# *Wind driven building to building fire spread*

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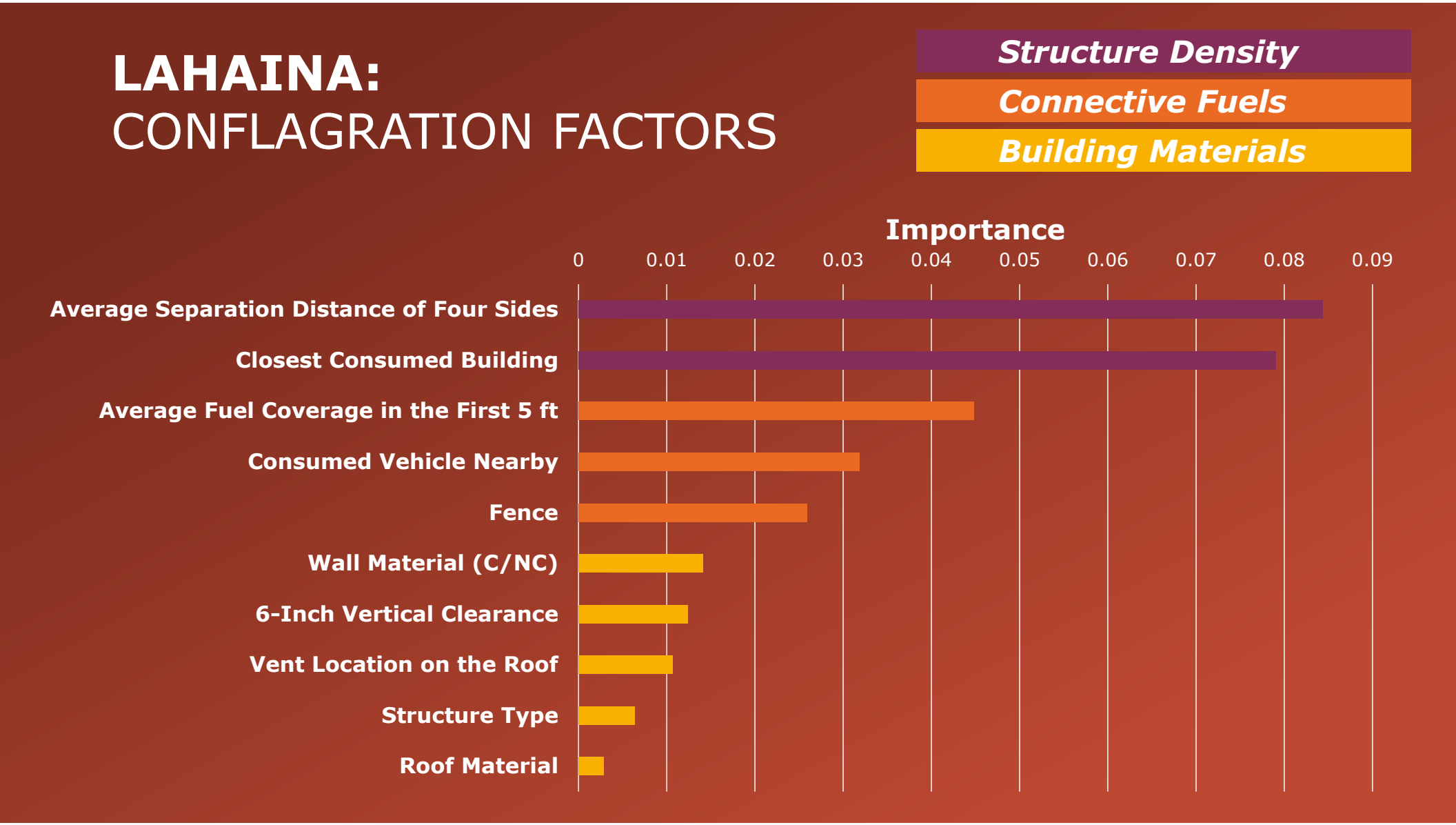
KUNA

# **LAHAINA:**
# CONFLAGRATION FACTORS




WIND-DRIVEN BUILDING-TO-BUILDING FIRE SPREAD
Target Angle
Wind Speed
Target Building Material
Structure Separation Distance
Shed Material

# PHASE 1 EXPERIMENTS

# DAMAGE CATEGORIES

## NO DAMAGE

- *Melted Vinyl Glazing*
- *Vent Replacement*
- *Scorch Marks*

## *COSMETIC DAMAGE*

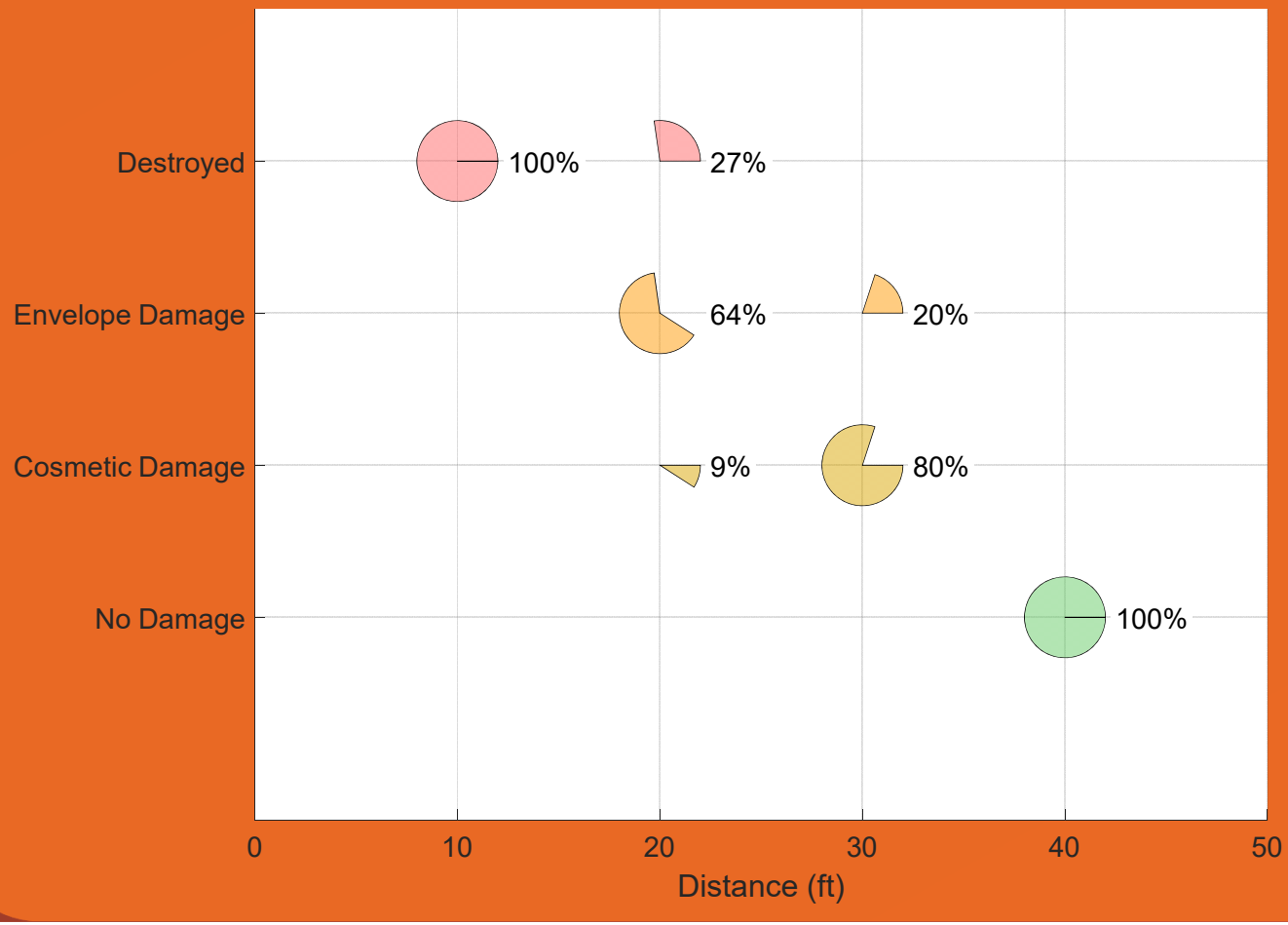
# ENVELOPE DAMAGE

- Deformed Window Frame
- Shattered Window
- Lost Pane of Glass
- Cracks in Fiber Cement Siding

## DESTROYED

- *Eave Ignition*
- *Siding Ignition*
- *Failure of Both Windowpanes*
- *Window Frame Failure*

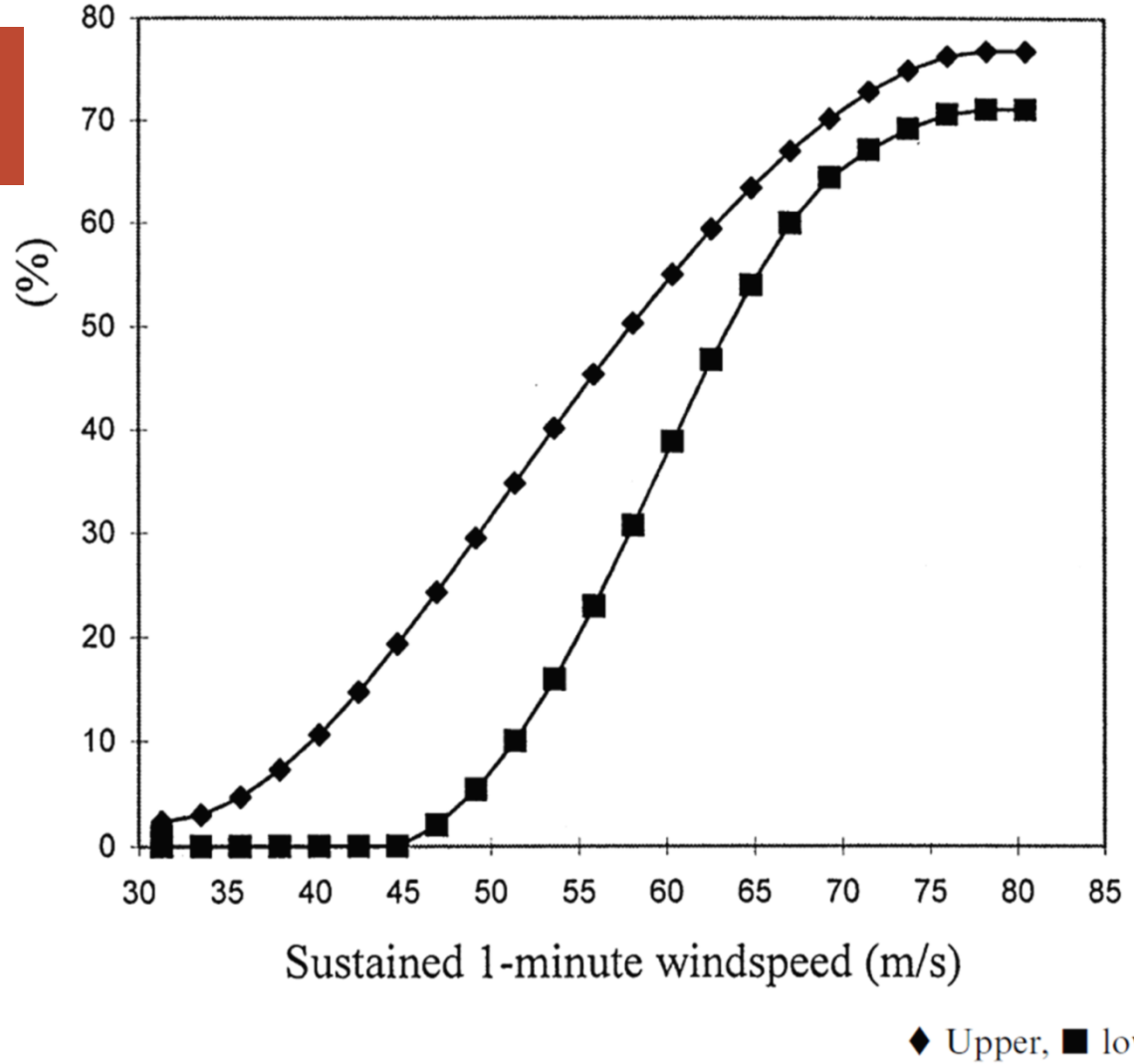
# Classification by Final Building Status



# WIND FRAGILITY

Wind **damage increases** with wind **speed.**

Heat Flux
Total Energy



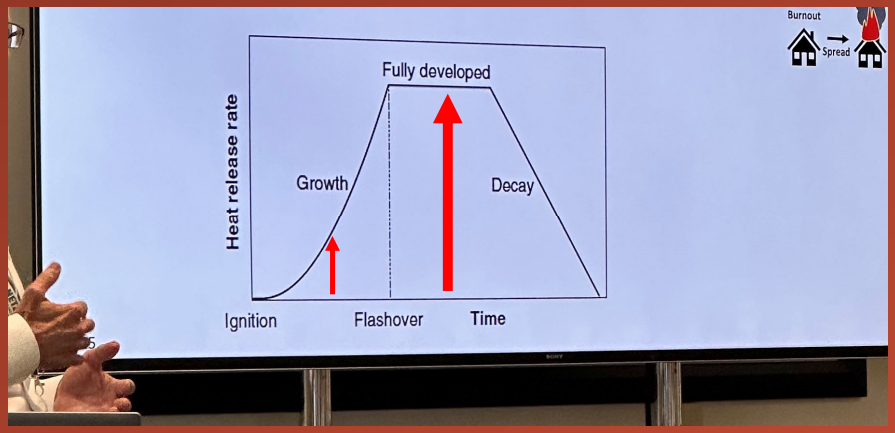
# *HEAT FLUX and ENERGY*

*THE FLOW OF THERMAL ENERGY, PER UNIT OF TIME.*

*THE THERMAL ENERGY ACCUMULATED DURING A TIME PERIOD.*

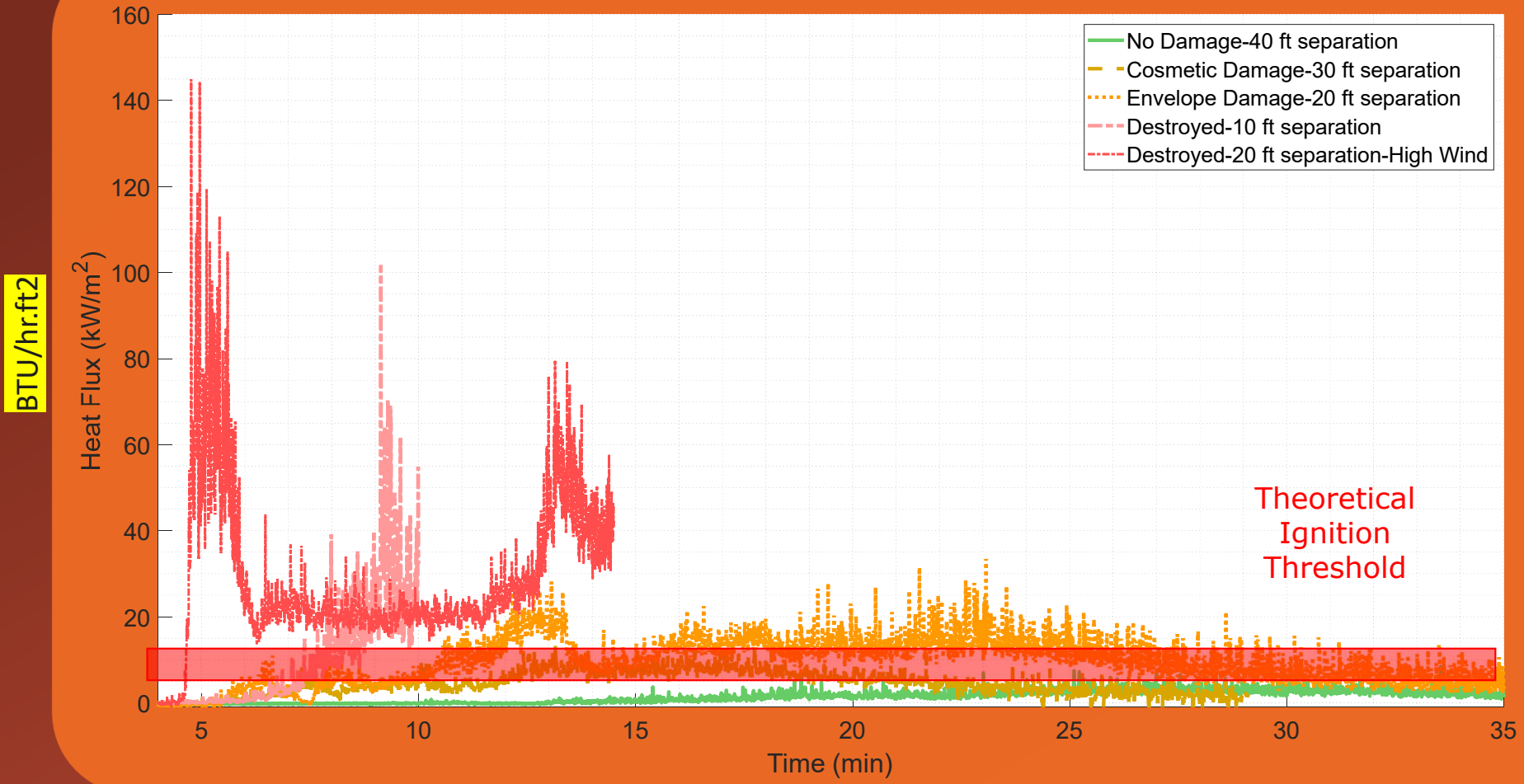

NIST
FIRE RESEARCH


CertainTeed


Burnout
Spread
Fully developed
Heat release rate
Growth
Decay
Ignition
Flashover
Time

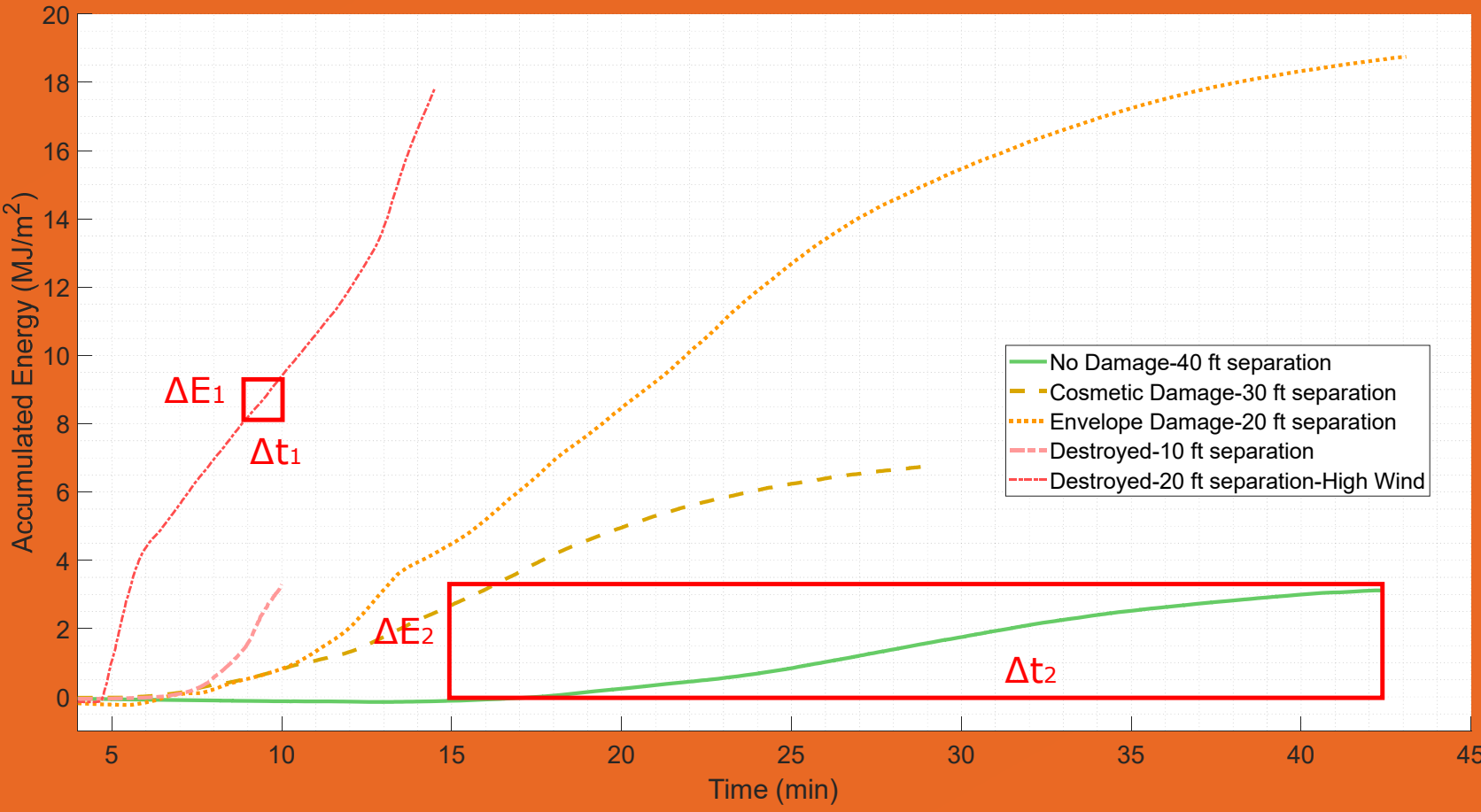
# STRUCTURAL FAILURE SHAPING FIRE DYNAMICS

# ***INSTANTANEOUS*: Peak Heat Flux**



# Heat Load

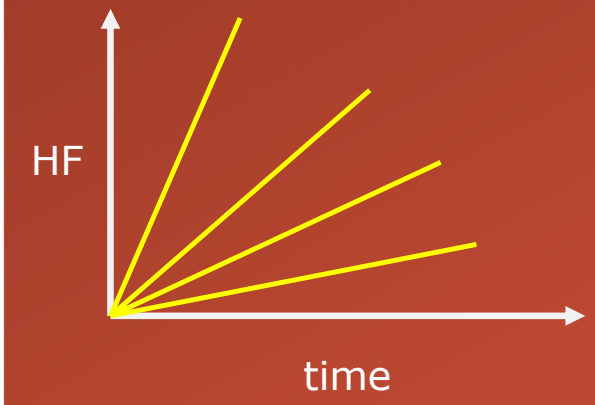
BTU/ft2



# Characteristic response time

**Table 4[4].** Thermal response time (sec) of materials to reach the average mentioned failure temperature range in seconds (failure time) from initial temperature of 20°C.

| Ramp rate ($W/m^2 \cdot s$) | Window glass pane (93-265°C) [73] | Plywood (300-365°C) [74] | PVC (115-245°C)[5] [75] | Fiber cement boards (>400°C) [76] |
|---|---|---|---|---|
| 1000 | 49.5 | 25.4 | 19.4 | 33.9 |
| 2000 | 31.2 | 16 | 12.2 | 21.3 |
| 3000 | 23.8 | 12.2 | 9.3 | 16.3 |
| 4000 | 19.6 | 10.1 | 7.7 | 13.3 |
| 5000 | 16.9 | 8.6 | 6.6 | 11.6 |
| 6000 | 15 | 7.8 | 5.9 | 10.3 |
| 7000 | 13.5 | 6.9 | 5.3 | 9.2 |

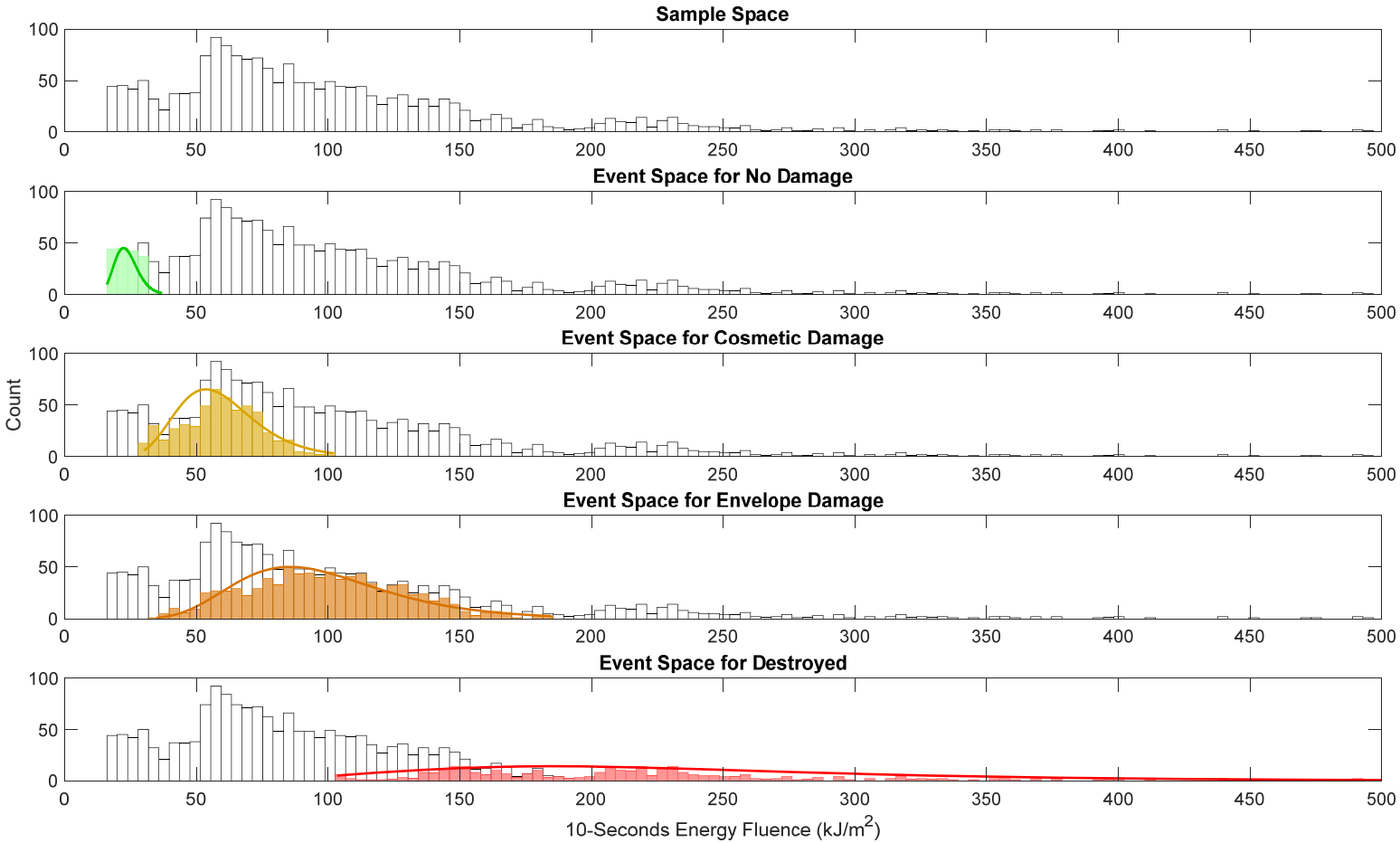


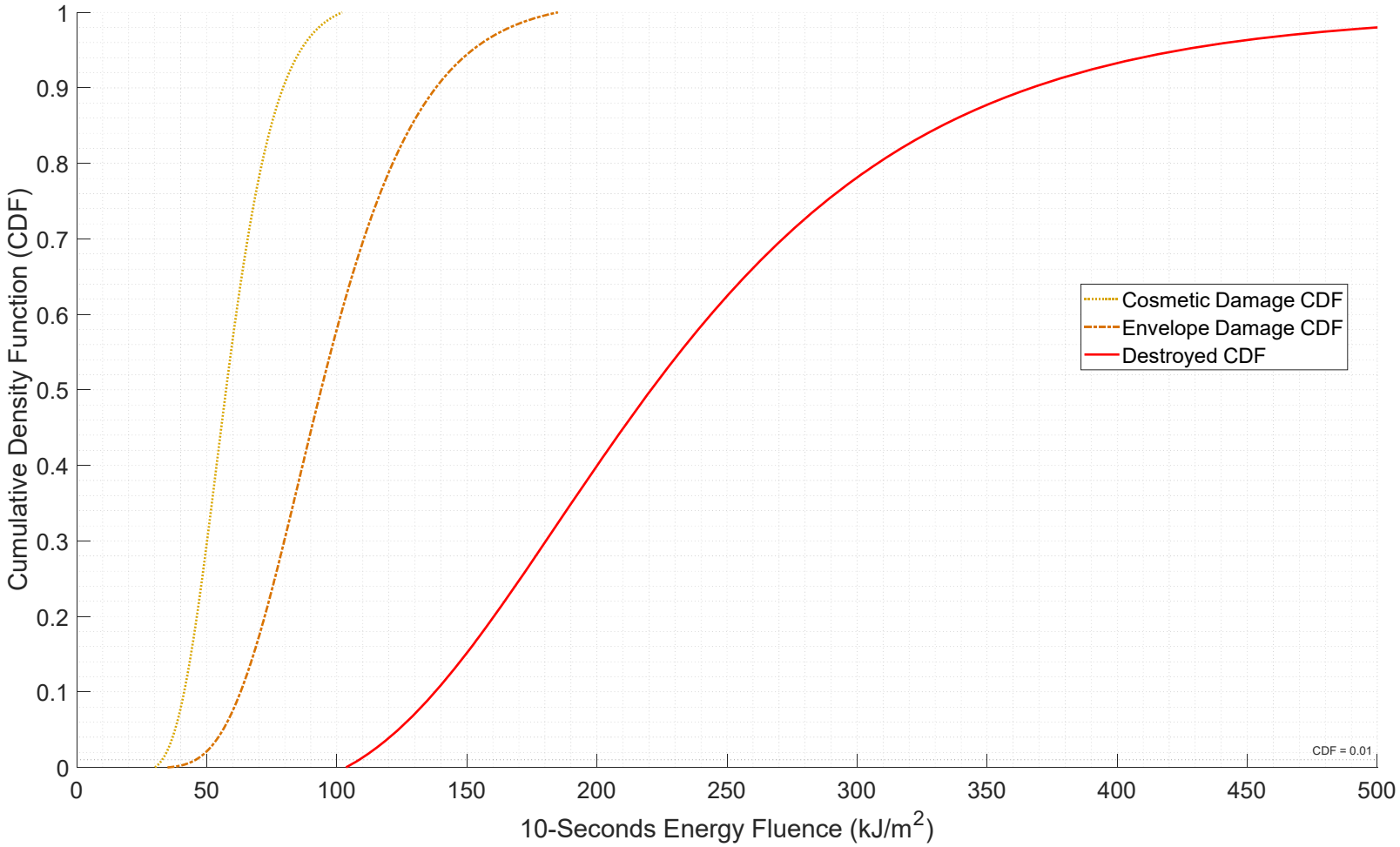
# *ENERGY FLUENCE*

*THE FLOW OF THERMAL ENERGY, PER UNIT OF TIME.*

*THE THERMAL ENERGY ACCUMULATED DURING A TIME PERIOD.*


IGNITION PERSPECTIVE
NOT INSTANT
NEW FRAMEWORK
NOT TOTAL
TIME


Sample Space
Event Space for No Damage
Event Space for Cosmetic Damage
Event Space for Envelope Damage
Event Space for Destroyed
Count
10-Seconds Energy Fluence (kJ/m2)
0
50
100
150
200
250
300
350
400
450
500


Cumulative Density Function (CDF)
10-Seconds Energy Fluence (kJ/m2)
Cosmetic Damage CDF
Envelope Damage CDF
Destroyed CDF
CDF = 0.01
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500

# FIRE FRAGILITY

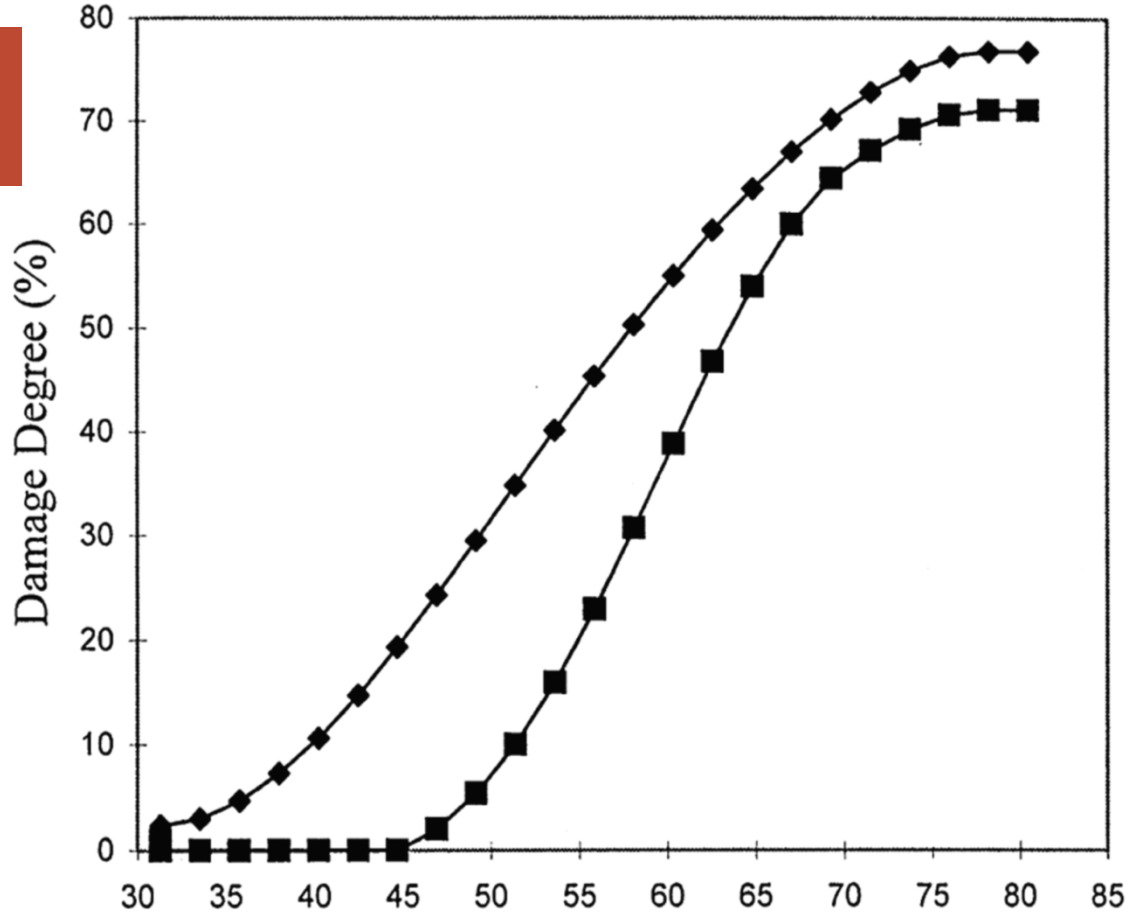


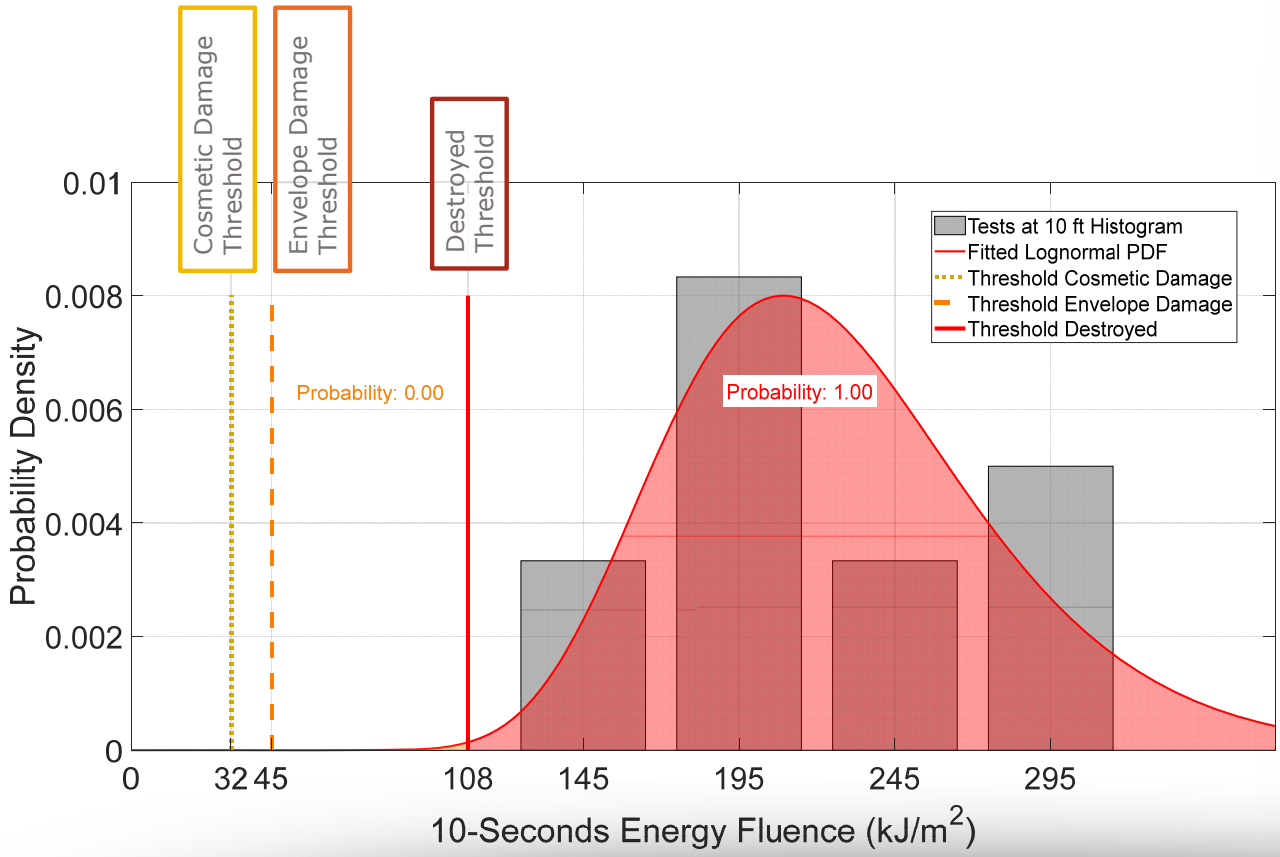

Fig. 11. Wind damage band for 1–3 story residential buildings. ♦ Upper, ■ lower.

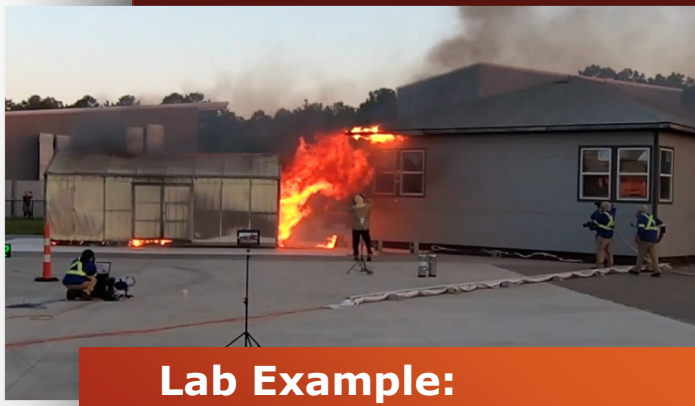
# Thresholding based on RISK APPETITE establishes PROBABILITIES OF DAMAGE by distance.

**Limitations:**

- *Experimental testing for fire intensities like a shed*
- *Building materials like the target building*
- *No connective fuels*
- *Continuous downwind heating*

# 10 ft Separation *Damage Probabilities*

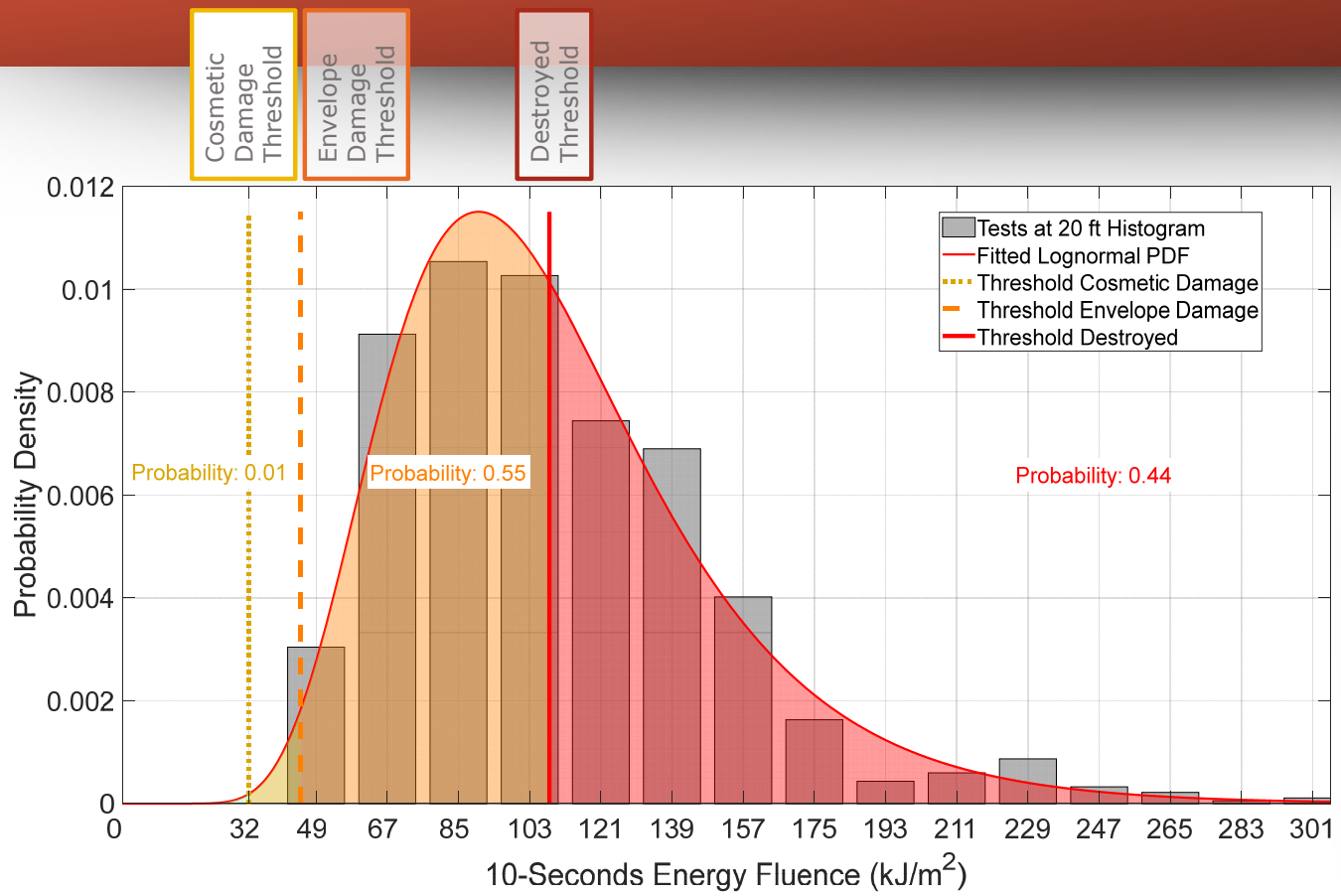


**Lab Example:**
***DESTROYED***

***NO DAMAGE: 0%*** ***COSMETIC: 0%*** ***ENVELOPE: 0%*** ***DESTROYED: 100%***

# 20 ft Separation *Damage Probabilities*

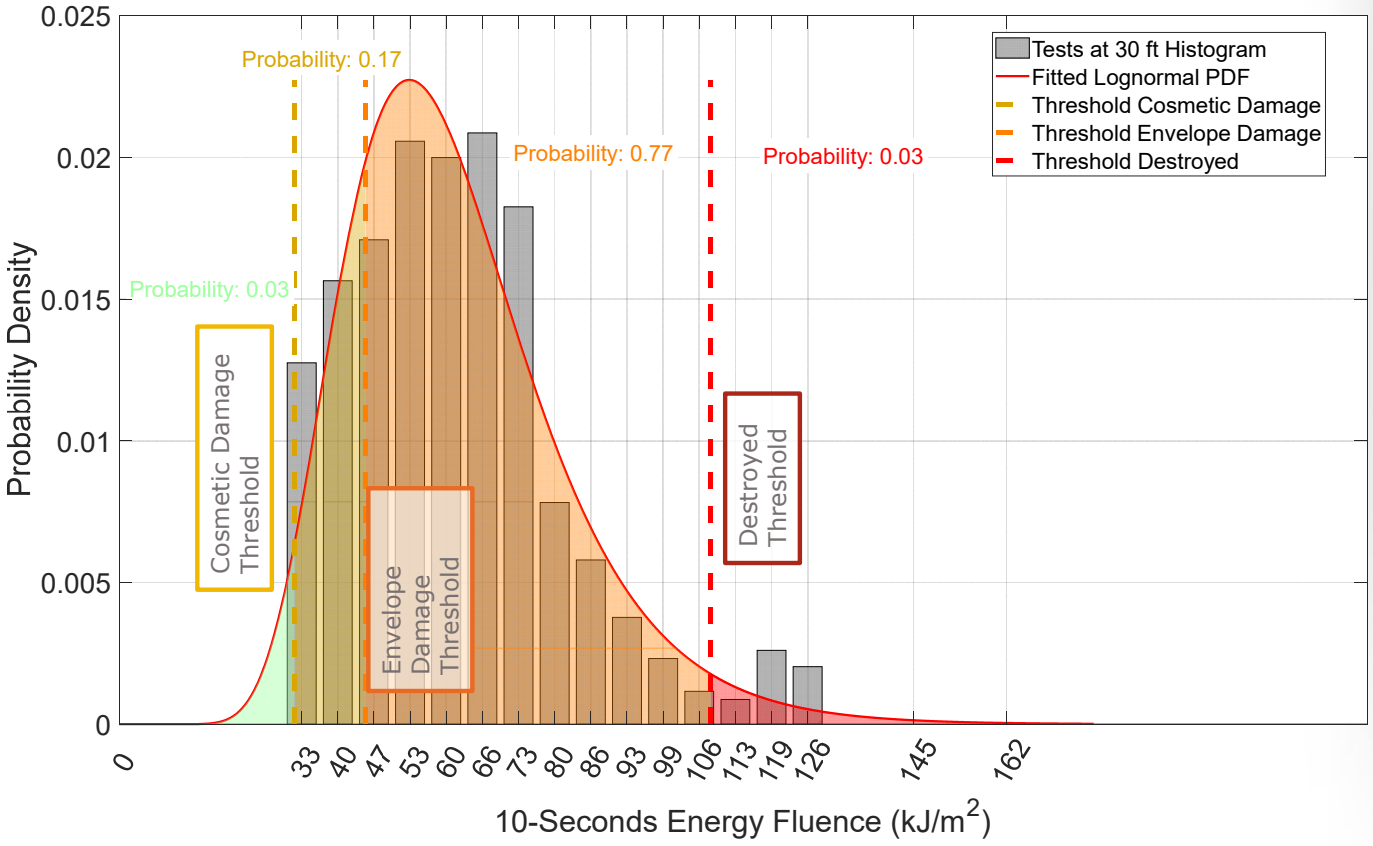



**Lab Example: Damage**

**Lab Example: Destroyed**

***NO DAMAGE: 0%*** ***COSMETIC: 1%*** ***ENVELOPE: 55%*** ***DESTROYED: 44%***

# 30 ft Separation *Damage Probabilities*



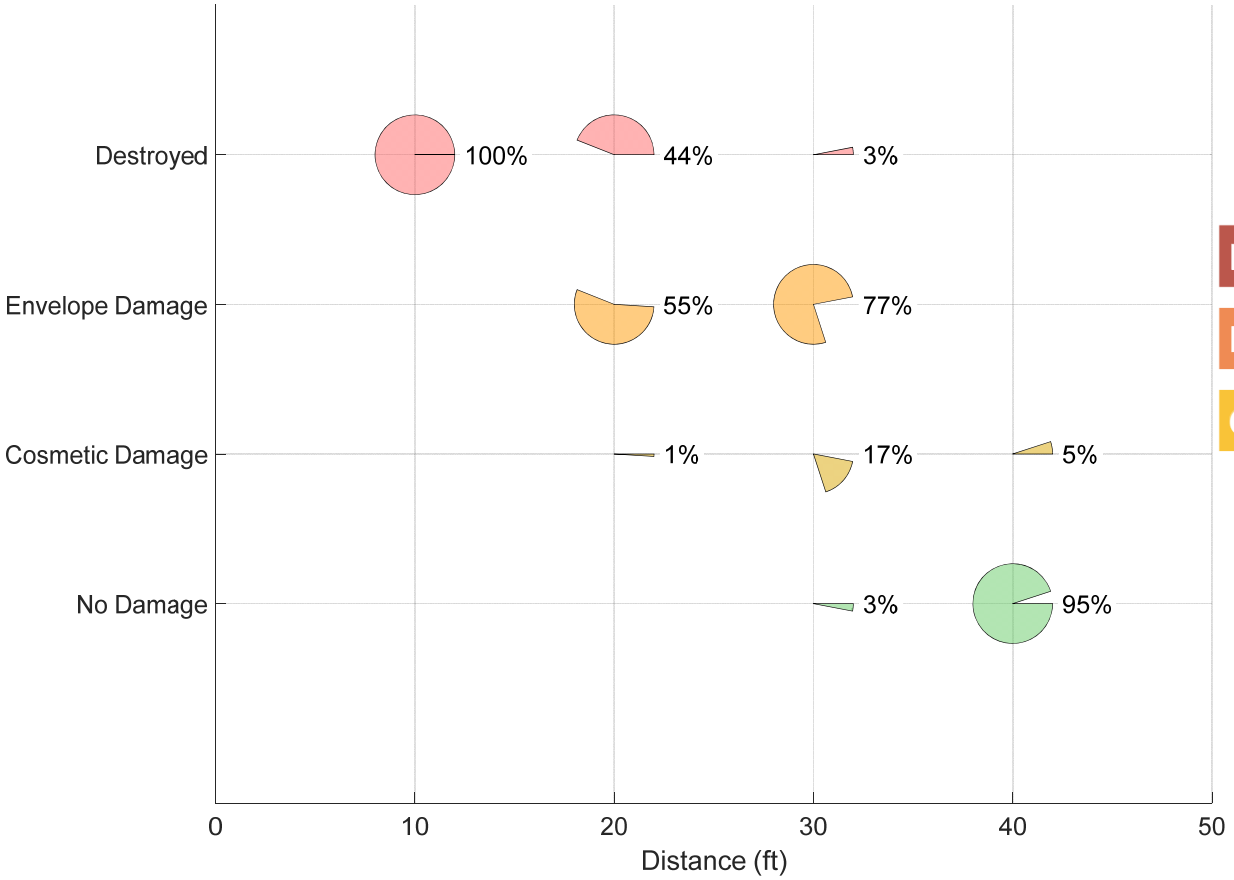

**Lab Example: Damage**

**Lab Example: Destroyed**

***NO DAMAGE: 3%*** ***COSMETIC: 17%*** ***ENVELOPE: 77%*** ***DESTROYED: 3%***

# **40 ft Separation** *Damage Probabilities*

# THE PROBABILISTIC FRAMEWORK




**Destroyed:** 235 kJ/m$^2$

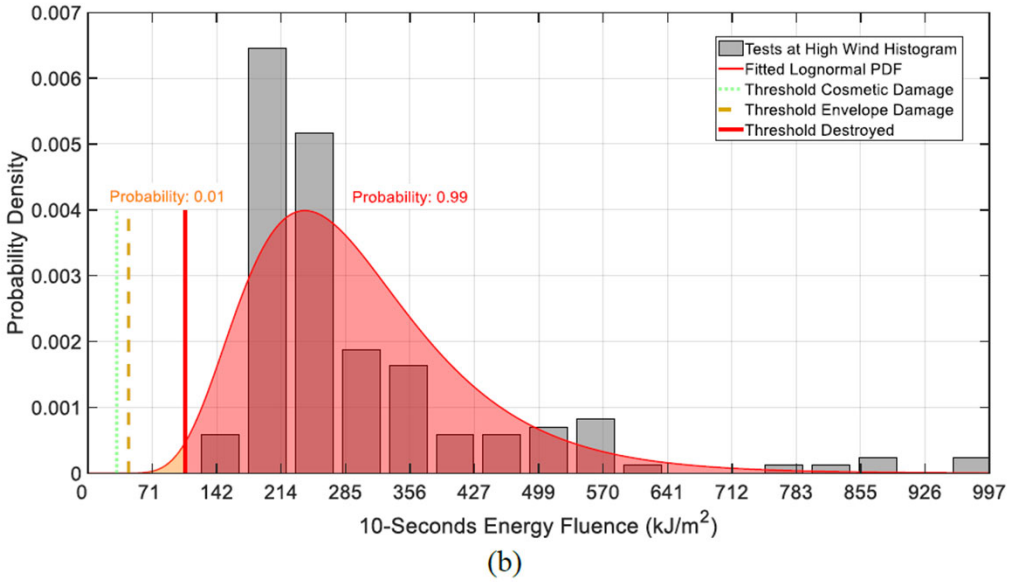
**Envelope Damage:** 99 kJ/m$^2$

**Cosmetic Damage:** 59 kJ/m$^2$

# Extreme Wind Conditions

# HIGH WIND TESTS

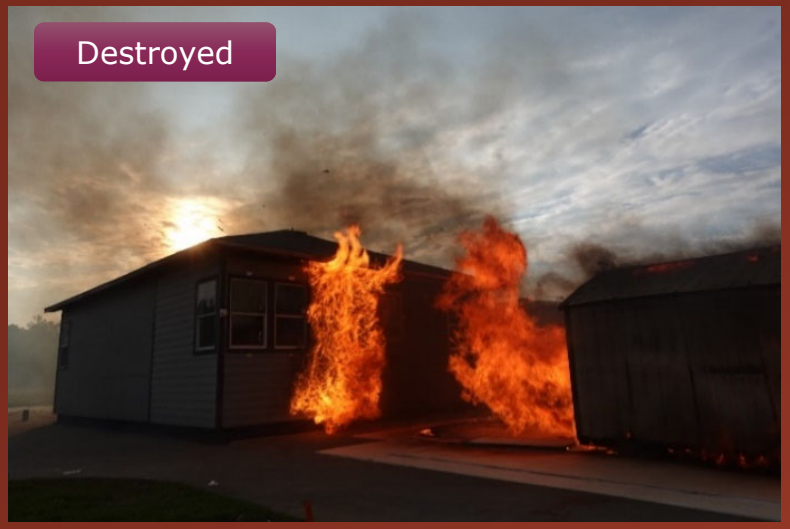




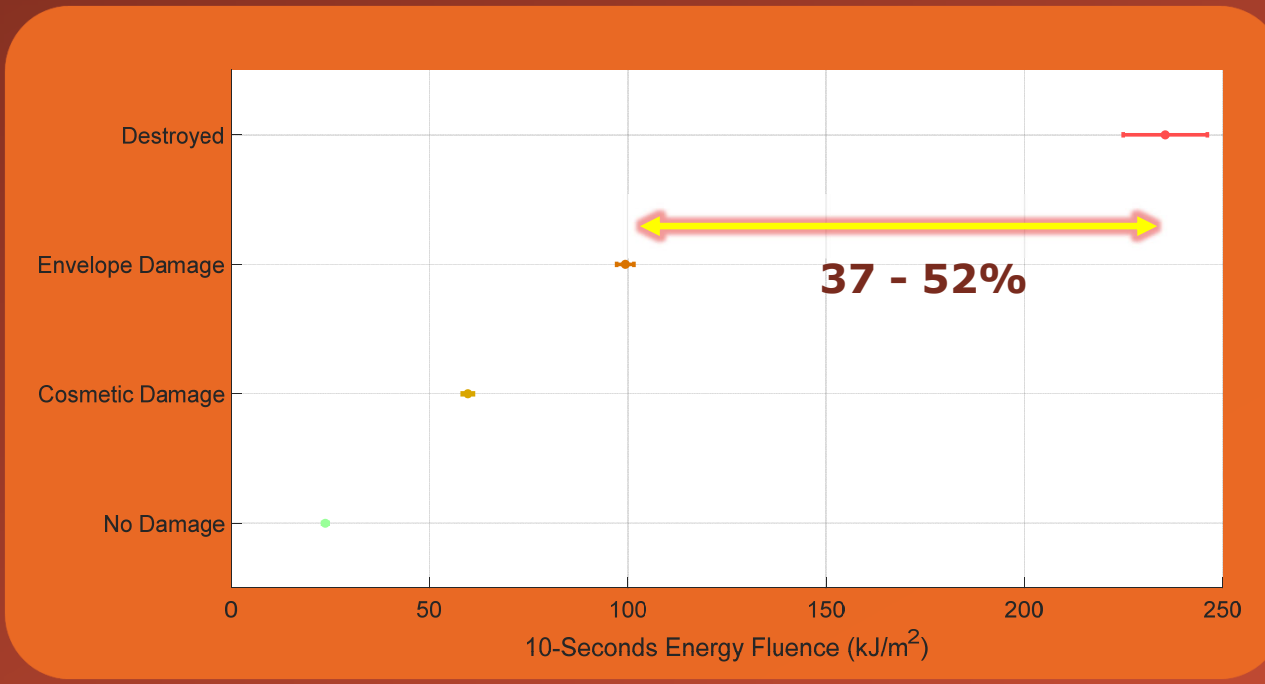

(b)


Outside

Inside the Attic


Destroyed


Envelope Damage


Destroyed
Envelope Damage
Cosmetic Damage
No Damage
37 - 52%
0
50
100
150
200
250
10-Seconds Energy Fluence (kJ/m2)

# 7A Recommendations

**Under typical wind conditions**

1. For a structure separation of approximately 30 feet:
   windows should be upgraded or protected.

2. For a structure separation of approximately 20 feet:
   In addition to 1, only noncombustible siding should be allowed.

3. For a structure separation of approximately 10 feet:
   In addition to 1 and 2,
   - Eaves should be enclosed
   - A noncombustible fence should be required.

# Experimental: What is next?

***Phase 1***

***Phase 2***

Test non-chapter 7A compliant ADUs

Create a library of heat flux data under wind driven conditions

Test medium scale samples

Continue with the statistical analysis

***Phase 3***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