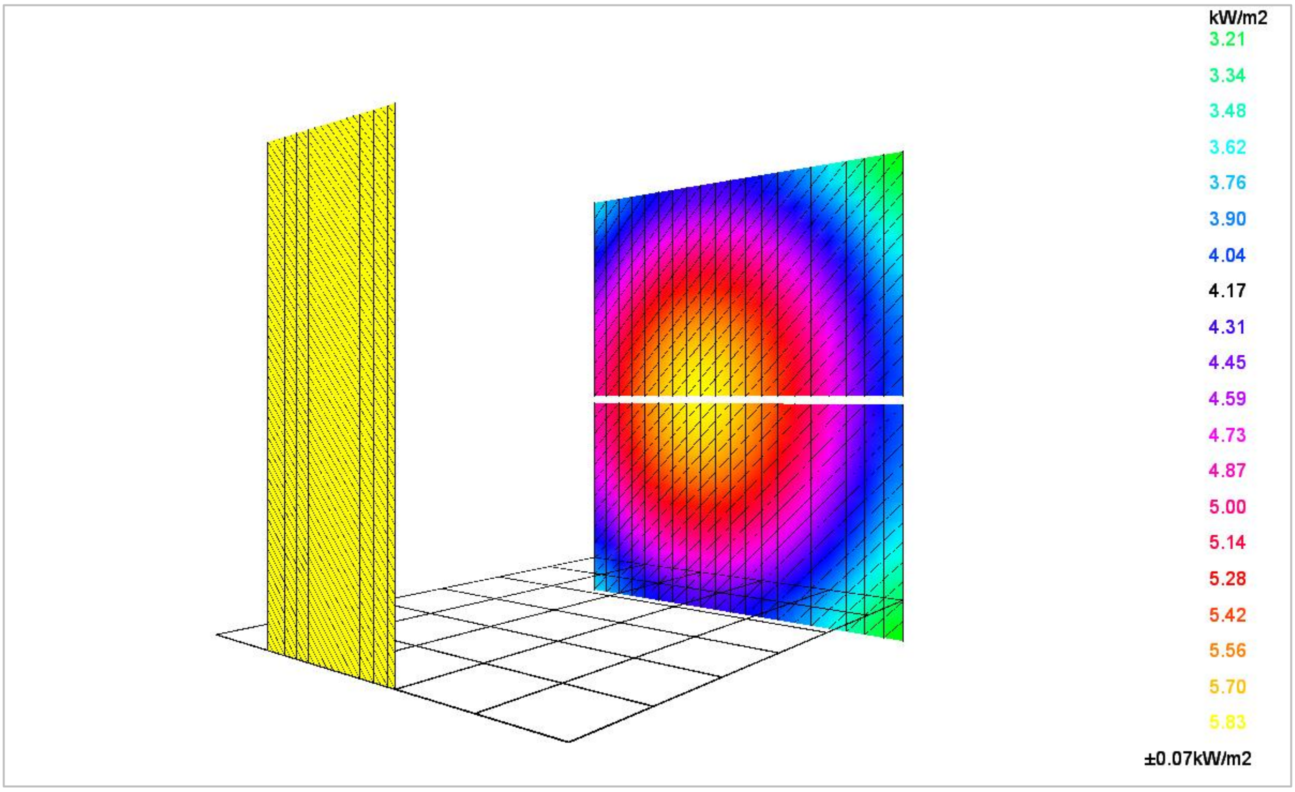


Figure 11: Typical TRA analysis indicating radiation received (right) from emitter (left)

Cellular Automata and Bayesian Network approaches

The FDS analysis of building fire seeks to faithfully capture the dynamics of fire including the rates of heat energy release and the speed and extent of fire spread. When such insight is available it can be used to directly evaluate fire outcomes, and it can be harnessed within decision support systems.

FDS can be particularly helpful for the development of fire safety design rules that can be applied to many buildings. By contrast, FDS is not yet a practical tool for the in-field assessment of buildings in as-built condition. As discussed in the preceding section, the utilisation of FDS requires specialised expertise. Current models' capability to deal with complex architectural features, environmental conditions and material combinations is immature. There are also challenges around defining and parameterising sufficiently-sized simulation ensembles which capture the stochastic variability in fire outcomes (e.g., whether fire will or will not bridge combustible fuel gaps) and the variety of potential ignition locations on a building.

One solution to these limitations of FDS within a decision tool is to instead use more approximate models of fire propagation. Practically useful predictions of fire extent can be made using *Cellular Automata* (CA) or probabilistic techniques including *Bayesian Networks* (BN). As background:

- Finer-scale CA modelling of building fire is reported in [28].
- CA-based modelling of wildfire at landscape scale is an established capability, including within the Australis fire spread model that is used chiefly in Western Australia [29], and more recently by [30] for wildfire in China.
- A BN approach for building fire simulation was proposed by [31] and has been frequently cited since.
- Other variants of network-based probabilistic methods have also been explored in literature (see review in [32]).

Fire modelling using CA is based on iteratively computing whether cells are engaged in fire, and moreover whether proximal fire leads to ignition in a cell that is not currently engaged in fire. The cells in context are logically composed spatial units which can sustain fire. The criteria according to which the fire propagates to cells can be based on physical science models and/or empirical models of fire within a CA approach. In a probabilistic network approach like BN, this reduces to the expression of *probabilities* of fire transition between cells. These probabilities do not *necessarily* have a basis in the (explicit) modelling of fire, however they may (as is the case in [32] for example), and certainly modern models utilise time-dependent conditional probabilities which reflect physical phenomena including fire flashover.

Within BN the cells are more appropriately termed *compartments* and this is the term used by [31]. In one sense this reflects that the compartments represent elements at the scale of whole rooms in BN rather than (say) voxels in the case of CA; so there is a literal preference for compartment as a term. In another sense it draws a relevant connection to compartment-based epidemiological models (such as Susceptible-Exposed-Infected-Recovered compartment models) which are well established and successful approaches to studying disease propagation, and share much of the mathematics on the BN-based approach to fire propagation.

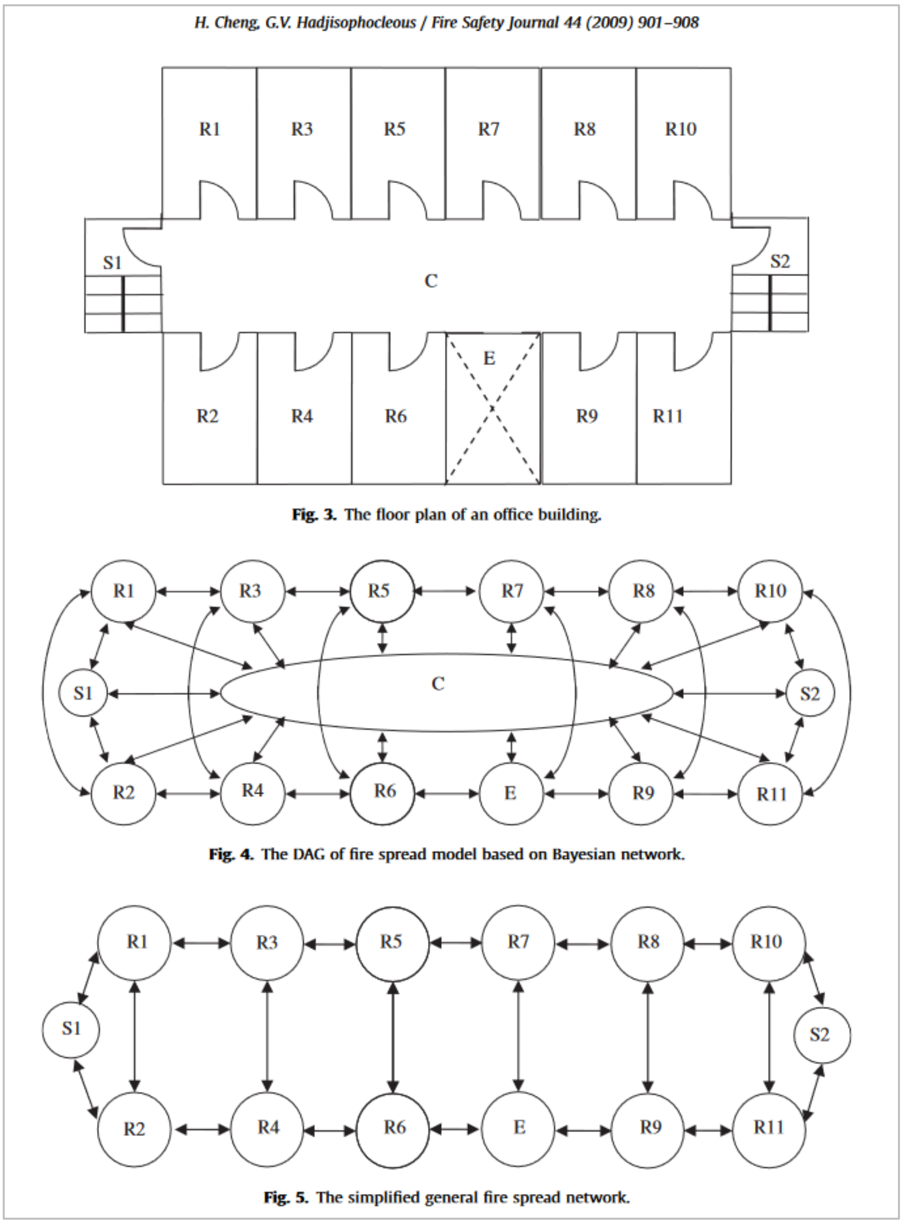


Fig. 3. The floor plan of an office building.

Fig. 4. The DAG of fire spread model based on Bayesian network.

Fig. 5. The simplified general fire spread network.

Figure 12: Compartment representation and network for BN fire propagation modelling [31]

BN approaches to fire propagation which build upon and/or complement the work of [31] include Cheng and Hadjisophocleous [33], Matellini et al [34], Kacem et al [32] and Matellini et al [35]. The BN in [32] addresses fire spread through 113 distinct compartments of a naval vessel, this demonstrating that larger-scale structures can be successfully addressed using BN. The work by Cheng & Hadjisophocleous tackles structure fire at the building scale, including a two-storey office building as a worked example in [33] (refer Figure 12).

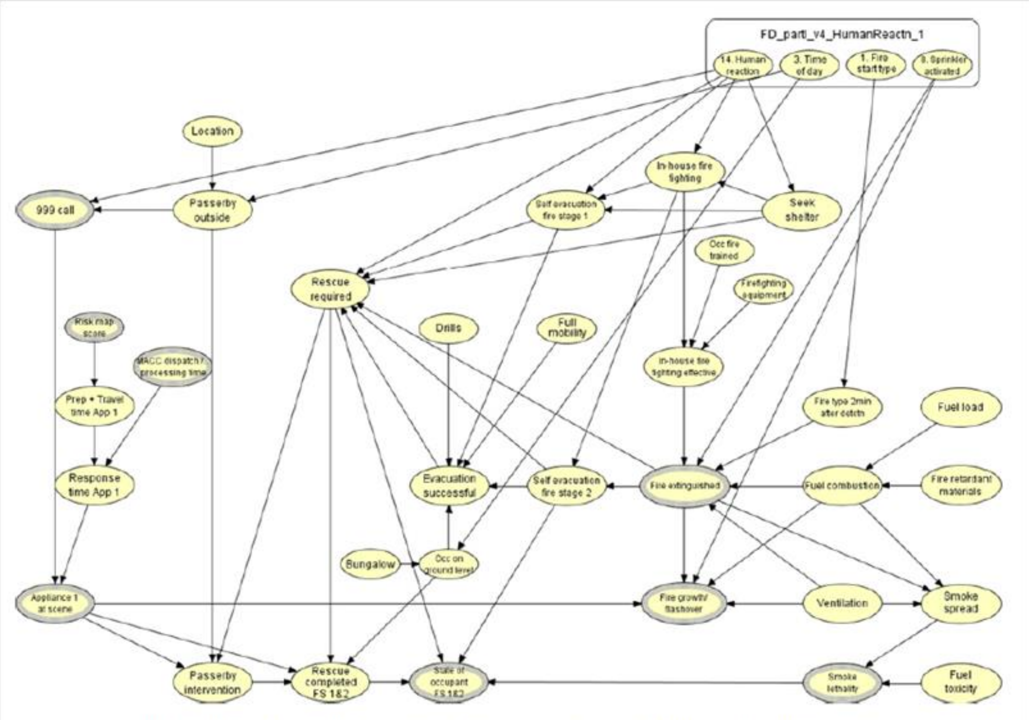


Fig. 4. BN model part II representing occupant response and further fire development.

Figure 13: Bayesian Network utilised for representing occupant response and fire development [34]

The Matellini et al. papers [34, 35] use BN where transitions are between building fire, occupant and rescue services' states (such as "Human awake", "In house firefighting" and "Fire growth/flashover"), and where these states are not spatially explicit (refer Figure 13). Both the spatially explicit (fire propagation focused) and the state-of-entities focussed work is relevant in our context.

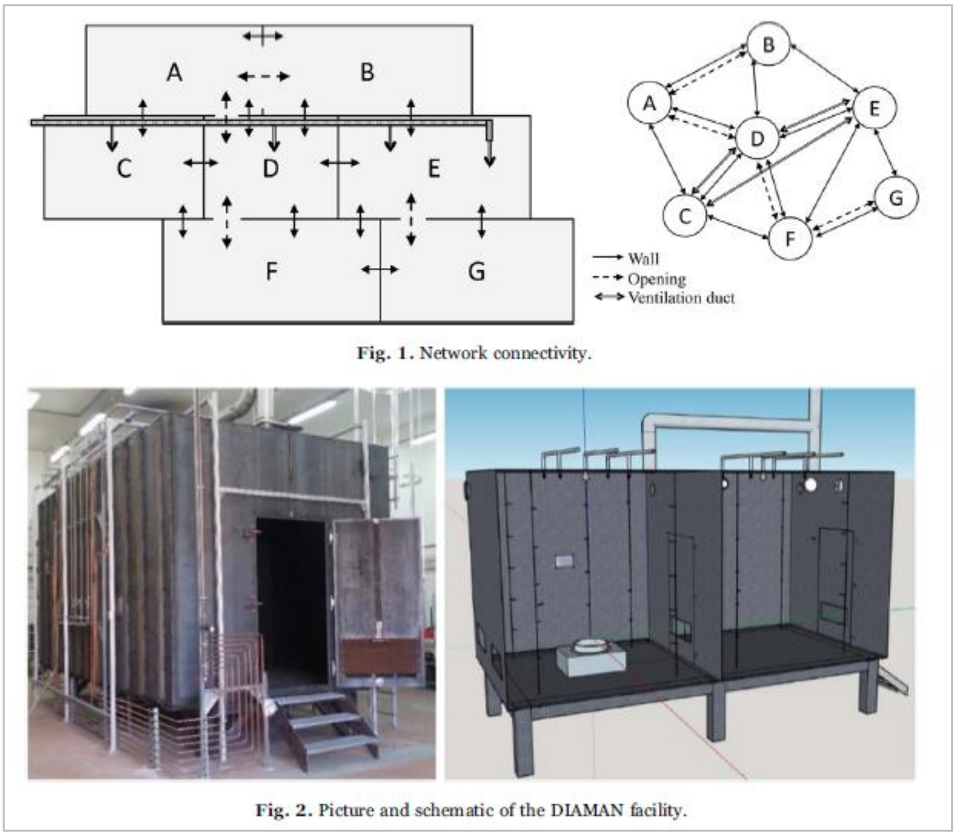


Figure 14: Compartment network (top) and physical experimentation rig (bottom) used as part of the BN approach to naval vessel fire [32]

The parameterisation/validation of a BN is a challenging task and requires assimilation of subject matter expertise, lab/field experimental data, modelling, and data assimilation. Naval vessel fire spread probabilities [32] have complex physical and time dependencies and their parameterisation involved data analysis, modelling and physical experimentation (refer to Figure 14). Fischer et al. [36], De Sanctis et al. [37], and Matellini et al. [34, 35] each utilise data, expert elicitation and fire science findings in various combinations in order to parameterise their BN models.

Main findings from literature review

In terms of standards and guidelines, the following findings have been concluded from literature:

- The identification of hazards based on building fire safety design can be found in both the SFS Practice Guide and the NFPA FRAT Report.
- SFS Practice Guide proposes a systematic design of fire scenarios for cladding-related fires.
- There is a lack of a specific risk rating tool for combustible cladding with the consideration of the extent of vertical cladding connection as well as the coverage of combustible cladding over the building height.
- The consideration for possible interventions can include those proposed in the SFS Practice Guide and NFPA FRAT Report.
- The PAS is based upon ‘stay in place’ evacuation philosophy (evacuation strategies for blocks of flats in the UK).
- All reviewed methodologies indicate limited consideration for the number of levels that may be impacted explicitly by a cladding fire, nor the number of potential apartments that may be adversely impacted. Whilst it is considered that no spread of flame beyond the area, apartment or level of origin be optimal and spread beyond this to be minimised, it is

clear that all methodologies avoid numerical benchmarks for the assessment of risk. Whilst cladding cannot be evaluated in isolation for the purposes of a holistic evaluation of a buildings relative fire safety – the quantification and explicit evaluation of cladding specific risk can be undertaken.

- The PAS also states that in building fires, even when external walls do not contribute directly to a fire, it is accepted that fires will spread between apartments via other fire spread mechanisms.
- The PAS discusses the risk of rapid fire spread but does not include the number of levels or compartments that could be involved relative to this perceived time (i.e. rapid). The PMCR seeks to apply a risk mitigation strategy that acknowledges the likely number of apartments involved in the cladding fire.

In addition, the ALARP principle is a well-known approach for policy makers in risk mitigation and management where the risk is within the tolerable zone and a proportionate strategy is needed to balance between the cost and benefits of risk remediation activities. Research has also shown that the best strategy for the application of ALARP is through a regulatory framework or standards and not as a piece of recommendations or opinion.

Another finding from testing and simulation shows the governing role of cladding types in facade fires. While most testing relates to a standard flat facade system (with and without the secondary wing), further work into parameters other than materials properties such as the relative location and configuration of cladding system should be conducted for a more accurate assessment of associated risk.

Fire Dynamic Simulator (FDS) and Thermal Radiation Analysis (TRA) are two software packages that can be utilised to reduce load of physical tests which often involve significant resources and time. However additional strategies utilising methods such as *Cellular Automata* (CA) or probabilistic techniques including *Bayesian Networks* (BN) have been proven to effectively complement the deployment of FDS and other fire simulators, and may find use within decision tool.

Cladding risk premium and the risk equivalence of alternative solutions

In this subsection we establish the notion of a *cladding risk premium*. In doing so, we also establish the notion of a *comparable prototype* building that which does not have combustible cladding but to which buildings retaining combustible cladding can be compared.

Comparable prototype buildings

Comparable Prototype (CP) buildings are abstractions (i.e., hypothetical buildings) sharing as many features as possible with the particular *Subject Building* (SB) that presently has combustible cladding. In effect, the CP is the SB without combustible cladding.

- CP do not have combustible cladding.
- The SB may retain combustible cladding in a risk-acceptable future state.
- CP achieve “Deemed To Satisfy” status with respect to fire safety measures.
- CP has the same architecture as the SB, sans combustible cladding, and the CP experiences the same threat rates for fire ignitions as the SB.
- The CP is an embodiment of tolerable fire risk, so is therefore able to be treated as a benchmark for the cladding-related risk of the SB.
- Risk equivalence between the SB and CP is considered to be practically achievable.
    - At minimum, the option exists for the SB to have its combustible cladding removed. If this occurs, then by the CP definition of the SB without cladding will have an equal or lesser fire risk in comparison to the CP.

The notion of a hypothetical CP building is extremely useful as a theoretical construct. It allows definitions, models and mathematics to be developed, and can also be useful in defining regulations and in a legal context. By contract, practical people such as MBS may have difficulties utilising hypothetical notions of this kind. In an implementation of practical processes and tools in PMCR, much thought and care has gone into the articulation of a CP and its utilisation by decision makers.

Cladding risk premium

The idea of a cladding risk premium has been described and utilised in past work undertaken by/for CSV. Descriptively it is defined as the additional fire risk (of injury and fatality) of a building which is directly attributable to combustible cladding. The CP notion provides us with a way to define cladding risk premium in a logically consistent and mathematically useful manner:

[Cladding Risk Premium]

equals [Fire Injury/Fatality Risk of the Subject Building]

minus [Fire Injury/Fatality Risk of the CP Building]

Importantly this definition of cladding risk premium advantages subject buildings with greater than standard fire safety: in the sense that the opportunity to make use of alternatives to full removal of combustible cladding is not eclipsed by the fact that the SB starts in an otherwise excellent fire safety state. It also accommodates fire safety system improvements as viable interventions which decrease cladding risk premium and can bring the SB to risk equivalent with the tolerable-risk CP.

Alternative solutions and risk parity

Through PMCR we seek to:

1. Construct candidate risk-reducing solutions where (some) combustible cladding remains in situ on the Subject Building (SB).
2. Define the Comparable Prototype (CP) building for the SB.
3. Assess candidate solutions for the SB with respect to fatality/injury risk, computing the cladding risk premium between the modified SB and CP.
4. Identify which candidate solutions (if any) have a cladding risk premium that is tolerable:

Where the cladding risk premium is reduced to zero or a negative number, this can be termed *risk parity*, and in this document synonymously as *CP equivalence*.

- As already discussed, whether a cladding risk premium of zero is <u>required</u> is a question of policy; and the answer to this question is not yet determined (since drafting this early PMCR content, the Victorian Government has released *Minister's Guideline 15*).
    - This determination might be an outcome of industry consultation, or might result from government direction via legislation or regulation.
- Subject to this future determination, it may come to pass that stakeholders accept a non-zero residual cladding risk premium. This may be expressed as a ratio of the CP risk value.

It is our underlying hypothesis that stakeholders will accept the risk parity principle, or a form of it with some non-zero value of residual cladding risk premium. Further, we hypothesize that stakeholders will be significantly more likely to accept solutions retaining (some) combustible cladding if future risk-based performance can be quantitatively established or otherwise convincingly demonstrated in some manner.

- At the present time the risk parity principle is a proposition which needs to be tested with stakeholders.
  - Stakeholder consultation to confirm or reject this certainly needs to be part of ongoing PMCR development work.
- The key proposition to be explored in the present work is that there can exist ways to reduce the cladding risk premium to zero (or to an acceptably small value) which retain some or all of the combustible cladding that is originally present.
- It is not expected that all in-scope (Elevated Risk) buildings can be brought to CP equivalence except through cladding removal.
- It is not expected that it is financially beneficial to pursue alternatives to full combustible cladding removal on every given building that is in scope for PMCR.
- The full set of alternative means should also include the removal of combustible cladding from certain locations on a building facade/exterior.
- Whether a sizeable proportion of Elevated Risk buildings in Victoria can reach a nominated tolerable risk without resort to full cladding removal is not presently known.

At this juncture it is *not* established that permitting an excess of risk is in fact *necessary* to allow for financially reasonable solutions for the majority of in-scope buildings. While it is intuitive that permitting some risk excess can be expected to reduce the cost of rectification for certain in-scope buildings, this is also not yet proven.

The overall approaches to risk evaluation and decision-support canvassed in this document can be applied equally well whether we are strict or more permissive around CP equivalence.

Expected loss equivalence versus maximum loss equivalence

In the foregoing we concentrate on *expected loss* equivalence. In general, the pursuit of *maximum foreseeable loss* equivalence is challenging. It is difficult to assess maximum foreseeable loss for any building. We acknowledge the notion that combustible cladding could increase the perceived maximum foreseeable loss in various circumstances.

Sources of risk premium due to combustible cladding

Combustible cladding can support a fire ignition, fuel a fire, and transport a fire. A flammable facade potentially poses danger from each of these.

1. Combustible cladding can provide fuel to sustain an ignition which would otherwise be unlikely to occur.
2. Fire fuelled by combustible cladding can consume the building structure.
3. Combustible cladding transports fire from one location to another on the facade.

The risk premium from combustible cladding stems from one or more of these. In general, non-combustible facade systems do not present these risks.

Sources of combustible cladding ignition

There are three broad categories of building fire ignition source that are relevant to combustible cladding facade fire as acknowledged in both the NFPA Cladding Risk Assessment Tool and PAS 9980:2022 [6]:

1. Fires that begin ***inside SOU*** or more generally start ***internal*** to the building that are able to "flash over" from the building interior to the facade.
2. Fires which are ignited ***external*** to the building or external areas of the building, including the following:
    a. Ground level fires due to vehicles, bins, litter, vegetation, ground floor common areas, vandalism, and so on;
    b. Balcony or courtyard fires occurring, including from outdoor cooking and faults in electrical equipment placed on balconies;
    c. Transmission of fire from adjacent structures;
    d. Transmission of fire from adjacent vegetation;
    e. External sources not otherwise listed; and
3. Fire that results from electrical faults (***inside walls***) or unprotected ***penetrations.*** Electrical malfunction is one of the leading causes of fire and failure of electrical components that penetrate through combustible cladding trigger a higher possibility of cladding ignition.

Through the review of CSV's building cohorts, it has been considered that external fires typically involve two different risk (group) types. The first group is concerned with the risk of combustible cladding on the ground floor level, while the second group relates to cladding installed at height and proximal to openings of SOUs.

In the case of the Lacrosse building fire in Melbourne, external wall combustible cladding had been installed to the balconies returning walls. The configuration of the returning walls facilitated fire spread via installed cladding by:

1. Providing a pathway for fire spread from the outermost parts of the balcony back into the SOU; and
2. A pathway for fire spread via the cladding vertically to the returning walls of the SOUs directly above.

For the purposes of PMCR the set of potential ***external wall fires*** is divided into two different sources, namely ***ground level fires*** and ***balcony fires***. This division aligns with NFPA EFFECT assessment tool [5].

Hazard identification

It is acknowledged that in many instances, hazard identification requires familiarity with the process of identifying fire scenarios. Identification of fire hazards is often a subjective process. It is the realm of experienced professionals, with scenario development relying on group consultation/discussion and intuition.

The process of hazard identification, the development of fire scenarios and the selection of an appropriate set of risk mitigating measures has been conducted by an internal-to-CSV expert panel who engaged in review and discussion. The process was informed by globally accepted risk assessment tools and based on the characteristics of buildings, derived exclusively from CSV's data. As indicated in the previous section, four key hazards have been identified. These are nominated as the following:

Internal fires (SOU fires)	▪ Fires starting within an SOU that breach the envelope threshold, igniting the cladding.
External fires (balcony fires)	▪ Fires that begin on the balcony that either spread to the external wall transported by cladding; ▪ Fires that begin on the balcony and spread back toward SOU openings transported by the cladding; and ▪ Fire spread in both directions from the externally clad walls to SOUs and vice versa.
Ground level fires	Fires that begin at ground level such as: ▪ Vehicular fires; ▪ Waste bin fires; and ▪ Arson.
Electrical faults and penetrations	Fires resulting from electrical faults and penetrations: ▪ Openings or gaps around penetrations proximal to cladding such as air conditioners; ▪ Power points; and ▪ Higher voltage illuminations.

Exceptions, special cases and duplications will exist within this taxonomy, e.g., balcony fires due to electrical penetrations.

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