THE DANISH APPROACH TO RESILIENT DEVELOPMENT

OVERVIEW

The Danish Approach to Resilient Development
Ministry of Foreign Affairs of Denmark - Ailish Dunn
- Introduction: Denmark in North America
- Nordics: Climate & Wildfires
- Denmark: Holistic Material Approach
- Mineral Wool Insulation

Off Prescription – First Principles Approach to Wildfire Resistant Design
RDH Building Science - Robin Urquhart

Discussion & Q&A

DENMARK IN NORTH AMERICA:
SUSTAINABLE URBAN DEVELOPMENT ADVISORY

PURPOSE

We strengthen Denmark–North America collaboration, with a particular focus on California, New York, Ontario, and British Columbia, fostering knowledge exchange with the public sector, the real estate industry, architects and engineers, and universities.

OBJECTIVE

By leveraging Denmark and North America's strengths, we aim to advance energy efficient, resilient, low-carbon, and affordable new developments, retrofits, and asset transformations of buildings and communities.

VALUE

Our unique position bridges North American and Danish stakeholders and solutions through targeted activities such as workshops, delegations, networking events, and bilateral meetings.

NORDICS: CLIMATE CHANGE & WILDFIRES

- **Increasing heatwaves**

- Nordic forests historically low-risk, but events like **2018 Sweden fires** highlight vulnerability

- **Nordic Forests:**
  - 53% of Northern Europe is forested
  - ~75% coniferous (pine, spruce)

- **Fire Management**
  - Remove fuels, thin/prune, controlled burns
  - Firebreaks & forest road access

- **Nordic Cooperation**
  - Share data, coordinate strategies, cross-border collaboration

DENMARK: CLIMATE RESILIENCE

- Denmark faces **rising temperatures, intense flooding, and sea level rise,** putting pressure on buildings and urban infrastructure.

- The country adopts a **holistic approach** to resilient development, designing buildings to withstand multiple environmental stresses.

- Material selection is central: Denmark prioritizes multi-benefit materials that tackle several challenges at once, such as **energy efficiency, fire safety, moisture management, and long-term durability.**

- For example, mineral wool insulation is widely used in Denmark with ~60% of buildings incorporating non-combustible insulation because it delivers **multiple resilience benefits** in a single solution.

STATE OF GREEN

MOISTURE & FLOOD PROTECTION

- Denmark's building code, **Building Regulations 2018 (BR18)**, integrates moisture and water protection into overall building design, rather than treating flooding separately.

- Flooding and moisture risks are managed across the **entire building envelope** to safeguard insulation and interior spaces from long-term damage.

- Mineral wool insulation is widely used because it **resists water, allows vapor diffusion to prevent condensation, mold, and rot**, and maintains thermal performance.

ENERGY EFFICIENCY

- Energy efficiency is a cornerstone of **Denmark's climate strategy** and is strongly emphasized in BR18.

- Requirements cover **new construction, major renovations, and building extension.**

- Denmark has extensive experience with **building retrofits** and has cut household energy use with insulation improvements playing a key role.

- Mineral wool insulation is commonly used because it provides **high thermal resistance** and maintains performance under varying temperatures, therefore reducing energy loss and lowering energy costs.

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INTERIOR FIRE SAFETY

- **Interior fire safety** is another key component of Denmark's building regulations.

- **Materials are classified by fire reaction:** A2-s1,d0 = non-combustible; lower classes allow more combustibility.

- **Height-based rules:**
  - Buildings >16.7 ft (2–3 stories): combustible insulation allowed if structural materials are steel or concrete (A2).
  - Floors >72 ft: only non-combustible insulation is permitted.

- **Mineral wool is the preferred choice,** as it is non-combustible, withstands temperatures above 1832°F, ensuring both fire resilience and energy efficiency.

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LOW CARBON CONSTRUCTION & MASS TIMBER

- Denmark has introduced **lifecycle carbon limits for new buildings**, averaging ~7.1 kg/m²/year— among Europe's most ambitious construction standards.

- Timber structures, such as **cross-laminated timber (CLT) and glulam,** can meet or exceed carbon targets, while traditional brick-and-concrete structures often struggle.

- Mass timber buildings require **enhanced fire safety measures,** including non-combustible insulation.

- Mineral wool's **fire-resistant properties** make it a highly suitable to support Denmark's growing use of mass timber construction.

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RESILIENT URBAN DEVELOPMENT

- Denmark's resilient urban development relies on **multi-benefit materials** that support energy efficiency, fire safety, moisture management, and low-carbon timber construction.

- While Denmark's regulations focus on interior fires and energy efficiency, the principle of using high-performance, non-combustible, multi-benefit materials is directly relevant to California's goals of **wildfire resilience, home hardening, and energy-efficient buildings.**

DENMARK AND CALIFORNIA

- Support **California-Denmark** collaboration by facilitating knowledge exchange, sharing best practices, and fostering strong climate resilience partnerships.

- Recognize California's wildfire mitigation priorities and aim to contribute to community rebuilding and statewide resilience through **home hardening and retrofitting**.

Off Prescription

First principles approach to wildfire resistant design

Robin Urquhart | P.L.Eng, RSE, CWMS — rurquhart@rdh.com

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What's the problem

→ The public policy problem is increasingly one of concentrated, cascading neighborhood loss rather than dispersed isolated loss.

→ The goal is not more complexity for everyone, but better resolution where the consequence of error is community-scale loss.

What current guidance does well

→ Reduces ignition susceptibility at the parcel scale

→ Translates wildfire risk into practical public guidance

→ Performs especially well where defensible space is feasible and adoption is widespread

The highest-consequence events are defined not by isolated parcel ignition, but by transition into neighborhood-scale fire spread

CALIFORNIA BUILDING STANDARDS COMMISSION

CALIFORNIA 2025 WILDLAND-URBAN INTERFACE CODE

CALIFORNIA CODE OF REGULATIONS | TITLE 24 PART 7
BASED ON THE 2024 INTERNATIONAL WILDLAND-URBAN INTERFACE CODE®
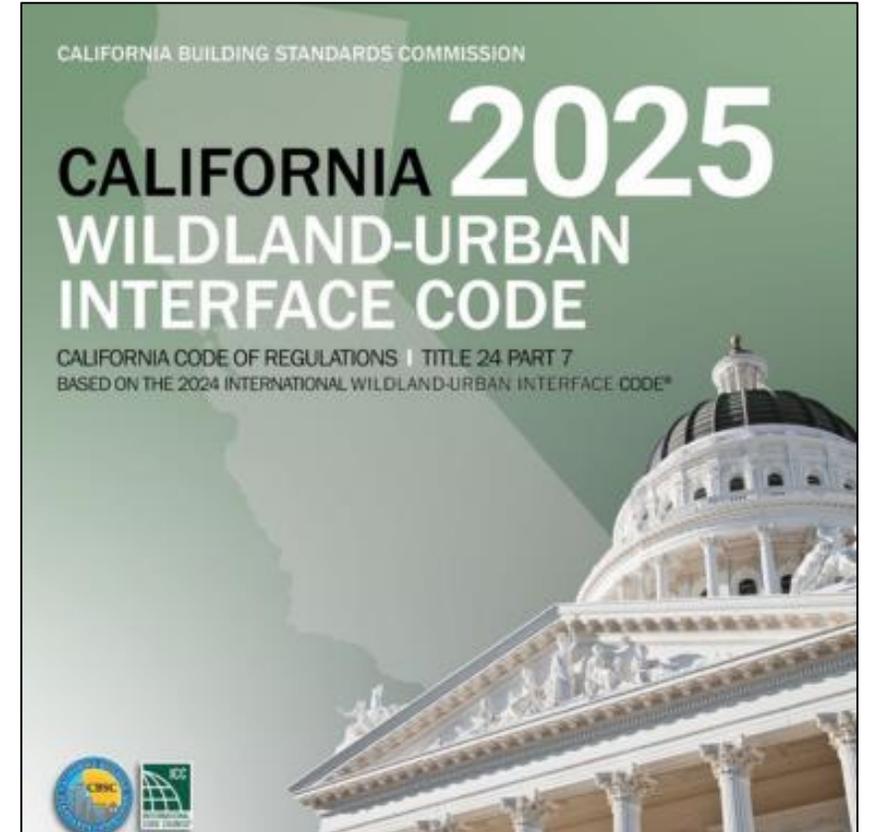
Characterizing wildfire

→ Load vs. resistance issue

→ there is no single "wildfire load"

→ buildings may be subjected to multiple distinct exposure typologies

→ these loads may act sequentially or concurrently

Two design fire families:

1. **Wildfire-driven design fire**
2. **Structure-to-structure design fire**
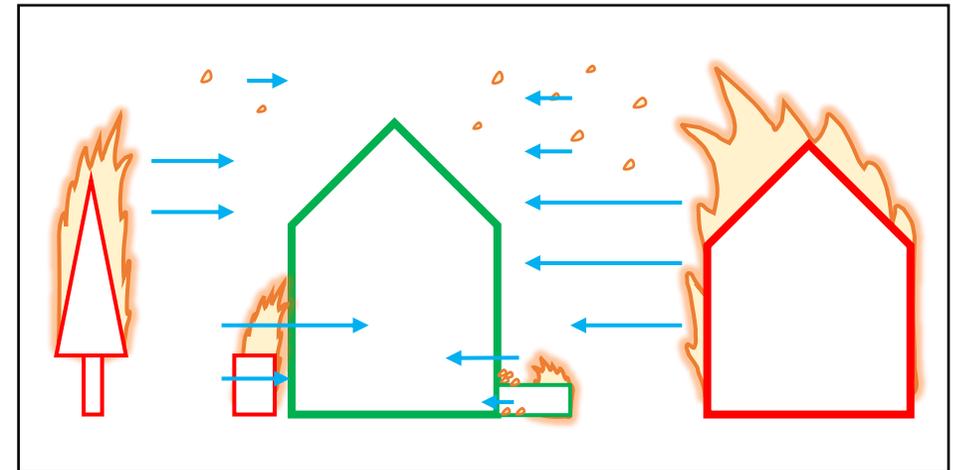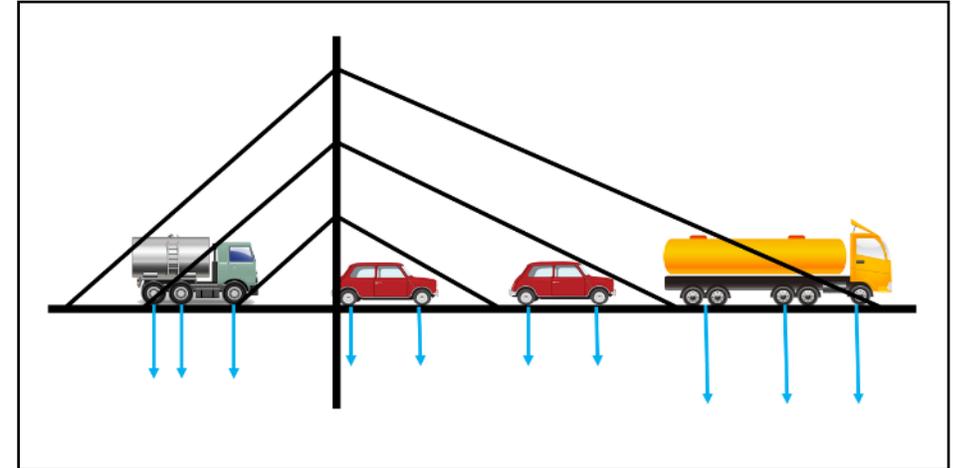
AS 3959 BAL Rating

BAL-FZ	BAL-40	BAL-29	BAL-19	BAL-12.5	BAL-LOW
BAL-FZ Direct exposure to flames, radiant heat and embers from the fire front.	**BAL-40** Increasing ember attack and windborne debris, radiant heat between 29 kW/m² and 40 kW/m².	**BAL-29** Increasing ember attack and windborne debris, radiant heat between 19 kW/m² and 29 kW/m².	**BAL-19** Increasing ember attack and windborne debris, radiant heat between 12.5 kW/m² and 19 kW/m².	**BAL-12.5** Ember attack, radiant heat below 12.5 kW/m².	**BAL-LOW** There is insufficient risk to warrant any specific construction requirements, but there is still some risk.

AS 3959 methodology

(b) if $d > 0.5L_f \cos\alpha$, then

$$\phi = \frac{1}{\pi}\left\{ \frac{X_1}{\sqrt{1+X_1^2}} \tan^{-1}\left[\frac{Y_1}{\sqrt{1+X_1^2}}\right] + \frac{Y_1}{\sqrt{1+Y_1^2}} \tan^{-1}\left[\frac{X_1}{\sqrt{1+Y_1^2}}\right] + \right.$$

$$\left. \frac{X_1}{\sqrt{1+X_2^2}} \tan^{-1}\left[\frac{Y_2}{\sqrt{1+X_2^2}}\right] + \frac{Y_2}{\sqrt{1+Y_2^2}} \tan^{-1}\left[\frac{X_2}{\sqrt{1+Y_2^2}}\right]\right\}$$

... B6

$X_1 = (L_f \sin\alpha - 0.5L_f \cos\alpha \tan\theta - d \tan\theta - h)/(d - 0.5L_f \cos\alpha)$

$X_2 = [h + (d - 0.5L_f \cos\alpha) \tan\theta]/(d - 0.5L_f \cos\alpha)$

$Y_1 = Y_2 = 0.5W_f/(d - 0.5L_f \cos\alpha)$

where

L_f = flame length (m), determined in Paragraph B7

W_f = flame width, determined in Paragraph B8

α = flame angle (degrees), determined using the algorithm in Figure B5

θ = slope of the land between the site and the classified vegetation (degrees), determined in Paragraph B5

d = distance between the site and classified vegetation (m), determined in Paragraph B6

h = elevation of receiver (m), determined in Paragraph B9
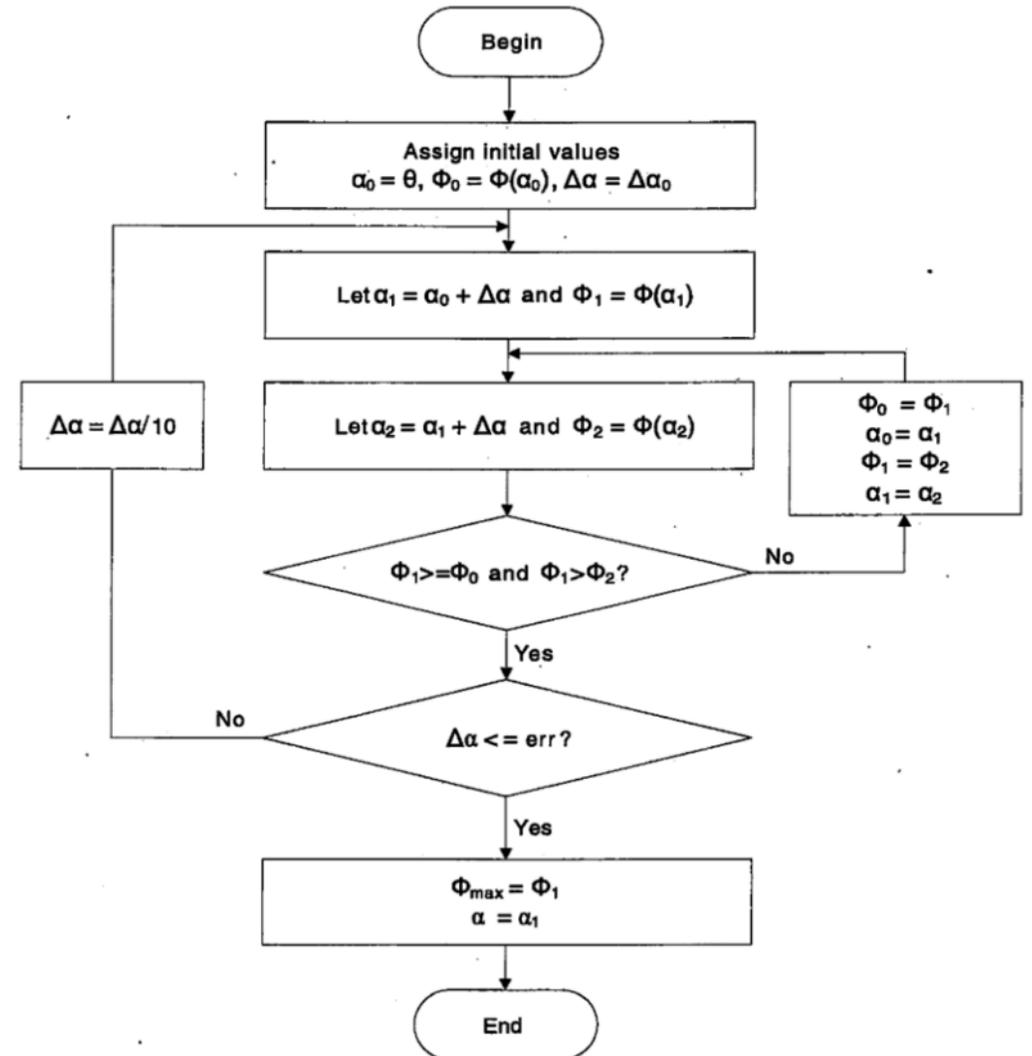
ICC 605

## SECTION 402
DEFENSIBLE SPACE REQUIREMENTS

402.1 Objective. Provisions of this section are intended to modify the *fuel load* in areas adjacent to structures to create a *defensible space* that protects building against exposure to direct flame contact and reduces the radiant heat and ember exposures to a level that minimizes potential for ignition or other damage to buildings and structures.

✤**Commentary:** The target wildland fire exposure for a structure in wildfire hazard areas are ember exposure, and heat exposure less than 15 kW/m2. These exposures form the basis of the defensible space provisions of Section 402.

402.2 Defensible space distance. The provisions of this section establish *defensible space* distances based on fire hazard severity. Minimum and expanded *defensible space* distances shall be in accordance with Table 402.2. De*fensible space* distances shall be maintained in accordance with Sections 402.3 and 402.4.

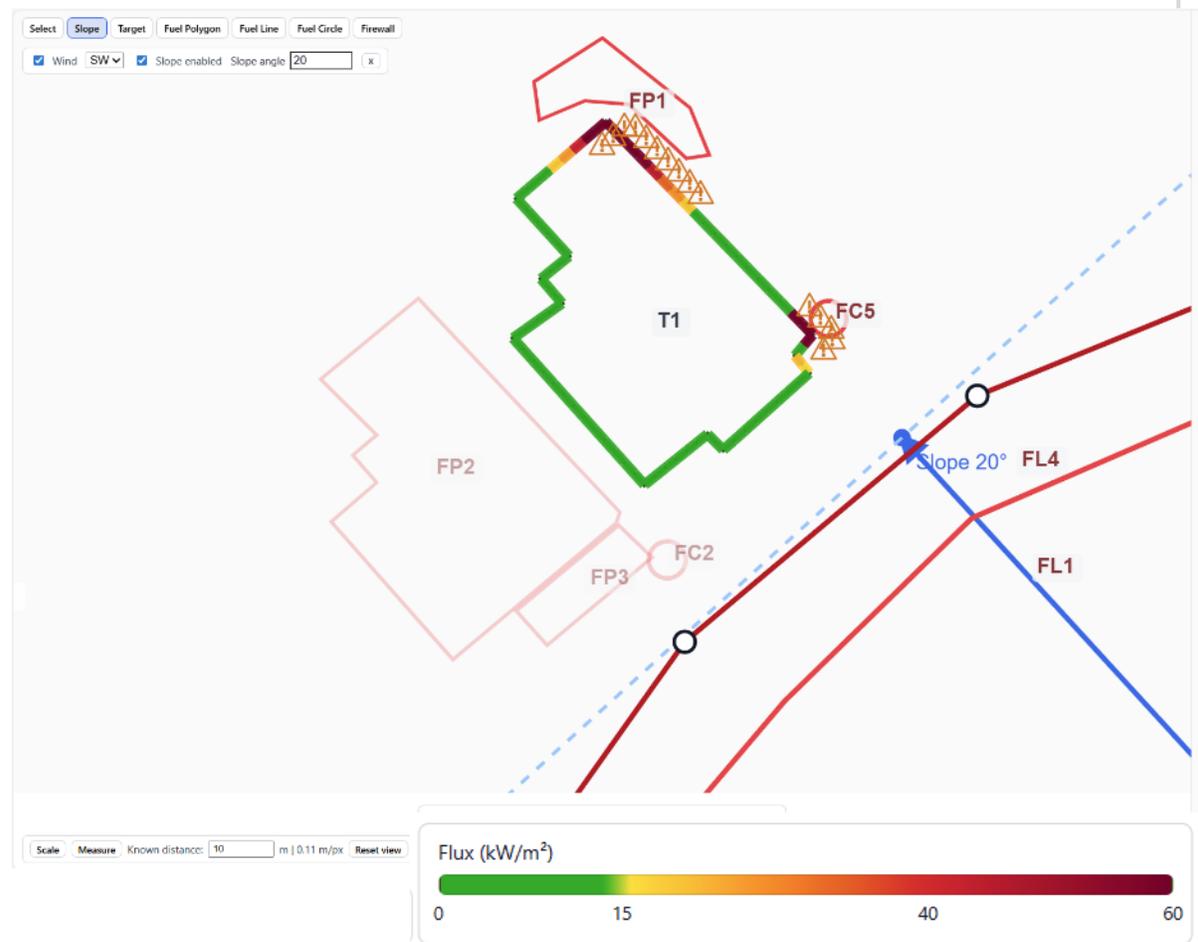### TABLE 402.2. DEFENSIBLE SPACE DISTANCES

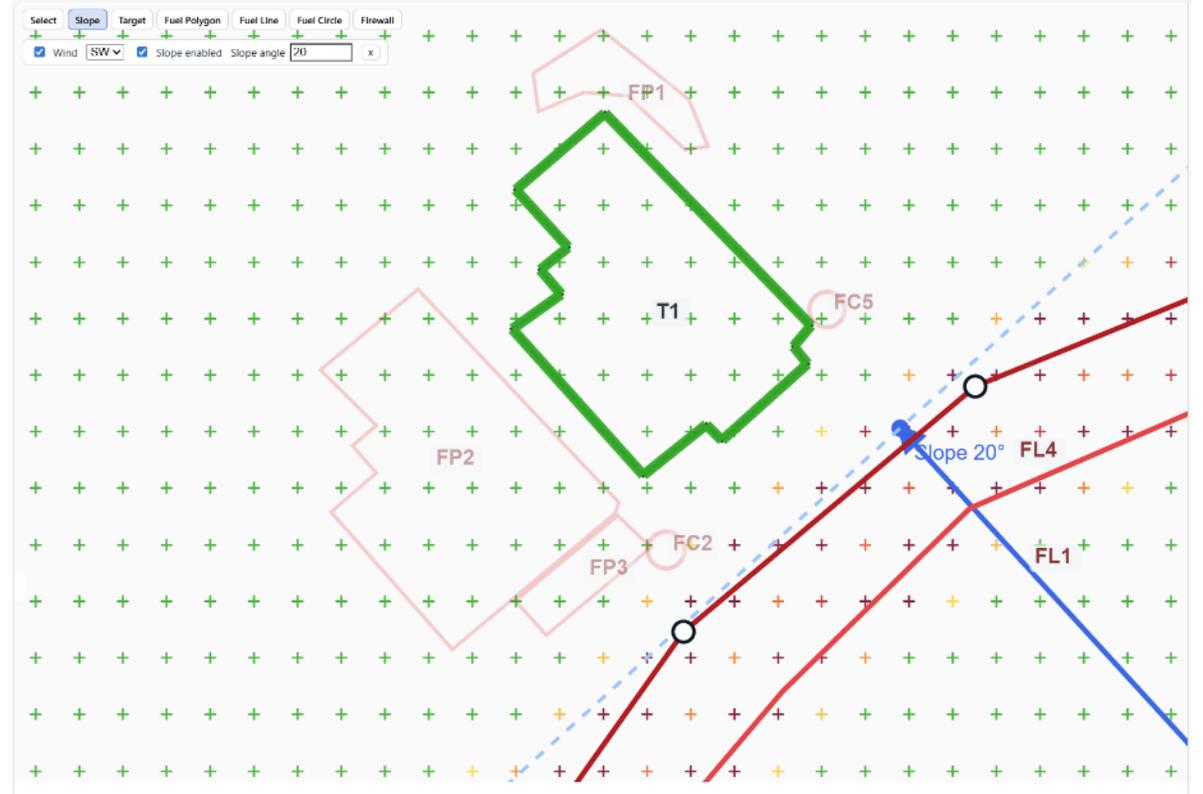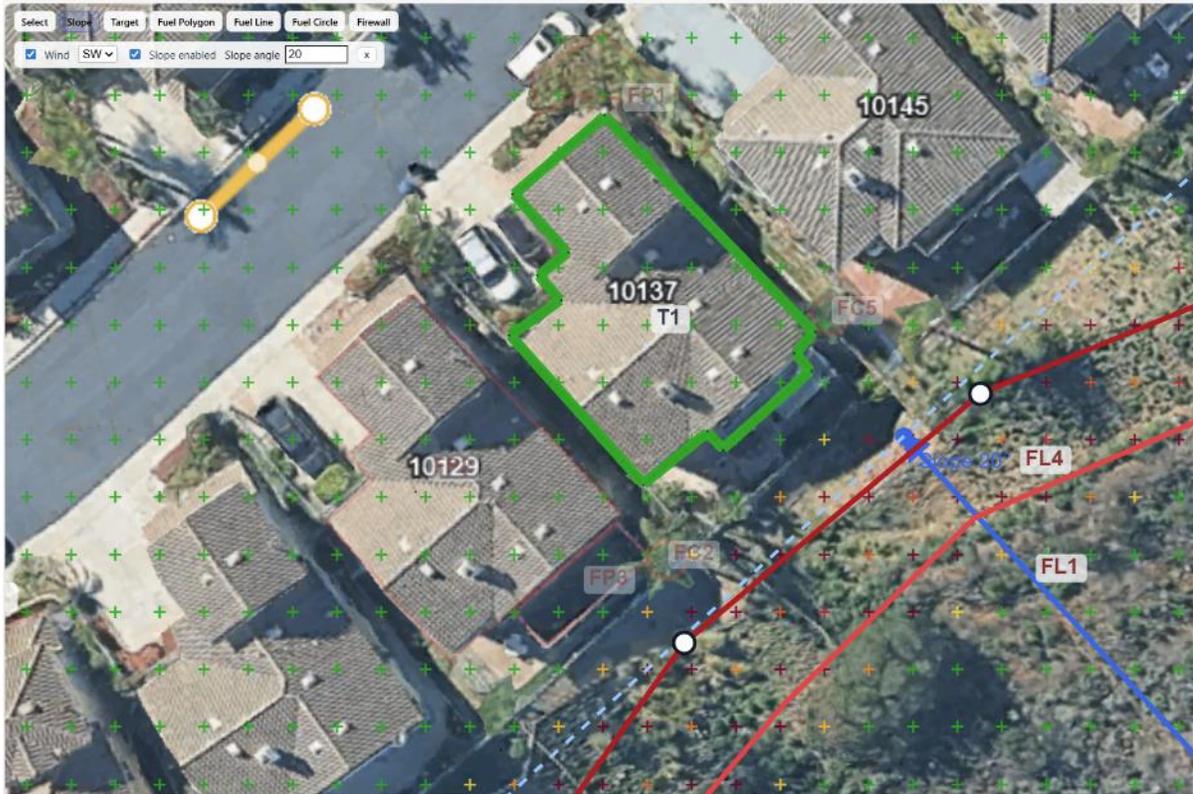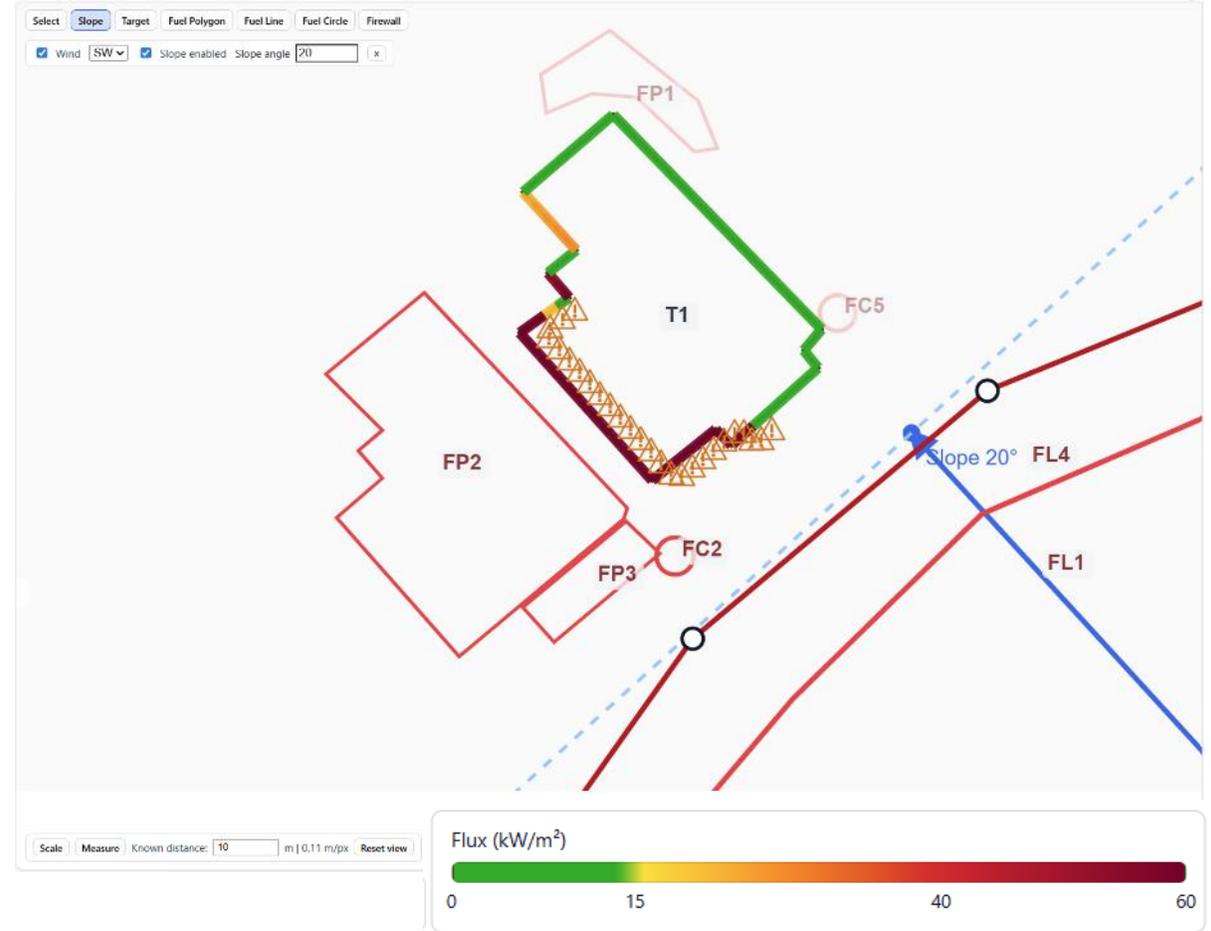| FIRE HAZARD SEVERITY	MINIMUM DEFENSIBLE SPACE (feet)	EXPANDED DEFENSIBLE SPACE (feet)
Moderate	30	45
High	50	75
Extreme	100	150
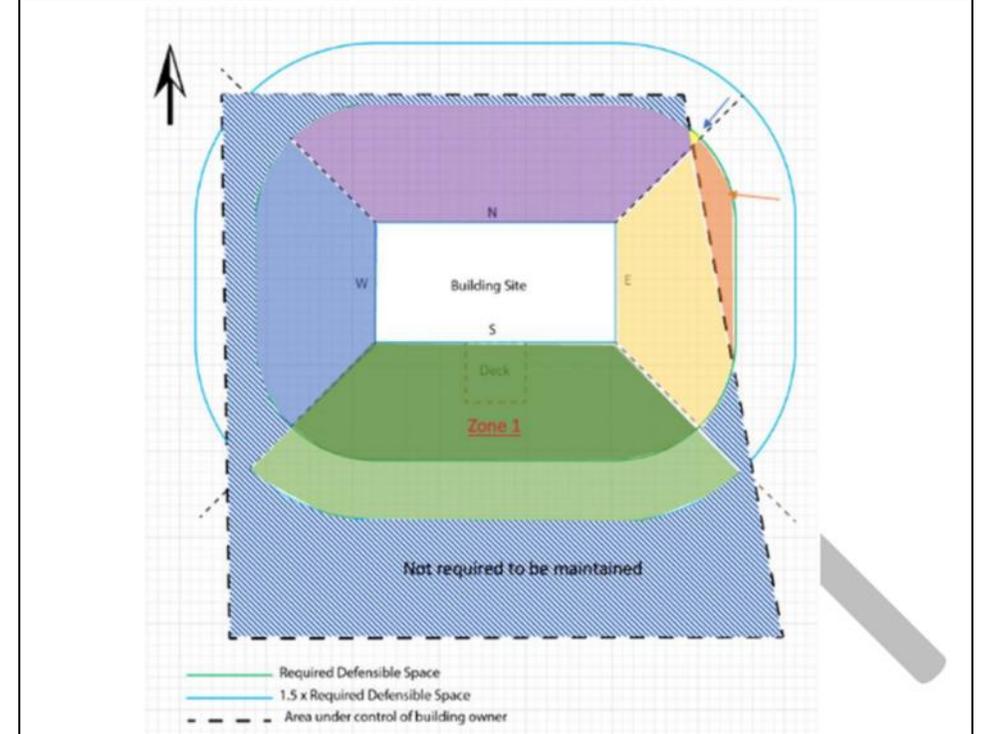
Parcel / Neighbourhood Modeling
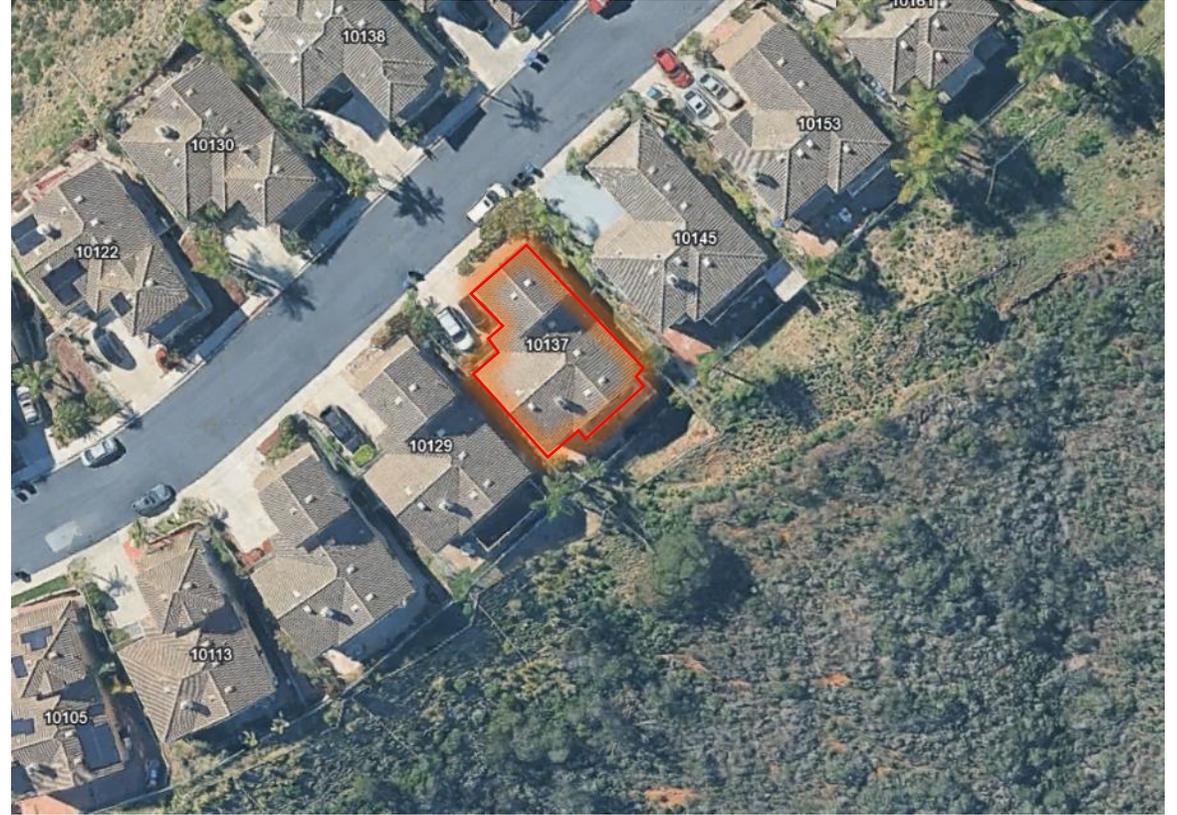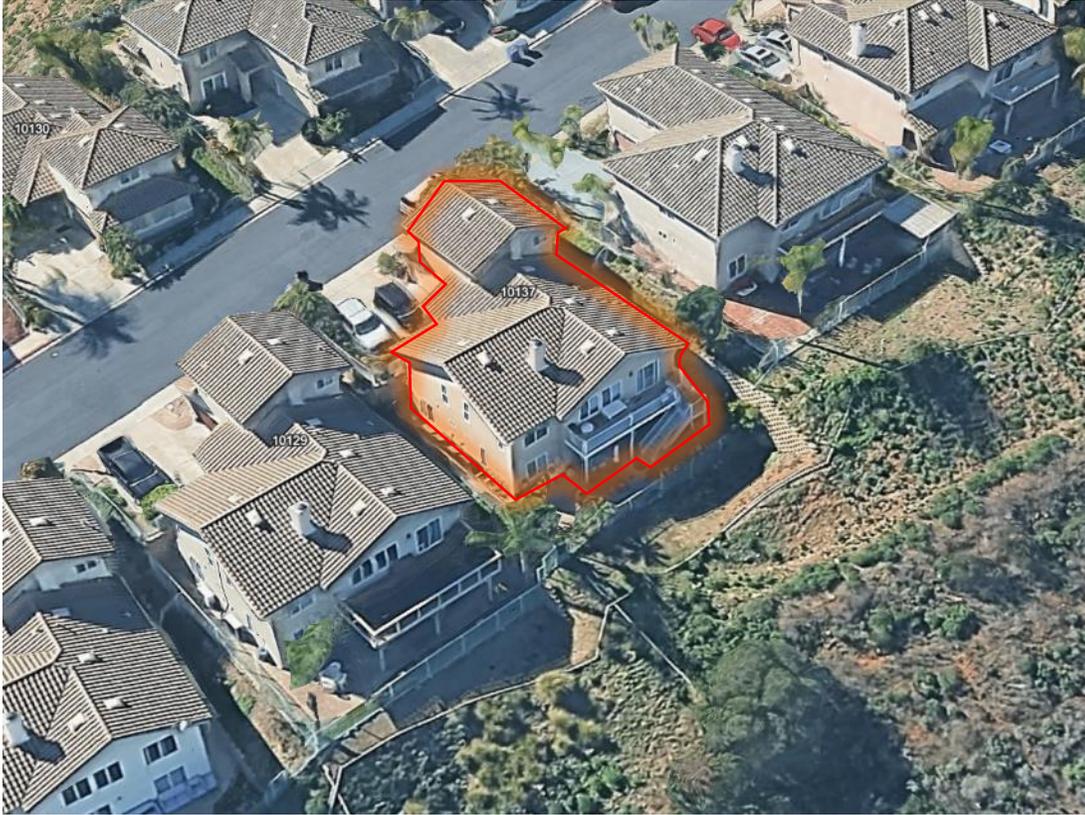
Individual parcel level

Weak path changes with the design fire

→ Failure initiates where local resistance is exhausted

→ Resistance is non-uniform

→ Local minima govern outcome

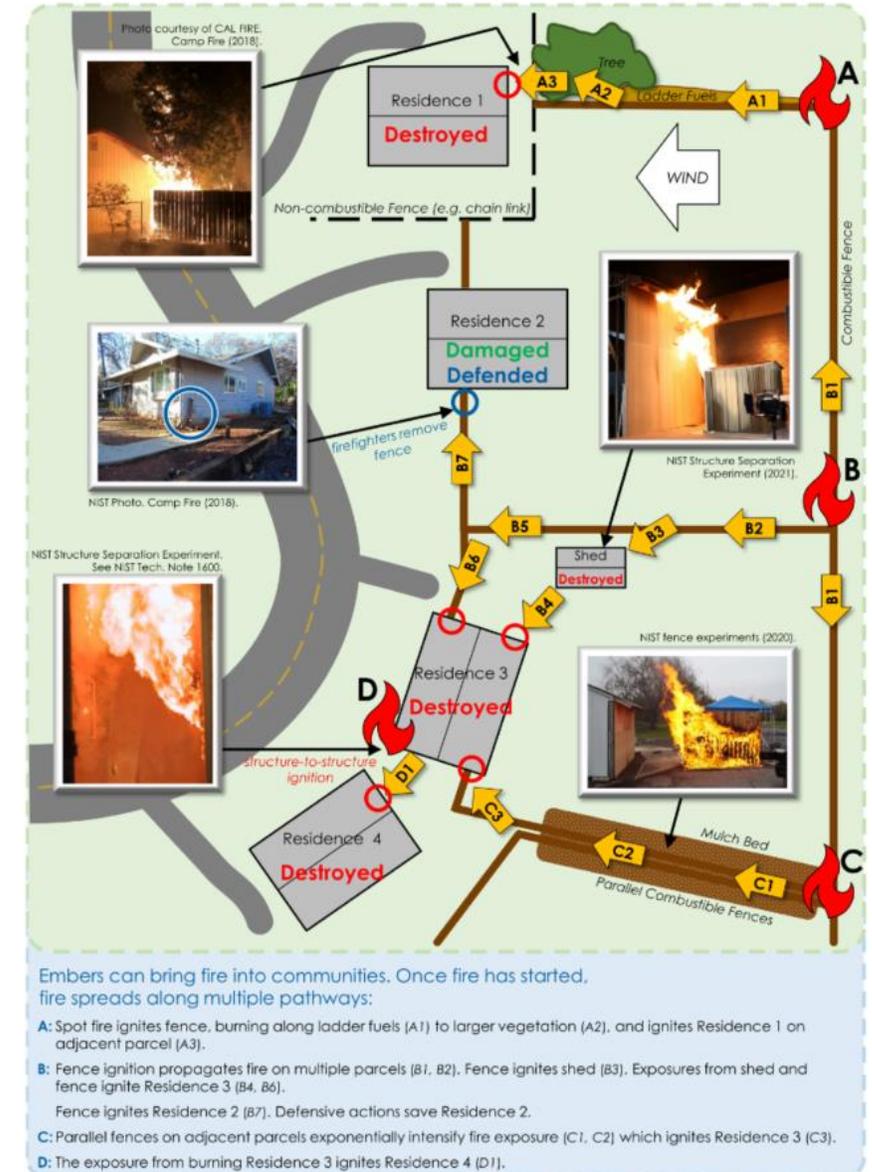→ The governing weak path is conditional on the exposure regime

Figure 10. Illustration of numerous fire spread pathways among neighboring parcels via linear features and other combustibles. Inset photographs are from field observations and experiments.

Graphic: Maranghides, A., et al. (2022). *WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology*. Technical Note (NIST TN) 2205, National Institute of Standards and Technology, Gaithersburg, MD.

Resistance must be continuous

→ the enclosure behaves as a connected barrier system

→ failure occurs when wildfire load finds a continuous path through the enclosure where resistance is insufficient

→ **Continuity governs whether local weaknesses become system failure**

WFRB

Wild**F**ire

Resistant

Barrier
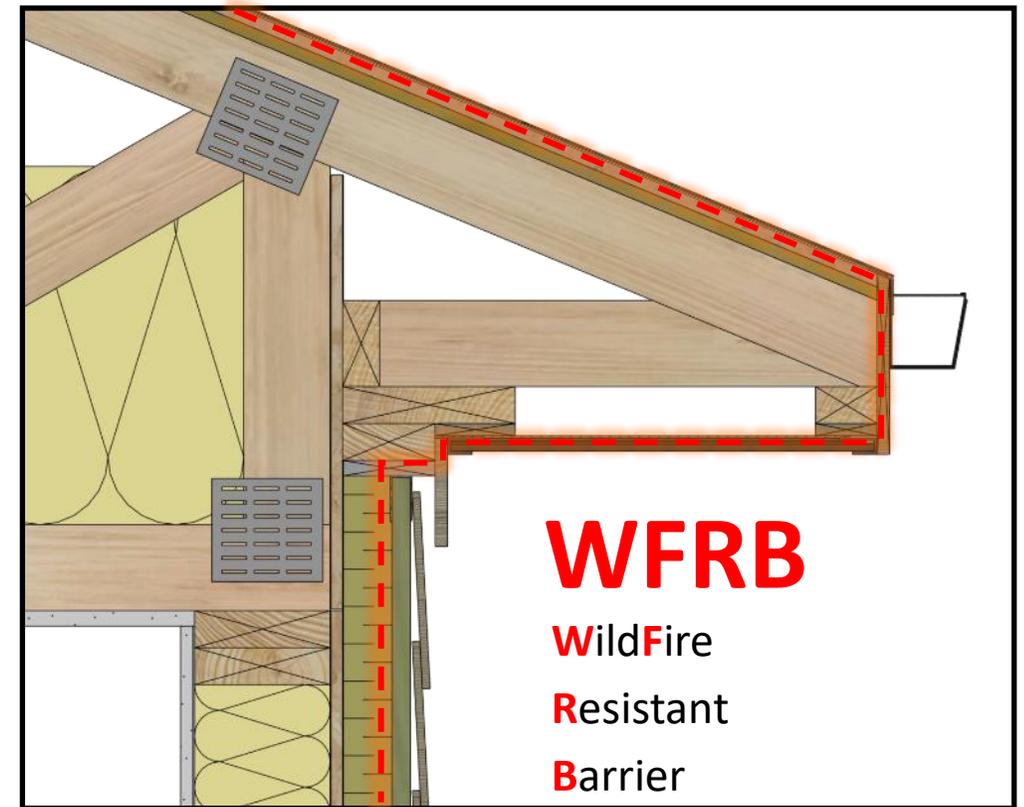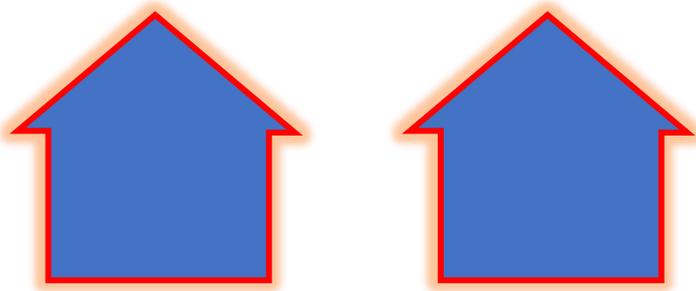
Enhanced resistance

→ Continuity does not mean the same intervention everywhere. It means an unbroken resisting system for the loads expected at that location.

→ 1h Fire Resistance not needed everywhere, but it must be continuous where it is needed

→ Ie.. walls, windows, doors, soffits, etc.

QAI Design B1067-1g – ROCKWOOL – Exterior Wall Assembly
CAN/ULC S101 / ASTM E119
1-Hour Load-Bearing[1] Fire-Resistance Rated
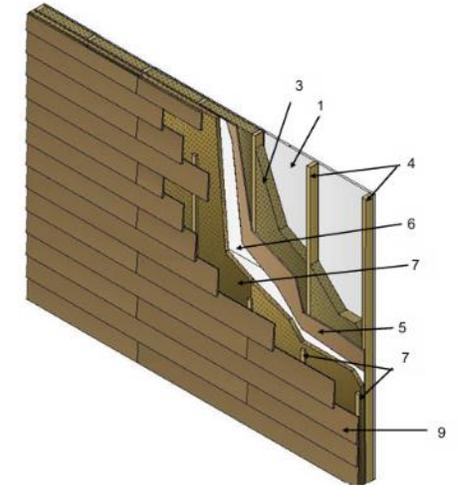
Window reqs in CWUIC 2025

504.8 Exterior glazing.

Exterior windows, window walls and glazed doors, windows within exterior doors, and skylights shall be *constructed of any of the following:*

1. *Multilayered glazed panels with at least one pane of tempered glass complying with Section 2406 of the California Building Code.*

2. Glass block.

3. *Glazing with* a fire-protection rating of not less than 20 minutes *when tested according to NFPA 257 or UL 9, and shall be exempt from the hose stream test.*

4. *Glazing meeting the performance requirements of SFM Standard 12-7A-2.*

Wall/soffit testing

Window testing – SFM 12-7a-2

Annealed + vinyl frame

Tempered + nc frame

Borosilicate + nc frame

Core principles of wildfire performance

1. Define load

2. Match resistance to expected load

3. Assume failure occurs at the weakest path

4. Maintain continuity of resistance across the system

$$L_{design} \leq \min(R_{\text{path},i})$$

where,

$R_{\text{path},i} = $ *resistance of each critical component, interface, or pathway*

DISCUSSION AND Q&A

THANK YOU!